ADVERSE IMPACT
REDUCTION HANDBOOK

Reducing Onshore Natural Gas and Oil Exploration and Production Impacts Using a Broad-Based Stakeholder Approach

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Adverse Impact Reduction Handbook

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APD: Application for Permit to Drill

BLM: United States Department of the Interior, Bureau of Land Management

CBNG: Coal Bed Natural Gas

CE: Categorical Exclusion

CEQ: Council on Environmental Quality

CFR: Code of Federal Regulations

COA: Condition of Approval

DOA: United States Department of Agriculture

DOE: United States Department of Energy

DOI: United States Department of the Interior

EA: Environmental Assessment

EIA: Energy Information Administration

EIS: Environmental Impact Statement

EMS: Environmental Management System

EOR: Enhanced Oil Recovery

E&P: Exploration and Production

EPA: United States Environmental Protection Agency

EPAct: National Energy Policy Act of 2005

FS: United States Department of Agriculture, Forestry Service

F&WS: United States Department of the Interior, Fish and Wildlife Service

FONSI: Finding of No Significant Impact

IOGCC: Interstate Oil and Gas Compact Commission

LINGO: Low Impact Natural Gas and Oil

MBOGC: Montana Board of Oil and Gas Conservation

NEPA: National Environmental Policy Act of 1969

NEPDG: National Energy Policy Development Group

NETL: National Energy Technology Laboratory

NGO: Non-Governmental Organization (concerned citizen groups)

NOI: Notice of Intent

NPS: United States Department of the Interior, National Park Service

NSO: No Surface Occupancy

O&G: Oil and Gas

PAC: Project Advisory Council

P&A: Plugging and Abandonment (of a well)

ROD: Record of Decision

SUA: Surface Use Agreement

TLS: Timing Limitation Stipulation

USDW: Underground Source of Drinking Water

WOGCC: Wyoming Oil and Gas Conservation Commission.

SECTION 1
Purpose and Overview

1.1 INTRODUCTION

The United States Department of Energy (DOE) National Energy Technology Laboratory (NETL) has initiated several studies on low impact natural gas and oil (LINGO) development. This particular LINGO project presents research concerning environmental impacts resulting from onshore oil and gas exploration and production and their corresponding mitigation strategies.

Research has been conducted and this manual prepared by the Interstate Oil and Gas Compact Commission (IOGCC) and its contractor, ALL Consulting. The researchers have followed oil and gas industry activities throughout the country and made numerous observations important to successfully achieving reduced or "low" environmental impacts as a result of exploration and production activities.

The researchers' background and experience has been conceived from participation in committees structured to address perceived problems with exploration and production activities (e.g., Montana House Bill HB790); participation in public meetings and hearings in oil and gas producing states throughout the country; participation in nationally organized working groups formed by organizations such as the IOGCC, Western Governors' Association (WGA), and the Ground Water Protection Council (GWPC); through discussions with landowners, industry organizations, non-governmental organizations (NGOs), and state and federal government agencies.

1.2 OBJECTIVES

The objectives of this research project are to collate and disseminate information on technologies and practices that will help minimize environmental impact resulting from oil and gas development. It is anticipated that this, in turn, will facilitate the removal of barriers and/or delays to exploration and production on federally owned lands and/or mineral estates. The resurgence in domestic oil and natural gas development activity has prompted regulators and operators to address real and/or perceived environmental problems with consideration of new rules that will, or might , affect oil and gas operations. These rule changes are creating impedances or delays to onshore exploration and production activities. Agencies and non-governmental organizations (NGOs) are demanding that reduced impacts resulting from oil and gas activities be incorporated into current operations.

Often efforts to reduce environmental impacts resulting from oil and gas exploration and production activities do not include input from NGOs such as environmental-oriented citizen groups, as well as individual ranchers, farmers, and other concerned landowners. Lacking this avenue of input can result in practices that ultimately fall short of the mutually desired result. With that in mind, this research project strived to gain input from a broad variety of stakeholders including: NGOs, local governmental bodies, industry, state and federal agencies, and individual landowners. The research team evaluated those key practices from onshore oil and gas development that are important to moving projects forward and also those that have the potential to cause the most notable environmental impact issues leading to delayed or curtailed exploration and production activities. This included a wide range of exploration and production activities --- from pre-drilling seismic surveys, to full-field development activities, and through to final reclamation.

The result of the project is this handbook summarizing solutions to issues that pose the most significant impedances or delays to onshore exploration and production activities. The handbook outlines approaches to avoid, minimize, and/or mitigate environmental impacts. Further, the research provides beneficial analysis of various practices to serve as a starting point for choosing practice options. It has national applicability in sparsely populated rural areas as well as in highly populated urbanized areas. In addition to its usefulness to regulatory personnel and the regulated exploration and production community, it is hoped that this handbook also will be of value to non-industry readers wishing to gain an understanding of the advantages and disadvantages of the various approaches available to oil and gas operators for environmental impact mitigation.

Never before has an issue such as reducing exploration and production impacts been as important as it is today for operators, regulators, and other stakeholders. These stakeholders are concerned with the overall issues of adverse environmental impacts from oil and gas operations and the benefits that may occur if effective impact-reducing technologies and practices are implemented. In light of the expanding regulations aimed at reducing impacts it is imperative that the challenges associated with impact issues be understood and documented to minimize any impacts that do occur, lower operator management costs, and extend the productive life of wells, thereby ultimately increasing/conserving our nation's recoverable oil and gas reserves.

It is conceivable that some emerging practices could yield significant technological advances that industry can capitalize on. But the more likely outcome is that developing a better understanding of existing technologies will identify new ways to benefit existing operations and the environment. It is anticipated that the availability of this Adverse Impact Reduction Handbook will lead to tangible reduced environmental impacts as well as reduced regulatory compliance costs to industry.

The key objectives of LINGO extend beyond simply reducing the impact of exploration and production activities. LINGO has far-reaching benefits to environmental and stakeholder concerns, as well as industry economics. Also, it is hoped that this effort will elicit a more positive perception of the petroleum industry by the public and minimize future litigation aimed at blocking resource development.

1.3 APPROACH

Research has been conducted to gather and evaluate data pertinent to common practices and mitigation strategies. The project team has reviewed a wide range of existing documents discussing environmental mitigation practices for various aspects of onshore oil and gas development as well as those presenting issues of concern voiced by NGOs. One-on-one interviews were conducted with some NGOs (unfortunately others contacted were unwilling to speak with the research team). Interviews also were conducted with individual ranchers and landowners to solicit their input on both the recognition of environmental impacts and the identification of desirable mitigation strategies from the specific viewpoint of the surface rights owner. Numerous regulatory and industry meetings also were attended; information gathered at these meetings directly contributed to the discussions presented herein.

In the course of this research, many potential environmental issues worthy of further review were identified. Unfortunately, the research team was forced to conclude that the full universe of potential issues and corresponding mitigation strategies exceeded the resources available to this project. Consequently, and as a result of information gathered, the research team has determined that the three most vital issue categories facing onshore domestic exploration and production today are: 1) surface damages, including development, in urbanized areas, 2) impacts on wildlife, and 3) air pollution, including its potential contribution to global climate change. Therefore, this project has emphasized these focus areas. Each area is discussed in a separate chapter of this handbook.

It is hoped that conducting research along this theme will serve to reduce the technological and regulatory uncertainties of operators by openly sharing the information, thus enhancing the understanding and use of new low-impact technologies. The soundness of the technical aspects of the project is further ensured by leveraging the experience of state oil and gas agencies and operators that have applied various technologies to the issues identified. The project team researched the details of various technologies and practices that reduce oil and gas operation-induced environmental impacts. This approach has allowed compilation of this handbook of low-impact technologies and their applicability in the field. Geographical and political challenges were reviewed. The project team understands that local conditions and requirements often dictate local approaches; however, it is also recognized that similar challenges experienced in different regions can benefit from others' successes and failures.

To ensure this information is readily available for state regulators, operators, and the public for their use in the evaluation of low-impact development approach technologies --- thus streamlining these activities with stakeholder buy-in --- this handbook is available from the following:

- *Interstate Oil and Gas Compact Commission: www.iogcc.state.ok.us*
- *ALL Consulting: www.all-llc.com*

1.4 UNDERLYING PHILOSOPHY

While some might view the impact-reduction measures discussed herein as best management practices (BMPs), we firmly believe it is necessary to stress the local or regional adaptability of these approaches. Following this logic, there are few if any practices that are indeed "best" on a nationwide basis. Instead, individual approaches must be tailored to local or regional circumstances. We resolutely believe best management practices (BMP) is potentially misleading at best. At the worst, it actually creates a disservice by implying that if a particular BMP solution used at Location A is not used to address a situation at Location B, then the latter issue is not being approached in the "best" possible manner. To put this in perspective, an approach that is considered "best" on the North Slope of Alaska might have absolutely no applicability to development in the Black Warrior Basin of Alabama.

1.5 PURPOSE & NEED

With the onset of the 21st Century has come the intersection of a number of trends – sharp increases in energy demand both in the United States and throughout the world, declines in world-wide energy supply, increases in oil and gas drilling targeting "unconventional plays", spread of the suburbs into rural countryside, and technological advancements in the oilfield. These trends have affected the perception of the upstream petroleum industry and have sharpened the need for lower impact development strategies.

As noted earlier, efforts to reduce environmental impacts resulting from exploration and production activities have not always included input from affected landowners, ranchers, farmers, and other concerned citizens. Lacking this avenue of input can result in practices that ultimately might not achieve the mutually desired result. This project has strived to gain input from a broad variety of sources including NGOs, local governmental bodies (e.g., conservation districts), farmers/ranchers, industry, state and federal agencies, and others. It is hoped that identifying and reducing impacts resulting from exploration and production activities by engaging a broad-based stakeholder approach will lead to practices that ultimately overcome impedances or delays to development. Furthermore, reducing the impact of exploration and production activities has far-reaching benefits for environmental concerns, stakeholder and industry economics, and the public's perception of industry; these issues are all among the central objectives of DOE's LINGO program.

Throughout the project, the research team evaluated the most notable potential environmental impact issues that might delay or curtail exploration and production activities. This includes activities from pre-drilling seismic surveys to development activities (such as installing gathering and flow lines), and continuing through to final field reclamation. This handbook summarizes those issues that create some of the most significant impacts relative to impedances or delays to onshore exploration and production activities; the handbook also suggests approaches to avoiding, minimizing, or mitigating those impacts. Further, the goal is to provide beneficial analysis of various practices to serve as a starting point for operators to select practice options and perhaps also for non-industry people to understand the advantages and disadvantages of various approaches.

This document is aimed at providing information that can be utilized nationwide to increase access to federal lands through the development of consistent environmental impact avoidance, minimization, and mitigation specific to onshore oil and gas development. The goal is to accomplish this by fostering sound environmental impact mitigation methods. The approach utilized to reach such objectives begins with identification of common adverse environmental impacts and the technical tools and methods that can be implemented in a practical and feasible manner; while simultaneously maintaining a legitimate balance between environmental protection and fluid mineral development consistent across state and federal agency jurisdictions. This guide is intended to enable land management agencies and oil and gas operators to make decisions that support access to federal resources while achieving that balance.

1.6 OVERVIEW OF RESEARCH

This document contains the results of research conducted to provide an overview of potential adverse environmental impacts resulting from onshore oil and gas development on federal lands and/or mineral estates and possible mechanisms that can be employed to avoid, minimize, and mitigate such impacts. The research was conducted on a nationwide basis with federal and state agencies as well as interviews with industry personnel, NGOs, and individual citizens from a variety of states.

- *Surface Disturbances: The researchers examined non-regulatory and regulatory guidance documents and also conducted interviews with industry personnel, NGOs, and individual landowners to identify surface impacts and their respective potential corrective measures. Impacts to surface can include loss of cropland, loss of wildlife habitat, soil erosion, and subsequent impact to surface water bodies, etc. This section is intended to provide readers with a familiarity of the range of environmental disturbances and selected appropriate corrective measures associated with onshore oil and gas exploration and production in the United States.*
- *Wildlife – Specifically Sage Grouse: The researchers examined non-regulatory and regulatory guidance documents and academic documents. They also conducted interviews with industry personnel, NGOs, and individual landowners to identify environmental impacts to wildlife in general and western sage grouse in particular. Potential corrective measures also were examined. Several different species are an issue in parts of the western United States; not only does the western sage grouse share many of the challenges confronting these various species, but its management has become highly visible and contentious for all manner of land use development, including oil and gas.*
- *Sage grouse are being considered for potential listing as a threatened or endangered species; such a designation would have significant bearing on future oil and gas and agricultural industry activities in sage grouse habitat areas. This could greatly impact the economies of several Rocky Mountain States; therefore, measures that can be taken to sufficiently protect the grouse without requiring a listing status are beneficial to both the birds and a variety of local industries. An analysis of sage grouse population data for Montana and Wyoming, with a specific emphasis on the Powder River Basin (PRB), an area of intense coal bed natural gas (CBNG) development, is presented. This section is intended to provide readers with a basic familiarity of wildlife impact issues in general and an examination of available sage grouse population data for the PRB demonstrating the limitations the data pose on interpreting population trends within the data.*
- *Air Emissions: The researchers examined non-regulatory and regulatory guidance documents and also conducted interviews with regulatory and industry personnel to identify air emissions issues resulting from onshore oil and gas activities. Air quality issues are becoming an increasingly important focus in the United States, particularly in the western states. This section is intended to provide readers with a familiarity of the range of air pollution issues and appropriate corrective measures associated with onshore oil and gas exploration and development in the United States.*

1.7 PROJECT ADVISORY COUNCIL

The research herein was conducted under the direction of the IOGCC, with oversight and direction from a Project Advisory Council (PAC). The PAC was comprised of a diverse group with interests related to federal land management and oil and gas development that included state oil and gas agency directors and industry representatives. Input was actively sought during various stages of the research to provide direction for the research, and to help to identify issues relevant to the success of the research. The diversity of the PAC has resulted in the research obtaining unique perspectives into the environmental impact issues potentially resulting from oil and gas development activities on federal lands and/or mineral estates.

1.8 OPPORTUNITIES FOR FUTURE RESEARCH

Recommendations for future research, pertinent to each of the focus categories, are included at the end of each of the respective focus chapters.

SECTION 2

Introduction to Onshore Oil and Gas Development

2.1 BACKGROUND

The United States currently relies on oil and gas to supply more than 60 percent of the nation's energy needs and nearly 100 percent of its transportation fuels (National Energy Policy Development Group {NEPDG}, 2001). The energy needs of the United States exceed domestic sources, a situation that is projected to continue with ever increasing disparity as energy needs continue to rise. Furthermore, the rapidly growing economies of China and India are placing greater and greater demands on the global availability of fossil fuels.

The Bush Administration's Energy Policy highlighted the means to meet the nation's future energy needs through conservation, increasing domestic supplies, strengthening the energy infrastructure and increasing alternative and renewable fuels (NEPDG, 2001), while sustaining environmental responsibilities and strengthening foreign alliances. The National Energy Policy Development Group, which provided the basis for the Bush Administration's Energy Policy, suggested that one way to raise domestic on-shore production is to increase access to federal land and mineral estate holdings with potential oil and gas reserves to produce a greater percentage of the nation's oil and gas resource needs.

The federal government owns approximately 30 percent of the land in the United States. Much of the nation's public lands are estimated to have substantial undiscovered energy resources (NEPDG, 2001) representing a favorable potential source for increased domestic production. Therefore, access to federal lands for the leasing and development of oil and gas resources is critical to helping meet the nation's current and future energy demands.

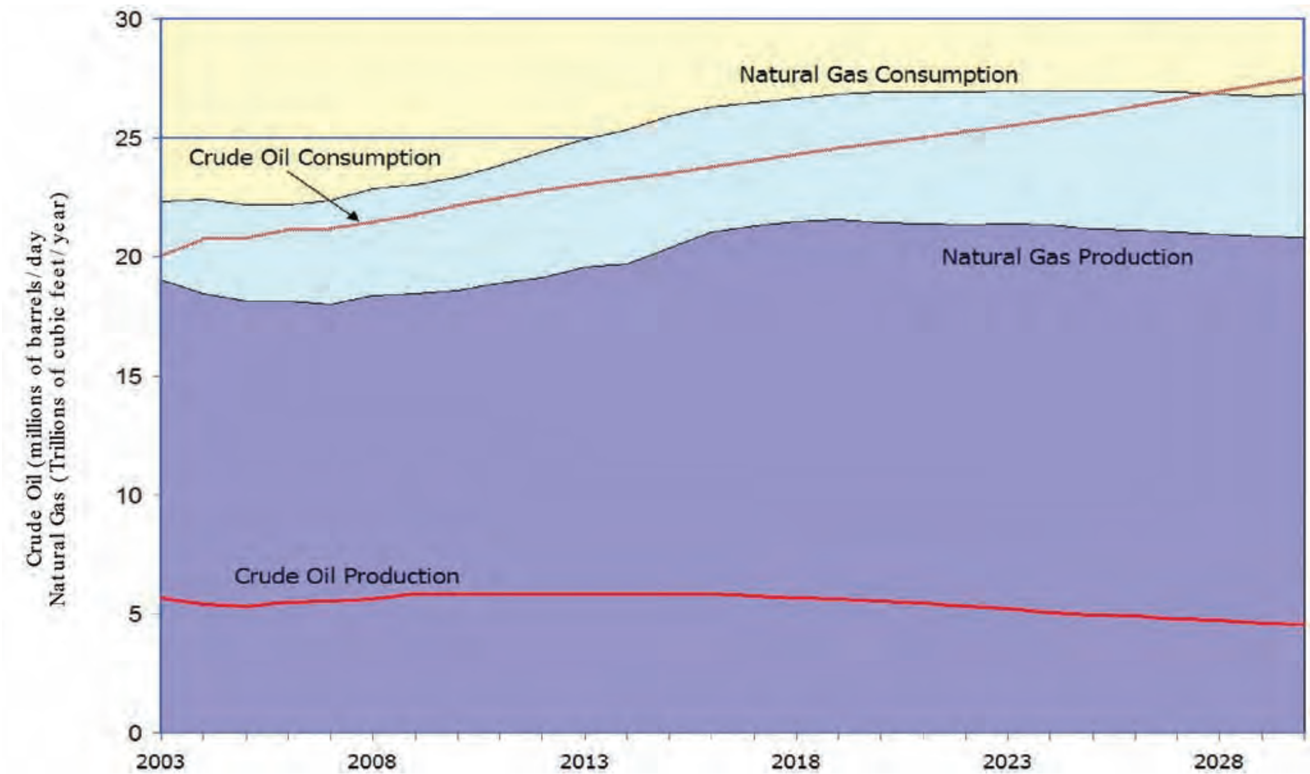
Considering the national importance access to federal lands has for energy development and supply, it is also critical to understand and address associated environmental and social concerns related to activities involving oil and gas exploration and production. This document is intended to serve as a reference for operators, land managers, and other stakeholders to implement development with greater environmental protections.

The need to improve access to federally administered minerals is perhaps best demonstrated through oil and gas development statistics over time. Statistics from the Energy Information Administration (EIA), the agency that tracks energy-related data, demonstrates how the consumption of energy from oil and gas resources in the United States is outpacing domestic production (Figure 2-1 on the following page). The current domestic supply of crude oil is approximately 5.5 million barrels per day, while consumption of crude oil is in excess of 20 million barrels per day; a domestic production shortfall of 14.5 million barrels per day (EIA, 2005). Projections for domestic production of crude oil show fluctuations around approximately 5.5 million barrels per day through 2015, after which production is predicted to slowly decline (Figure 2-1). However, consumption of crude oil is expected to steadily increase to more than 27.5 million barrels per day by 2030, resulting in a domestic production shortfall of more than 20 million barrels per day.

EIA's projections for natural gas through 2030 also are shown on Figure 2-1. Current natural gas consumption is greater than domestic production, yet the natural gas domestic production shortfall is not as large as that for crude oil. The difference between domestic production of natural gas and consumption was approximately 4 trillion cubic feet (TCF) per year in 2003. While production of natural gas is expected to grow over the next 15 years, consumption is expected to grow at a faster rate. Predictions indicate a domestic production shortfall of approximately 7 TCF/year by 2030 (Figure 2-1). The implications of these trends suggest that the oil and gas industry will be forced to make up the increasing shortfall between growing demand and shrinking domestic supply. The shortfall can only be narrowed with increased production or costly imports.

Figure 2-1: United States Domestic Oil and Natural Gas Production and Consumption

Graph depicts estimated domestic oil and natural gas production and consumption through 2030 (EIA, 2005)



Shortfalls of natural gas might best be ameliorated by increasing development of tight gas, coal bed natural gas, and other unconventional resources. The EIA forecasts unconventional gas to grow as a percentage of total gas production from 28 percent in 2003 to 36 percent in 2025 (EIA, 2003). Unconventional gas resources frequently demand large numbers of wells and more intense infrastructure --- factors that could create environmental impacts that, in turn, might constrain access to certain federally controlled land areas. In many cases, measures can be taken to avoid, minimize, and mitigate environmental impacts. They include use of low emission motors; more environmentally sensitive water treatment and disposal methods; and minimization of the drilling footprint through use of single drilling pads with multiple, directionally drilled wells (EIA, 2002). Such measures might help to offset constraints to accessing federal land and mineral estates and; therefore, serve to help increase domestic production rates and decrease the rate of increasing reliance on foreign imports.

The United States Geological Survey's (USGS's) national assessment of oil and gas resources estimates the current mean oil and gas resources of the United States to be 47.3 billion barrels of oil, 622 TCF of total natural gas, and 11.4 billion barrels of natural gas liquids (USGS, 2005). Analysis of oil and gas fields with the highest known reserves (see Figure 2-2) indicates these fields are concentrated in five regions: California, the Rocky Mountain States, the south-central United States, Alaska, and the Gulf of Mexico. Figure 2-3 depicts federal surface management by responsible federal agencies. Federal lands comprise approximately 30 percent of the United States, with the majority being located in the western half of the United States, including Alaska. A comparison of Figures 2-2 and 2-3 indicates that Alaska and the Rocky Mountain States are the two regions with the greatest proven oil and gas reserves coincident with federally managed lands.

The Rocky Mountain Front contains considerable oil and gas reserves (Figure 2-2) and is a region with vast areas of land administered by the United States Department of the Interior, Bureau of Land Management (BLM); United States Department of Agriculture, Forest Service (FS); United States Department of the Interior, Fish and Wildlife Service (F&WS); and the United States Department of the Interior, National Park Service (NPS). At the same time, Alaska's North Slope is estimated to contain the greatest untapped oil and gas reserves in the United States, most of which is administered by the F&WS (USGS, 2005).

There are numerous federal agencies that administer federal surface estates (Figure 2-3) and each agency has its own administrative land uses policy for the areas they manage. Only one federal agency, the BLM, is responsible for managing the 700 million acres of subsurface mineral estates and is solely responsible for the leasing of fluid minerals on all Federal Lands (BLM, 2005). While the BLM is tasked with managing oil and gas leasing of federal mineral estates, the issuance of oil and gas leases and permits is not solely the responsibility of the BLM.

As noted by the House of Representative's NEPA Task Force, political pressure and litigation from Non-Governmental Organizations (NGOs) have resulted in increasing numbers of delays for oil and gas leasing and development. According to the Council of Environmental Quality, more than 565 lawsuits regarding NEPA actions were filed between 2001 and 2004 (CEQ, 2006). Each of these lawsuits has the potential to postpone a major development project for long periods of time. Development is sometimes further delayed if additional analyses or supplements to National Environmental Policy Act of 1969 (NEPA) analysis documents are ordered to be written by the court.

The need for additional domestic production of oil and gas resources was identified in the Bush Administration's National Energy Policy. Some of the largest potential reserves of oil and gas in the United States are present on lands managed by the federal government. To develop the resources present on federally managed lands, oil and gas operators need to be able to access these lands. The intent of the LINGO effort is to evaluate strategies that would allow oil and gas exploration and production to occur with less environmental impact so that there might be less public resistance to projects contributing towards increasing domestic production.

Figure 2-2: Total Dissolved Solids from the Produced Waters Database in the United States

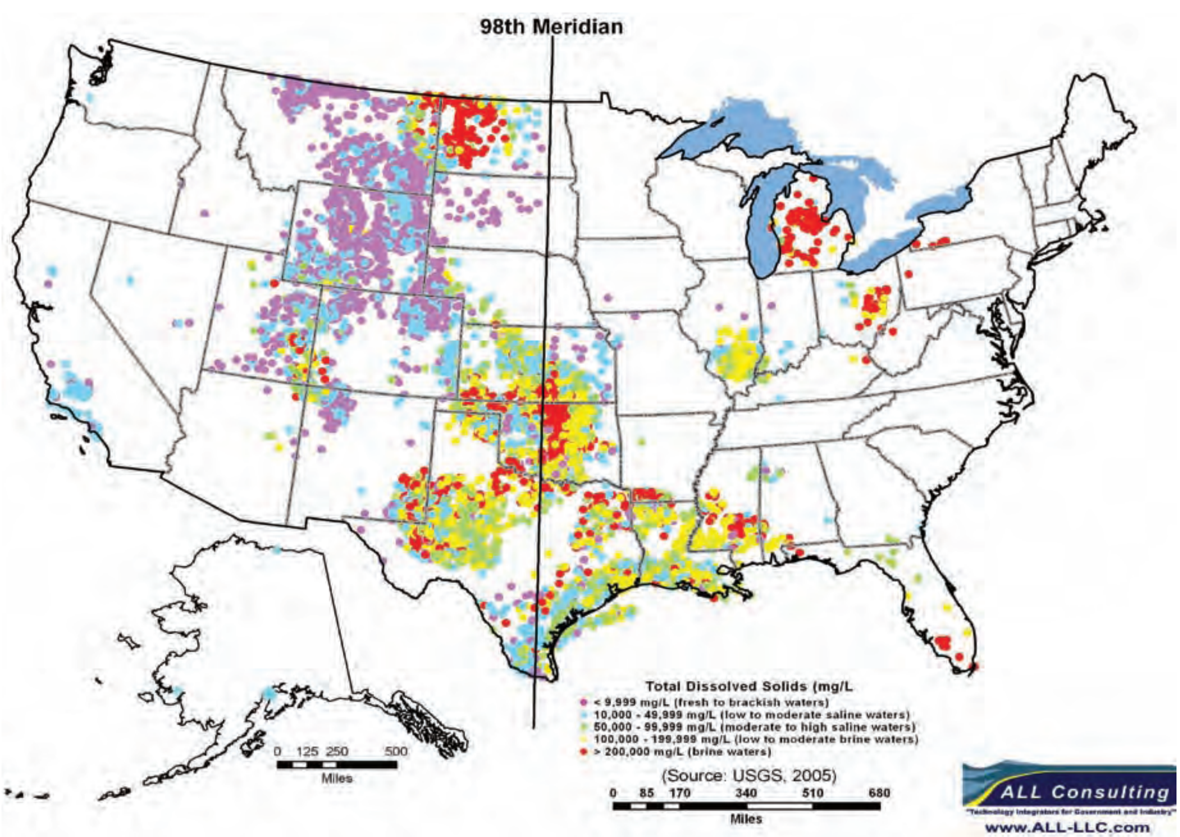
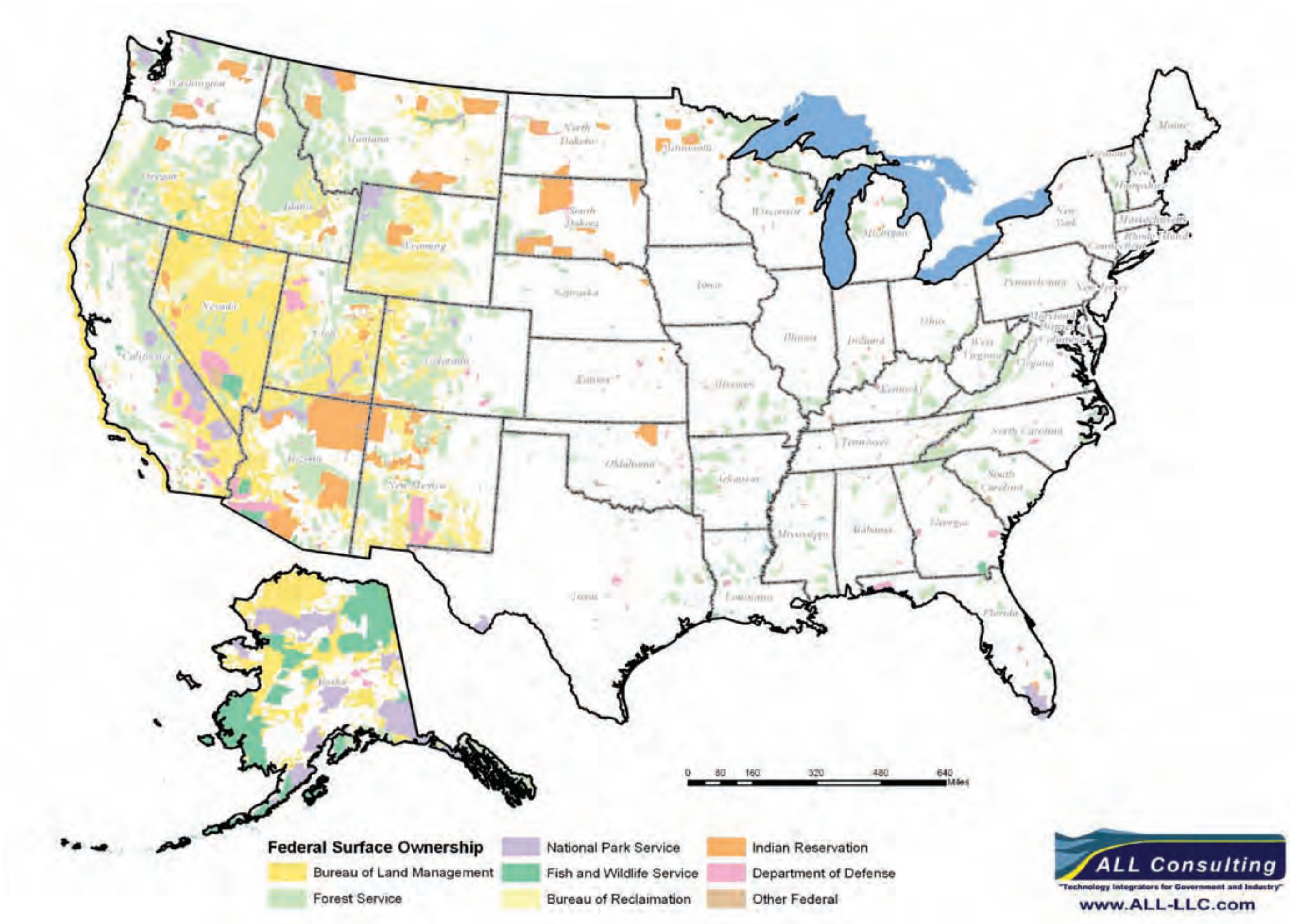


Figure 2-3: Federal Surface and Surface Managing Agencies



2.2 THE PROCESS OF ONSHORE OIL AND GAS DEVELOPMENT

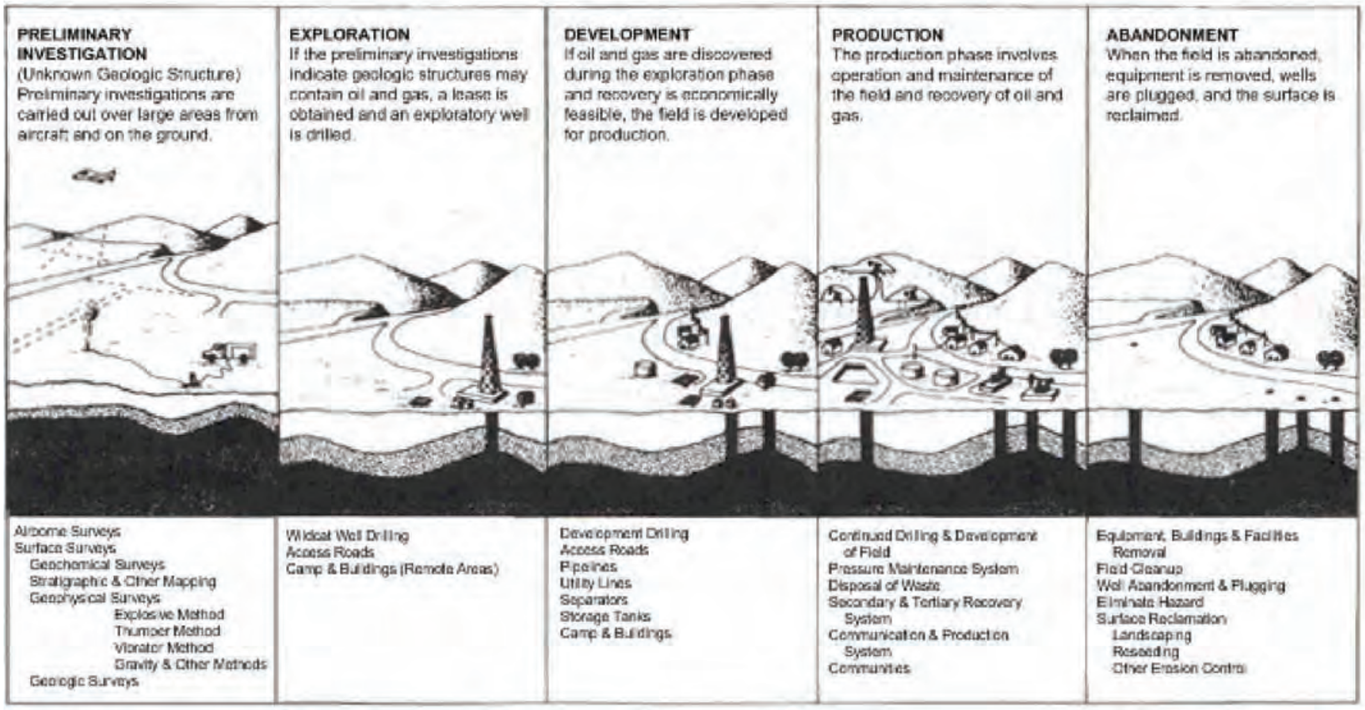
This section provides a brief primer on the sequence of events leading up to a producing oil or gas well and field. Activities associated with onshore oil and gas development can be divided into a sequence of events that occurs in phases as a project progresses from exploration to development. These can include the following five phases: leasing, exploration, development/construction, production, and final reclamation. Figure 2-4 presents a sequential breakdown of activities that occur in the development of oil and gas fields, providing information on each of the phases of oil and gas development.

2.2.1 LEASING

An oil and gas lease is a legal right granted to an operator (the lessee) "...to explore and drill for, extract, remove, and dispose of oil and gas deposits, except helium, that may be found in the leased lands" (BLM, 2004). The BLM was assigned the responsibility for oil and gas leasing of minerals owned by the Federal Government in the Mineral Leasing Act of 1920, the Mineral Leasing Act for Acquired Lands of 1947, the Federal Oil and Gas Royalty Management Act of 1982, and subsequent amendments to these Acts (BLM, 2004). Public lands are made available for oil and gas leasing only after the BLM has assessed the lands using their multiple-use planning process (BLM, 2004) pursuant to NEPA. Although environmental disturbances ultimately might be provided for by the act of making a land or mineral estate parcel

Figure 2-4: Summary of the Phases of Oil and Gas Development

BLM, 1986, Pinedale RMP



eligible for leasing, environmental impacts are not incurred during the leasing phase itself.

2.2.2 EXPLORATION PHASE

After a lease has been acquired but before an operator initiates drilling or other surface disturbing activities for an exploratory (wildcat) well, the operator must post a lease bond and file an Application for Permit to Drill (APD) or Notice of Staking. The BLM must then perform an assessment of potential impacts by completing either an Environmental Assessment (EA) or an Environmental Impact Statement (EIS) pursuant to NEPA prior to approval of the APD. The operator must specify in the APD information relative to the type of oil and gas well and depth of the targeted exploration zone. This information is used by the operator to determine the equipment and access needed to drill the exploratory well, and is used by the BLM to evaluate environmental consequences of the proposed action pursuant to NEPA (NPS, 2003). The construction activities for an exploration well typically include a roadway and drill pad. The areas proposed for pads, roadways, pipelines, etc. must be staked or flagged prior to the BLM's field inspection, which is part of the APD approval process.

The size of access roads and drill pads, and hence the extent of potential surface disturbance, for exploratory wells vary based on the depth of the target exploration zone. Shallow exploratory wells (500 to 2,000 feet) may require a simple bladed road to clear brush and allow access for a short time period (typically a few days). Deep exploratory wells (5,000+ feet), on the other hand, might require construction of higher standard crowned and ditched gravel roads because drilling activities might take one to several months and require considerable heavy truck traffic (MBOGC, 1989). The size and type of drill rig necessary to advance a well is determined by the depth of the target zone; all other things being equal, the deeper the target, the larger the drill rig. Shallow CBNG wells in the Powder River Basin of Montana and Wyoming can be drilled with conventional water well rigs, while deeper oil and gas wells typically require the use of double- or triple-derrick rigs. The drill rig selected dictates the properties of the access road and size of the drill pad necessary to support the project. Water well rigs with small mud reserve pits or tanks can operate on drilling pads as small as ½ acre or less, while double- or triple-stand derrick rigs may require drill pads of 3 acres or larger. (MBOGC, 1989). Deeper wells require larger drilling rigs, mud tanks, reserve pits, produced water storage, oil and gas storage tanks, pipe racks, and crew parking, all of which contribute to the need for a larger pad and staging area. The construction of access roads is also based on the size of the drill rig. Some of the smaller rigs can use bladed roads with a typical width of about 10 feet while larger rigs can require 24-foot-wide graveled, crowned, and ditched access roads.

After the drilling site has been inspected by the BLM and the APD approved, access roads and the drill pad are constructed. Then exploratory drilling activities can be initiated (typically by a drilling contractor under the direction of the operator). An oil and gas well is typically drilled in three phases: 1) the pilot hole is spudded using a large diameter auger bit, 2) the drill rig then drills the surface hole in which surface casing is set with cement and 3) the production hole is drilled. After the pilot hole is drilled, large diameter casing (24-inch to 36-inch conductor pipe) is set. And cemented in place, then the surface hole is drilled inside the conductor casing string and a second casing string is cemented in place in order to isolate any fresh water aquifers from the production drilling operations and also to supply sufficient pressure protection for the production drilling. Once the target (or "pay") zone is reached and tested to determine if a successful well has been drilled, the priduction casing string is cemented in place. The purpose of the production casing is to provide access to the production zone, to isolate the producing horizon from other stratigraphic zones, and to provide pressure protection for the production zone.

While drilling the well, testing might be conducted when potentially productive rock strata are encountered. Typical oil and gas well testing is conducted through the drill pipe by a specialized contractor under the direction of the operator (MBOGC, 1989). Once the well is drilled to depth, a series of well logs typically are acquired by another specialized contractor. Well logs are used to further evaluate the well's potential as a producer. After the drill-stem testing, and/or logging the operator evaluates the potential for a producing well and makes the decision either to complete the well or plug and abandon the borehole.

If testing indicates the well might produce commercial quantities of oil and gas, the well is completed by running production casing into the borehole. The type of completion performed on a well will vary depending on type, depth, operator, and the characteristics of the producing formation. In some instances, casing is run to the depth of the producing zone. Then casing is set in cement from the bottom to a point above the pay zone (MBOGC, 1989). Once the casing is set and the cement has been given the appropriate time to cure, the casing is perforated at the appropriate stratigraphic horizon(s) based on the information obtained from well logging and drill-stem testing (MBOGC, 1989). Once the production casing is set, tubing and a pump (as needed) are placed in the well and a wellhead is installed at the surface. The well is then tested for a period of time before permanent production equipment is brought onto the site; the test period will vary based on the operator and the well characteristics.

Often prior to drilling a wildcat well, geophysical surveys are performed to evaluate the subsurface geologic stratigraphy and structure. This helps oil and gas operators to identify where a wildcat well has the greatest probability for discovering trapped oil or gas. Geophysical seismic surveys are conducted using a variety of techniques usually involving a signal source (vibrations source created by small explosives placed in shallow boreholes, or hydraulically controlled vibrating plates mounted on specialized trucks). Geophones record the reflections of those vibrations from subsurface rock strata. The degree of environmental surface disturbance created as a result of a seismic survey varies with the type of survey conducted and the equipment necessary.

2.2.3 DEVELOPMENT/ CONSTRUCTION PHASE

Once the exploration phase has been completed and a producing zone has been identified, the operator begins to plan for the development phase, which typically involves drilling and constructing additional wells, access roads, and production equipment. Production well spacing, the closeness of one producing well to another in the same field, is established by the state oil and gas agency and the BLM. Well spacing is determined based on regional production trends necessary to optimize oil and/ or gas production while also preventing drainage of adjacent properties not under lease to the operator. Well spacing distance typically is described as the area available to a well to produce from (e.g.: 40-acre, 80-acre, 160-acre, and 640-acre spacing units). This may vary by producing formation and from one producing trend (made up of multiple fields) to the next. Gas fields usually are spaced on larger acreage units than oil fields because most producing strata are more permeable to gas than to liquid and so a gas well typically drains a larger area than an oil well can. The operator completes and submits APDs for each of the proposed production wells, identifies their location and access routes, and identifies the locations of production facilities such as tank batteries, produced water management facilities, pipelines, and utility routes. Typically an oil field requires more wells and production equipment than a gas field of similar acreage (MBOGC, 1989).

Depending on the characteristics of the producing reservoir, wells may require stimulation to produce oil or gas in economically viable quantities. Specialized contractors generally handle well stimulation work. The type and extent of well stimulation required can affect the required well pad size significantly. For instance, massive hydraulic fracturing stimulations typical of some unconventional gas plays, like the Barnett Shale in the Fort Worth Basin of north-central Texas, might require the temporary staging and operation of numerous fractionation tanks and pumping units. This can influence the size of the well pad significantly and, hence, the extent of surface disturbance.

Once the operator has approval of the locations and drilling permits from the BLM, construction will begin. Construction begins much like exploration activities, with the building of access roadways and well pads. However, additional infrastructure such power lines, pipelines, and production facilities also might be included. The quality of roads constructed during the development phase might be higher than during the exploration phase commensurate with the increased level of traffic the roadways are expected to handle during production. Some roadways might remain as simple two-track trails to the well locations, while graveled, crowned, and ditched roads might be constructed for the main field access roads (MBOGC, 1989).

Depending on stipulations placed on the lease, the operator might be limited to certain types of production equipment or installations such as buried utility lines instead of overhead power lines, or cavitation pumps as opposed to pump jacks. Additional stipulations restricting construction activities can be set during certain times of the year, particularly at times when wildlife are more vulnerable to disturbance. Lease stipulations can result in fewer surface aces disturbed by construction activities, but at the same time may limit an operator's choices of equipment or delay a project if the timing of APD submittals/approvals conflict with timig of lease stipulations set for wildlife breeding seasons, etc. Other construction related limitations might be imposed depending on the surface management agency or private landowner requirements for a project.

Some federal mineral estates can be located under surface estates administered or managed by federal agencies other than the BLM. In these cases the operator may be subject to varying mitigation measures. BLM and FS-managed lands have strict requirements for the control of noxious weeds. As a remedy to control the spread of undesirable plants, the BLM and FS might specify particular seed mixtures for revegetation and reclamation activities. For most surface disturbing activities associated with the construction phase, project operators might utilize interim reclamation practices to minimize longer term impacts. Examples include backfilling utility trenches as soon as the lines are placed and reseeding backfilled trenches and portions of the well pad as soon as practicable.

2.2.2 PRODUCTION PHASE

The production phase begins when the operator receives approval from the BLM or state oil and gas agency to initiate continuous oil or gas production. Early in the production phase, onsite activities usually are limited to monitoring of equipment and production, maintenance of equipment, and disposal of production wastes. Volumetrically water typically is the most common oil and gas waste material; this water is referred to as produced water. Generally, a field hand, known as a "pumper", performs routine monitoring and maintenance activities; this might be conducted as frequently as daily or weekly depending on the size of the field and rate of production. The BLM estimates that one additional annual production job (pumpers, workover crew, water haulers, rig repair, etc) is created for approximately every 18 wells in production for any given year (BLM, 2006). Put simply, for a field with 180 producing wells, approximately 10 qualified workers are typically needed to properly operate and maintain the field.

The demographic pressure caused by this demand for qualified workers in the oil and gas industry can last for several decades. This can place significant demands on local communities as the need for schools, infrastructure, and housing can quickly outpace the former growth rate. While such growth is to be expected, technological advances are being made to automate some field activities and increase field efficiency through the use of remote monitoring equipment. The location and type of equipment used to monitor production activities vary depending on the type of well and the location of the nearest sales point or main gas line; it also can be influenced by mineral ownership. Production from oil and gas wells must be monitored by individual leases in cases where the field has not been unitized (i.e.: production is not shared by all lease owners) and production is gathered into a central processing facility (MBOGC, 1989).

As noted above, wells typically produce water along with the oil or natural gas. This produced water varies in quality and quantity - the two principal factors that govern how the water is managed. Depending on the characteristics of the producing formation, produced water quality can range from fresh water (near, or at, drinking water quality) to saline brines with total dissolved solids concentrations several times greater than that of seawater. Management of produced water can be handled by a variety of means, and there are numerous reports that discuss produced water management for the oil and gas industry (ALL Consulting, 2003a, ALL Consulting, 2005 Argonne National Laboratory, 2004). A few examples of how water is managed include:

- *High quality water can be managed through discharge where this activity can be permitted.*
- *Low quantities of water can be managed in impoundments through evaporation or seepage to groundwater.*
- *Underground injection is a common means of disposal for large quantities and/or poor quality water.*

In the latter case, the produced water typically is injected into non-productive disposal zones (Class II Disposal) or into oil or gas producing zones as part of an enhanced recovery operation (Class II Recovery). Enhanced oil recovery (EOR) generally occurs when the production rates of oil from a reservoir decrease as a result of declining reservoir pressure. Initial (primary) production activities that use the native gas or water pressure from the reservoir to facilitate production usually produce only 20 to 25 percent of the oil-in-place (MBOGC, 1989). Enhanced recovery phases may be utilized to produce an additional 10 to 20 percent of the in-place oil. Secondary recovery involves the re-injection of produced water into the pay zone to maintain the reservoir's drive pressure. Tertiary recovery involves enhanced water flooding scenarios such as the injection of carbon dioxide, (CO2; which improves the miscibility of oil in the formation water) or other chemical agents (typically surfactants) into the reservoir to facilitate the production of additional oil. The economic feasibility of secondary and tertiary enhanced recovery projects is influenced by many parameters, including the innate characteristics of the reservoir to accept injected fluids.

More recently, the injection CO_2, has received considerable attention for its potential value in geologic carbon sequestration. Carbon sequestration in oil reservoirs has the dual benefit of enhancing oil recovery and removing carbon dioxide from the atmosphere (CO_2 has been linked to global climate change as a greenhouse gas). The ideal carbon sequestration project would include a CO_2 source (i.e. coal-fired electric power plant) in close proximity to a carbon sink (i.e. aging oil and/or gas field). The United States Department of Energy estimates that 89 billion barrels of oil production could be added through CO_2 enhanced recovery, more than four times the current proven reserves of the onshore United States (DOE, 2006). This dual benefit of enhancing oil recovery and managing greenhouse gas emissions likely will continue to push the use of carbon sequestration on both public and private leases.

Maintenance activities typical of the production phase can range from routine maintenance of surface equipment, leaks, mechanical failures, etc., to more extensive well workover and stimulation. Field hands who either work for the operator or are contractors to the operator usually handle simple repairs involving the lesser day-to-day maintenance activities. Specialized contractors generally handle well work-overs or well stimulation work. Usually, it is not necessary to create additional surface disturbance to perform such maintenance.

2.2.4 RECLAMATION PHASE

Ideally, reclamation activities occur continually throughout the life of an oil and gas development project, with operators actively reclaiming temporary surface disturbances (interim reclamation) during the construction and subsequent phases, and performing final reclamation once production activities have ceased.

Well plugging and abandonment is a reclamation activity that might occur throughout the life of a project. Wells are plugged in a variety of ways depending on the status of the well at the time of plugging; a dry hole exploration well may require a different plugging and abandonment protocol than a production well. Various state oil and gas oversight agencies specify, regulate, and inspect the plugging and abandonment protocols required in their jurisdiction. Generally, plugging and abandonment activities are intended to isolate and protect underground sources of drinking water (USDW) as well as to isolate potential oil and gas producing zones from non-producing brine-filled strata. Therefore, cement and mechanical plugs typically are set at various intervals defined by the depth of the well, presence of USDWs, presence of saltwater zones, and agency regulations.

Surface reclamation of the wellsite and other facilities generally involves the removal of production equipment, backfilling of pits, and reseeding of graded areas, flow lines may be removed or abandoned in place, and the land surface restored to pre-development conditions. Unless the surface management agency or private surface owner specify otherwise, all oil and gas related materials are removed from the site and the land surface is restored according to the stipulations attached to the lease, including reseeding disturbed areas. After the reclamation has been initiated, managing agencies perform site inspections to document the success/progress and to identify any conditions requiring further attention. Only after the site reclamation has been completed in accordance with local regulations and/or lease stipulations will it be approved by the managing agency. Upon completion and approval of final reclamation the regulatory agency typically will release any bonding requirements of the lease.

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SECTION 3
Surface Disturbance

3.1 INTRODUCTION

Surface disturbances related to oil and gas activities represent a wide range of issues, some of which are specific to the conditions of the site whereas others are more common to a wide range of sites. Stakeholders such as landowners, ranchers, farmers, environmentally focused non-governmental organizations (NGOs), concerned citizens, land managers, and oil and gas personnel have differing views on surface disturbances and how they should best be managed. Section 3 uses case studies and examples to provide insight for stakeholders involved in various types of oil and gas developments, ranging from rural developments in existing or historical (vintage) fields to urban developments in emerging fields.

This section of the Impact Reduction Handbook is segmented in three parts. The first introduces a general overview of surface disturbance considerations that are applicable to nearly every type of oil and gas development project. Site-specific considerations also are introduced by segmenting oil and gas development projects into different land use, physiographic, and demographic categories and discussing surface disturbance issues relevant to each category.

The second discusses solutions and prudent management practices that have been utilized in various parts of the country to minimize surface disturbances. This is done through analyzing and examining case studies researched under a multitude of circumstances.

The final part provides a summary of the research findings and proposes recommendations for moving forward in consideration of the lessons learned from the case studies and observations made by the research team

3.2 SURFACE DISTURBANCE CONSIDERATIONS

Surface disturbances are a reality for the oil and gas industry whether they are on the plains of Kansas and Oklahoma, the arid regions of west Texas, the swamps and bayous of Louisiana, or in the Rocky Mountain States. The magnitude of disturbance may vary according to the region or physiographic setting; however, the fact remains that to produce oil and gas resources, the surface must be disturbed to allow access to the resource (e.g., roads, well pad, etc), as well as placement of infrastructure to allow for resource transportation (e.g., compressors, pipelines, etc). Section 3.2.1 discusses important surface disturbance factors to consider; Section 3.2.2 provides a general overview of the types of oil and gas construction activities that are associated with surface disturbances; and Section 3.2.3 provides examples of surface disturbances that are specific, unique, or otherwise receive special attention to various land use/physiographic/demographic categories that exist across the United States.

3.2.1 SURFACE DISTURBANCE FACTORS

GENERAL

The footprint of drilling and production operations for oil and gas projects is variable and is dependent upon the producer's equipment needs and the mutual objectives established by the operator, managing agency, and surface-rights landowner. Land uses within any producing area may vary considerably and can include forest preserves, residential communities, rangeland, wildlife habitat, etc. Regardless, oil and gas development within a given area must comply with the land use plans and policies adopted by federal, state, and (in some cases) local governments. In addition, different land uses often will require operators to adjust their approach during development and production to avoid or minimize impacts to existing land uses (ALL Consulting, 2004). Under these varying circumstances the development of surface use plans will allow for more efficient use of the land while balancing protection of important local resources by minimizing surface impacts and mitigating those impacts that are unavoidable.

Surface use planning is an important aspect of managing impacts because it can provide an opportunity for developers to work in cooperation with landowners to establish scientifically sound and economically profitable energy resource development while maintaining existing land uses, or possibly facilitating future new land use opportunities (ALL Consulting, 2004). For example, the location of ponds, roadways, and multi-well pads can allow for the continuation of current land uses while providing improvements to the landscape that would be beneficial to future uses. Additionally, surface use planning can alleviate concerns that development will impact cultural and wildlife resources, for example, through avoidance practices and noise reduction technology. In most cases a surface use plan will constitute an important component of the permit to drill application (APD) specifying measures that will minimize surface damage and degradation of visual resources, as well as defining actions that will not be detrimental to other uses or properties.

For example in CBNG development, not every subsurface completion requires a dedicated surface location, thus reducing further land disturbing activities. For example, disposal wells and deep wildcat tests can be placed on pads that also accommodate producing wells. There are a wide variety of control measures that can be utilized on oil and gas projects to reduce impacts that may arise from surface disturbing practices. Although the successful and appropriate implementation of these control practices will vary by situation, in many cases they can be established and monitored with minimal project costs.

SOILS

Impacts on soils and the ensuing consequences have been well documented in the oil and gas industry and as a result, many preventive and economically feasible measures have been developed. Surface soils have the greatest likelihood of suffering damage during the primary phases of development, more specifically during the exploratory and construction phases. The primary stages of construction require the removal of vegetation, leaving soil bare and more susceptible to erosion and sedimentation. During this time soil disturbance and erosion can result from the construction of roads, well pads, storage facilities, and other oil and gas infrastructure. Erosion peaks in this phase and wanes during reclamation.

To minimize soil erosion, the soil in any given project area should be characterized properly to identify the vertical profile of the soil located within the vadose (unsaturated) zone as well as a clear identification of the soil type. Special attention also should be paid to the physical and chemical nature of the soil, such as the soil structure, moisture content, porosity, bulk density, and hydraulic conductivity. Weather conditions in the area should be evaluated because wet soils compact more easily than dry soil; therefore, areas with higher precipitation levels may be more susceptible to soil compaction and rutting. If the soil in a project area is determined to be susceptible to compaction, then if feasible, the weight-bearing surfaces of equipment should be increased by using wider tires or tracks on vehicles and equipment to prevent significant soil compaction and rutting.

To further minimize soil erosion and to restore visual resources, vegetative covering to stabilize the surface should be performed immediately upon completion of construction or ground-clearing activities. There are numerous guidance documents on management controls and best management practices that can be implemented to minimize soil erosion, including the RAPPs Guidebook (Horizon Environmental Services, 2004), the BLM "Gold Book" (BLM, 2007), and Pollution Prevention at Exploration and Production Sites in Oklahoma (OCC, 2002). The best approach to controlling erosion on development-related roads and access ways is to adapt these resources to local conditions so they provide good drainage of runoff water at non-erosive velocities (Horizon Environmental Services, 2004). Ensuring that runoff occurs at non-erosive velocities can be accomplished using several methods based on regional conditions.

WATER RESOURCES AND WATER MANAGEMENT

The proper management of water resources during the developmental and operational phases of oil and gas production is directly related to minimizing surface disturbances. For instance, water can be used to create optimal soil moisture conditions to allow for the proper compaction of soils, thereby minimizing surface degradation caused by vehicular traffic and the occurrence of erosion events. Water is also important to help suppress dust and is necessary for drilling, completion, and hydraulic fracturing activities. Furthermore, since a large volume of water is often generated during the oil and gas production process, especially for CBNG production, additional surface disturbances may result without proper produced water management plans. For example, additional surface water can affect water quality, cause changes to channel morphology in nearby streams, or cause damage to access roads used by local residents.

Surface impacts resulting from additional surface water in the oil and gas industry are most likely to occur during construction activities when vegetative cover is reduced or during production operations if proper produced-water management practices are not being implemented. However, the release of produced water typically can be controlled to prevent surface disturbances by utilizing management practices appropriate to the location or circumstances. Depending on the region, local geology, and water quality, produced water can be used to support livestock/wildlife watering or for use in irrigation systems. The water can also be discharged into appropriate water systems or re-injected into suitable aquifers.

VISUAL RESOURCES

Oil and gas related surface disturbances may have negative impacts on visual resources that are important to local residents or for those who use the area. Impacts resulting from oil and gas exploration and production activities may occur locally as native vegetation is disturbed and small structures are erected. Exploration may involve minor visual impact from clearing operations for access to exploratory sites. The majority of these impacts typically result from access road and utility corridor construction, well-site construction, drill rig operations, and on-site generator use. Short-term visual disturbances would occur where construction and drilling equipment is visually evident to observers. Long-term impacts would occur from construction of roads and pads, installation of facilities and equipment, vegetation removal, and change in vegetation areas .Oil and gas operators on federal lands are responsible for complying with the visual resource management objectives outlined in BLM regional land use plans for activities that alter landforms, disturb vegetation, or require structures (BLM, 2006). Site-specific mitigation for visual resources often includes a selection of paint color for facilities to insure they blend in with the natural landscape. Other considerations from the BLM's "Gold Book" (2007) include:

- *Aesthetic siting of roads, well locations, and production facilities.*
- *Avoiding straight-line roads and utility corridors that disrupt the natural appearance of the land.*
- *Modifying production facility or well pad shape or size.*
- *Using low-profile or below ground pumping units and low-profile tanks.*
- *Avoiding placement of tanks on ridgelines.*
- *Manipulating vegetation to feather straight edges.*
- *Using natural-looking earthwork berms or vegetative screening.*
- *Completing interim reclamation of disturbed areas.*

GENERAL OVERVIEW OF CONSTRUCTION ACTIVITIES AND SURFACE DISTURBANCES

The key elements of surface disturbances common to most oil and gas developments include the following:

- *Wells, well pads, and centralized centralized facilities*
- *Roads and road construction*
- *Gathering and sales pipelines*
- *Electric power-lines*

This section will discuss these disturbances and why they are necessary or common to most developments.

WELL SITES, WELL PADS, AND CENTRALIZED FACILITIES

Well sites and pads are necessary to drill and produce from the well. Centralized facilities are involved in all facets of an oil and gas project. An example of a centralized facility on the upstream (in the field) side would be a tank battery collecting oil from multiple wells in a remote location. That oil is either trucked to market or transported via pipeline. In the midstream (transportation) area, an example would be a natural gas compressor site and/or meter run where multiple gathering pipelines are tied into a sales line. Examples of downstream centralized facilities would be gas processing plants or oil refineries. It should be noted that the focus of this section are the upstream and midstream centralized facilities since the handbook's objective is to identify low impact approaches for new surface disturbances.

The magnitude of the surface disturbance, whether it be a well pad or a centralized facility, will depend on several site-specific factors such as topography, soil type, depth of well to be drilled and completed, type of rig used, drilling, and new completion techniques. Using soil type as an example, soil compaction and rutting will vary and depend on the soil's texture, moisture content, and organic matter (BLM, 2003b). Soils composed of sand, silt, and clay are more prone to compaction than soils that are more homogeneous, and coarser textured soils are more susceptible to compaction than finer textured soils (BLM, 2003b). In addition, soils with higher organic matter content compact less than those with less organic matter (BLM, 2003b).

ROADS AND ROAD CONSTRUCTION

Small all terrain vehicles (ATVs) and trucks designed for off-road use are often used for accessing well locations without a properly maintained road. However, avoidable impacts to the surface can result if a road or two-track does not exist. Satisfactory roads that are well compacted are required for most drilling rigs and associated equipment to access the well site safely. Road construction can be as simple as designating a well traveled two-track, or primitive road that has little or no compaction or erosion concerns, such as in a relatively flat prairie or agricultural settings. Nevertheless, road construction can be complicated if the terrain and/or soil conditions are challenging, or if the anticipated traffic volume is such that the roads must be engineered with a crown and ditch to allow for higher loads and usage. Either way, roads are necessary both in the development stage of the project (for drilling) and during operations (for maintenance and production).

During road construction, ensuring that erosion is minimized or runoff occurs at non-erosive velocities can be accomplished using several methods that vary based on regional conditions:

- *The roadway should be designed with an overall shape that allows water to be shed into stable ditches and culverts.*
- *Drainage dips should be employed wherever useful or necessary.*
- *Water bars should be employed wherever useful or necessary.*
- *Turnouts and wing ditches should be employed wherever useful or necessary.*
- *Vegetation, gravel, and mulch should be used to stabilize surfaces.*

GATHERING AND SALES PIPELINES

In most cases, pipelines are required to transport efficiently most oil and gas resources from the field to market. Pipelines also are used to transport produced water to centralized management facilities. Because pipelines can be buried, and the surface reclaimed, long-term surface disturbance associated with pipelines can be avoided. The placement of pipelines should avoid steep hillsides and water courses. Pipeline routes, when feasible, should take advantage of road corridors to minimize surface disturbance (BLM, 2006). Also, when clearing is necessary, the width disturbed should be kept to a minimum and topsoil material should be stockpiled to the side of the routes where cuts and fills or other surface disturbances occur during pipeline construction (BLM, 2006). Retaining topsoil for replacement during reclamation can accelerate successful re-vegetation significantly.

In some cases, such as a marginal oil well (stripper well) located in a remote area, it is not economical to lay pipeline to the well; typically a tank is placed at the well head and the product is transported on a routine basis by tanker truck.

ELECTRIC POWER

Power is required at the well to operate the pump and controls at the wellhead. This is achieved primarily through the use of overhead or underground electric lines to each wellhead, or, in some cases, by utilizing remote solar power to generate electricity. There are distinct advantages and disadvantages to each power source. In remote areas, overhead electric lines can be expensive to install, but in less remote areas with existing lines nearby, it then becomes a cost effective method of power supply. Buried cable can be more expensive to install than overhead electric lines. Solar/Wind power is common in remote areas where there are no overhead electric lines and the size of the development has not yet reached the critical mass necessary to justify installation of utility lines. However, solar/wind power may be the least cost effective and reliable because the technologies still are relatively inefficient and dependent on unpredictable weather conditions. As such, battery requirements to supplement power during non-generating times might be costly to install and might not be fully capable of providing electrical power through non-generating times -- resulting in production loss. As with pipelines, electric power lines should take advantage of road corridors to minimize surface disturbance whenever feasible.

3.2.1 SURFACE DISTURBANCES SPECIFIC TO VARIOUS LAND USE/DEMOGRAPHIC CATEGORIES

Surface disturbances that are specific, unique, or otherwise receive special attention for various land use/physiographic/demographic categories exist throughout the United States. To better illustrate this, the following land use/physiographic/demographic categories are discussed in this section.

Rural Agricultural and/or Ranching – Surface disturbances from oil and gas activities can compete with existing land uses for agriculture and/or raising livestock in rural areas.

Rural Scenic/Wildlife – Surface disturbances from oil and gas activities can impact the scenic "viewshed" of a property as well as adversely affect wildlife habitat and behavior in rural settings.

Urban Population Centers

Established Urban – In well established urban areas where residential, commercial, and industrial improvements have been made, oil and gas surface disturbances must be sensitive to the multiple land uses existing in the vicinity.

Emerging Urban (Suburban) – In areas on the periphery of an urban center (suburban) and/or areas where urban developments/improvements are anticipated, oil and gas surface disturbances can be planned in a manner to be most compatible with future developments.

Sensitive Habitat and Categorized Areas – Sensitive habitat and categorized areas, such as the wetlands and floodplains of Louisiana and East Texas, have specific surface disturbance regulatory requirements that must be taken into consideration to avoid penalties and/or fines, and to protect environmentally sensitive areas.

Areas of Critical Environmental Concern (ACEC) – ACECs are unique to the BLM. BLM regulations (43 CFR Part 1610) define an ACEC as an area "within the public lands where special management attention is required (when such areas are developed or used or where no development is required) to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish and wildlife resources, or other natural systems or processes, or to protect life and safety from natural hazards."

Critical Wildlife Habitat and Special Status Species –
Critical habitat for special status species is typically managed to protect these species from actions that would contribute to their being listed under the Endangered Species Act (ESA). Under most conditions, surface use actions that may disturb critical habitat are not permitted without specific land use plans or waivers that show such disturbances will not adversely impact associated wildlife or plant species.

Riparian/Wetlands – The BLM's Riparian-Wetland Initiative (see BLM, 1999) defines "riparian" areas as "ecosystems adjacent to streams and lakes that are strongly affected by water"; "wetlands" are "areas that are inundated or saturated by water long enough to influence the type of vegetation present" and include: "bogs, marshes, shallows, muskegs, wet meadows, estuaries, and swamps." Allowable surface disturbance actions in these habitats are limited and their nature and extent typically are contingent upon approval by the U.S. Army Corps of Engineers through the Clean Water Act (CWA) Section 404 permitting process. In some instances, the Rivers and Harbors Act (RHA) Section 10 also is applicable.

Vintage Production Fields – A vintage production field is loosely defined as a field where oil and gas activities have been ongoing for several decades or more. The development of these fields often pre-dated environmental laws and/or conservation efforts, and as a result they might pose unique restoration and management challenges.

Emerging Production Fields – An emerging production field, or an emerging resource type, such as shale gas or coal bed natural gas, might pose unique conditions. In some instances, these areas have just recently (last 5-10 years) seen large-scale exploration and production activities. These fields typically are emerging due to a combination of rising energy costs and new technologies, which can introduce unique issues associated with the production.

Public or Indian Resource Ownership – On public (federal or state) lands/minerals or on Indian lands/minerals considerations for surface disturbance effects can be significantly different compared to fee land/minerals that may be adjacent to the public/Indian property. This is due to the fact that public and Indian resources are managed by agencies that are responsible for determining the best possible use of all of the resource, not just mineral development. Cultural, paleontological, recreational, wildlife, and viewshed issues are just a few among many outcomes that can require unique management approaches to developments in these areas.

The issues and the corresponding impact considerations specific to each of the categories above are summarized below in various tables. A discussion of possible solutions and Prudent Management Practices for these issues and impacts, many of which have already been employed in the field, are included in Section 3.3.

RURAL AGRICULTURE AND/OR RANCHING

A rural area where agriculture and livestock dominate the surface land use will have surface disturbance issues specific to the area, including concerns about:

- *Crops.*
- *Grazing/pasturelands.*
- *Water supply for livestock and irrigation.*
- *Impacts to soil quality and vegetation stability.*

These issues and the corresponding impact considerations specific to rural agriculture and/or ranching are summarized in **Table 3-1.**

RURAL SCENIC/WILDLIFE

Scenic and wildlife uses are often intermingled with farm and ranch land uses; however, surface disturbance issues related to rural scenic areas and wildlife vary somewhat due to the focus of the land use being passive (non-disturbed surface) rather than active (disturbed surface) as in agricultural settings. These issues include concerns about impoundments, surface discharge of water, geophysical surveys, production/operation equipment, and road/utility corridors. Implementing mitigation actions to minimize alterations to wildlife habitat or natural activities can be challenging and in some cases overwhelming, in part because the dynamics of any environment will vary from region to region and may also change over time. Regardless, wildlife management options should be directly related to project-specific procedures and the findings of wildlife surveys. Therefore, it is the responsibility of operators (and landowners) to submit work plans prior to the initiation of project

Table 3-1. Surface Disturbance Issues and Impact Considerations in Rural Agricultural and/or Ranching Areas

Surface Disturbance Issues	Impact Considerations
Irrigated and non-irrigated crops	Disruption of activities (harvest, irrigation, pesticide/ fertilizer application). Damage to existing irrigation equipment. Loss of production/acreage due to roads/well pads. Surface impoundments for the management of produced water may disrupt the natural flow of surface water and snow melt.
Grazing/ pastureland/ water for livestock	Open pits, water/oil impacts, increased traffic/open gates, loss of acreage, H2S hazards, and produced water impoundments may be hazardous to livestock.
Soil and vegetation stability/ quality	Soil erosion, spills, damage to standing crops, vegetation die-off, and introduction of invasive/noxious weeds. Reclamation can be time consuming and ineffective.

activities to ensure that planning elements consider the protection of wildlife and botanical resources.

These issues and the corresponding impact considerations specific to rural scenic and/or wildlife habitat are summarized in **Table 3-2.**

URBAN POPULATION CENTERS

Whether it be existing or emerging, an urban area with residential, commercial, and/or industrial activities poses unique surface disturbance issues due to the limited availability of land through zoning, public policy, set-back requirements, and higher population densities. Surface disturbances and impacts can be held to a higher standard due to the fact that they are directly in the public eye and not far removed from day-to-day viewing. Furthermore, city and/or county land planners and policy makers might not support oil and gas development that could impact future growth of the community. Other key issues in urban areas can include concerns about public safety, well pad spacing and size, noise, light, traffic, odors, visual disturbance, and waste management. These issues and the corresponding impact considerations specific to urban population centers are summarized in **Table 3-3.**

SENSITIVE HABITAT AND CATEGORIZED AREAS

Sensitive habitat and categorized areas include, but are not limited to: riparian corridors, wetlands, floodplains, estuaries, marine habitats, sand dunes, sea cliffs, wildlife winter range, and habitats supporting rare, endangered, and unique plant and animal species. In most cases, unless an area already has been defined as sensitive, a site-specific study should be performed to identify and categorize sensitive areas prior to development. Typically, this will occur in the form of a Resource Management Plan (RMP) if federal land/minerals are being developed to allow for the identification of federally designated sensitive areas, and to assess area-specific impacts or mitigation requirements

Table 3-2. Surface Disturbance Issues and Impact Considerations in Rural Scenic and/or Wildlife Areas

Surface Disturbance Issues	Impact Considerations
Impoundments and discharge to surface waters	Could be hazardous to wildlife and birds. Could impact fish populations and habitat by altering flow regimes, temperature, and chemistry. Channel geomorphology could be impacted in a manner that would be detrimental to scenic quality and possibly limit wildlife/fish use.
Geophysical surveys	Seismic surveys might disrupt wildlife, if not timed properly. Seismic surveys might also impact certain sensitive desert soils though compaction, damage to biological crusts, and disturbance that can lead to increased rates of erosion.
Production equipment	Noise from operations such as compressors can be disruptive to enjoyment of recreational areas and wildlife habits and patterns. Furthermore, the presence of oil and gas production equipment and facilities, if highly visible, might be detrimental to the scenic quality of a viewshed.
Roads/access/utilities	Increased access can improve the enjoyment of scenic resources through improved public access; however, this can also lead to increases in vehicle-wildlife accidents as well as poaching of wildlife. Birds flying into overhead electric lines can also result. Habitat can be fragmented by road and utility corridors if not properly planned. Dust generation from increased traffic can lead to a loss of scenic quality in a viewshed.

Table 3-3. Surface Disturbance Issues and Impact Considerations in Urban Population Centers

Surface Disturbance Issues	Impact Considerations
Public safety	H2S gas might be a concern. Drilling activities might put an undue burden on municipal water supplies.
Well pad spacing, size, and onsite waste management	Available surface for construction might be limited. On-site waste management at drilling locations (drilling mud, open pits, etc) might not be an option.
Noise, light, traffic, and foul odors increase	Noise from hydraulic-fracture stimulations, construction, and operations can be a nuisance. 24-hour drilling operations might not be possible. Increased traffic volume can lead to public infrastructure problems. Odors from construction and production activities can be a nuisance.
Visual aesthetics	Placing oil and gas operations in the landscape might negatively affect visual aesthetics.

Table 3-4. Surface Disturbance Issues and Impact Considerations in Sensitive Habitat and Categorized Areas

Surface Disturbance Issues	Impact Considerations
Disturbance of sensitive habitat	Surface disturbance impacts to some sensitive habitat areas could result in damages for which there might be no practical reclamation solution, such as placing earthen fill in wetland areas that displace rare flora and fauna, or cutting into steep slopes consisting of highly erodible soils.
Timing of disturbance	Construction and operation activities can affect migration, breeding, and foraging patterns of wildlife in sensitive areas, such as riparian corridors and/or winter range during certain times of the year.
Spill prevention	Construction and operations in sensitive habitat areas often involve water bodies, such as wetlands, estuaries, and marine habitats; therefore spill prevention of oil is considered extremely important and additional measures might be required to ensure that if a spill occurs it can be contained without unnecessary additional damage to the sensitive habitat.
Construction in floodplain	The construction of a well pad or a road within a floodplain might cause damage to upstream landowners if the construction causes the floodplain elevation to rise. Extensive modeling and permits are required if construction in the floodplain resulting in the addition of fill is proposed.

Table 3-5. Surface Disturbance Issues and Impact Considerations in Vintage Production Fields

Surface Disturbance Issues	Impact Considerations
Premature reclamation of TA locations	There is often a rush to reclaim TA well pads and plug and abandon the location to get closure on the site; however, if this occurs and the area is later determined to be suitable for enhanced recovery, then a new disturbance could occur. This could waste resources through reclamation of a site that could have been re-entered and also could make it necessary to disturb a new area.
Revegetation	In vintage fields, oil-impacted soils and brine scars are not uncommon; revegetation in these areas can be costly and often does not yield positive results.
Infill drilling	Vintage fields typically have been drilled at a set pattern (such as 160-acre or 80-acre spacing). Whatever the original spacing was determined to be, infill drilling at a tighter spacing is common. Infill drilling allows for the use of much existing infrastructure, but it also can provide new impacts/concerns if the infrastructure was not originally designed to handle the additional capacity (i.e. road traffic, pipeline and electric capacity).

to those sensitive areas. State, city, county, and park agencies also might develop guidelines as to what constitutes a sensitive habitat area in their jurisdiction. Once a sensitive habitat area has been identified, and development is proposed in that area, there are a number of issues and impact considerations that might arise that are unique to this category. A summary of these issues is included in **Table 3-4.**

VINTAGE PRODUCTION FIELDS

The term "vintage" is used herein to describe older producing fields that were developed years before environmental and conservation laws were enacted. Several of the operational practices typical of these fields led to the promulgation of many of the environmental and conservation laws that currently are administered. Very early in the history of the oil and gas industry operational practices occasionally included storing oil in unlined earthen pits, letting oil run in unlined earthen ditches, and allowing gushers to flow oil to the surface for several days prior to gaining control of the well. More recently, with the onset of environmental awareness, these practices have been curtailed. However, prior to the promulgation of environmental regulations, spills and releases were not uncommon. As a result, many vintage oil fields have notable areas of oil-impacted soils, areas of brine-impacted soil, plugged and abandoned (PA) wells of varying history and technical efficiency, and numerous temporarily abandoned (TA) wells (wells that have not been permanently plugged because they might have work-over potential that can return them to economic production). A summary of relevant issues unique to vintage production fields is included in **Table 3-5.**

EMERGING PRODUCTION FIELDS

The term "emerging" production field is used herein to describe newly discovered fields or oil and gas plays that previously were not technically or economically practicable to develop. This includes shale gas and shale oil plays, and coal bed natural gas (CBNG). Some of these emerging fields might not have realized large scale exploration and production until the last 10 or 15 years, or in some cases even more recently. As a result, they might be held to a higher environmental protection standard than a vintage field due, in part, to the fact that there are few, or no, pre-existing oil and gas surface damages in the area and many landowners and land managers want to ensure that impacts are managed and mitigated in an environmentally sensitive manner. Furthermore, these fields might lack the existing infrastructure (roads, pipelines, power, etc) necessary to effectively deliver the resource to market, and therefore, the amount of new disturbances can be greater than infill drilling in a vintage field (even for the same number of wells). A summary of relevant issues unique to emerging production fields is included in **Table 3-6.**

PUBLIC OR INDIAN RESOURCE OWNERSHIP

Public or Indian owned land and/or minerals have unique surface disturbance issues and considerations due to the fact that there is not a single owner with whom to craft a surface use agreement (SUA). Rather, land managers, tribal members, and policy makers are responsible for ensuring that the area's multiple resources and uses of these lands are managed appropriately.

Table 3-6. Surface Disturbance Issues and Impact Considerations in Emerging Production Fields

Surface Disturbance Issues	Impact Considerations
New technologies	Emerging fields may employ new technologies with a limited track record of implementation. For example, a new produced water treatment technology that has shown promise during a pilot scale study might turn out to be impractical in a specific field-scale implementation. Such a scenario might require redesign or replacement with an alternative technology. This in turn might create increased disturbances and also increased levels of truck traffic if hauling is necessary as an interim water management approach.
Visibility	Due to the lack of existing oil and gas facilities in an emerging field, the visibility of new oil and gas equipment is a unique concern, especially in areas where scenic viewsheds are a resource or where oil and gas development have never been experienced. These effects can compounded when tightly spaced wells are drilled with new technologies in areas where little oil and gas development has occurred before; an example is central New York state where operators are just now developing the Marcellus Shale for natural gas.
Infrastructure, improved access for use of land in remote areas	Emerging fields in remote areas are less likely to have pre-existing infrastructure in place to allow for efficient transportation of the resource to market. As a result, new pipelines, new electrical power lines and new roads are all required. The construction of this infrastructure also could contribute to increased public trespass.
Infrastructure, existing urban areas	Emerging fields in existing urban or residential areas are likely to have their own set of infrastructure issues. Existing power and roads can be utilized, but they might be under-designed to account for the additional loads brought on by the development of the field. Furthermore, the installation of pipelines and ancillary facilities can be challenging. Existing infrastructure must be worked around, causing increases is construction costs as well as inconveniences to the existing urban area.

Operators should consult with the appropriate state or federal agency, BLM field office, Forest Service office, or tribal agency to determine what type of planning documents might be required to gain approval to move forward with construction activities. A summary of relevant issues unique to public or Indian resources is included in **Table 3-7.**

3.3 SOLUTIONS AND PRUDENT MANAGEMENT PRACTICES

Section 3.2 discussed why surface disturbances are necessary when developing oil and gas resources.

Table 3-7. Surface Disturbance Issues and Impact Considerations on Public or Indian Resources

Surface Disturbance Issues	Impact Considerations
Cultural (archeological) and/or paleontological sites	To protect known and as yet undiscovered cultural and/or paleontological sites, a survey of the area might be required to confirm the absence of such sensitive sites prior to construction. If a site is noted in the survey, then it might be necessary to alter the proposed development to avoid the location. If a site is encountered during construction, all activities might be required to cease immediately until the significance of the site can be evaluated and any findings documented.
Recreation	Recreation activities might include wildlife observation, hiking, horseback riding, fishing, hunting, swimming, etc. Such activities could be affected negatively if an oil and gas development is not appropriately planned to address these competing land uses.
Wildlife and vegetation habitat	A wildlife and vegetation habitat survey might be required prior to construction activities. If threatened and endangered species, or sensitive habitats, are identified then it might be necessary to modify the proposed development to avoid disturbance of the sensitive area.
Reclamation requirements	Reclamation expectations and requirements might be elevated on public or Indian lands as compared to privately owned surface areas. This can lead to either costly reclamation activities or failure to gain approval to drill certain sites if conditions preclude full reclamation to pre-disturbance levels (e.g.: slopes steeper than 20% in highly erodible soils).
Conditions of Approval	An approved permit on public/Indian lands might have certain conditions of approval (COAs) that limit/ mitigate disturbances to wildlife, vegetation, and archeological sites identified in the surveys. These might consist of a No Surface Occupancy Stipulation (NSO) where no disturbance can occur within a buffered area surrounding a sensitive site, or a Timing Limitation Stipulation (TLS), where no disturbance can occur during specified portions of the year. An example of an NSO would be a raptor nest encountered during the wildlife survey. An example of a TLS would be suitable raptor nesting habitat discovered during the wildlife survey. Either situation could preclude access to the land during the nesting and rearing season.

This section will focus on what the oil and gas industry can do, and is currently doing, to minimize those surface disturbances and the adverse effects that result from them. Case studies, based on field experience, are explored to demonstrate how common surface disturbance issues, in various land use and demographic conditions, can be managed and mitigated using prudent management practices. Such practices might have applicability to other projects similar in scope and working environment.

3.3.1 REDUCING IMPACTS IN RURAL AREAS (RANCHING, AGRICULTURAL, REMOTE, ETC.)

The importance of reducing impacts in rural areas cannot be overstated. As global population fuels increasing demands for food, rural agricultural areas become increasingly important. In the western United States, many of these areas also have public and Indian lands and minerals interspersed among fee lands and minerals. The following case study was selected to demonstrate how impacts can be reduced in three such rural areas --- on managed irrigation farm land, livestock grazing on private and publicly leased lands, and scenic beauty with sensitive wildlife habitat along riparian corridors on public and private lands.

WILLISTON BASIN CASE STUDY

An exploration discovery was made in 2004 in western Billings County, North Dakota, near a roadless area managed by the U.S. Forest Service (USFS). The operator drilled dual lateral horizontal wells from fee locations on 1280-acre spacing (1 location per 2 sections) to minimize surface disturbances to the remote area and avoid disturbance to any USFS-owned/managed surface rights. Each location has two horizontal wells trending NW and SE respectively, and many of the wells are drilled beneath the USFS lands. The surface locations are staggered in a manner so the wells line up with one another in the subsurface. Eventually, the operator plans to convert every other well to an injection well to enhance recovery. This represents development of a protected roadless area by drilling directionally from adjacent lands. Furthermore, the water for water-flood injection will be sourced from a separate formation (~5,500' deep) and injected ("dump-flooded") into the producing formation (~10,500' deep) with a submersible pump precluding the need to pump the water to surface. This will eliminate or minimize the need for surface tanks , piping, and pumps.

POWDER RIVER COAL BED NATURAL GAS (CBNG) CASE STUDY

Ranching, irrigated agricultural, scenic, and sensitive wildlife habitat all occur on the various CBNG projects in the Wyoming portion of the Powder River Basin. The case study area encompasses several square miles of land with at least three major tributaries to the Powder River that have scenic viewsheds and sensitive wildlife habitat, managed irrigation, and livestock grazing. Within the case study area, multiple resource owners exist, including public (state and federal) and various fee resource owners. Multiple CBNG operators are working in the area developing hundreds of CBNG wells, many of which already have been drilled. For the purpose of this case study, one of the prominent operators in the area was selected based on its broad range of mineral lease holdings (federal, state, and fee) and the innovative low impact solutions achieved when faced with challenging issues involving gaining the acceptance and agreement from multiple stakeholders. Steps that were taken to minimize surface disturbances are included in **Table 3-8.**


View of CBNG infrastructure corridor designed to minimize contrast with the landform just prior to reclamation activities

3.3.2 REDUCING IMPACTS IN URBAN AND SUBURBAN AREAS

Reducing impacts in urban and suburban developments often is driven by necessity through

Table 3-8. Surface Disturbance Issues and Solutions Utilized in Powder River CBNG Case Study

Surface Disturbance Issues	Solution Implemented
Irrigated and non-irrigated crops	Negotiated with landowners in the planning process to locate new facilities and infrastructure. From this, the landowner would either have minimal impacts to existing operations, or the landowner might benefit from construction through improved access to the land with improved roads and additional water sources for livestock.
Grazing/ pastureland/ water for livestock	
Soil and vegetation stability/ quality	Project planning documents were established to minimize soil erosion through storm water pollution prevention measures. Damage to standing crops was managed through project planning and management of field crew members. Mitigating invasive/ noxious weeds was accomplished through the use of pesticides and field practices to minimize the transport of seeds around the area. Areas where reclamation was deemed not possible due to highly erodible soils with steep slopes were avoided.
Impoundments/ discharge to surface waters	Produced water is treated at a dedicated facility to render it suitable for discharge into the Powder River under an applicable WYPDES permit (obtained prior to discharge to ensure regulatory compliance). The treated water is also suitable for irrigation purposes.
Production equipment	Skid mounted compressor sheds were utilized to dampen the noise generated by the compressors. All above ground facilities (compressors, water treatment facilities, well heads, etc) were painted to blend in with the surrounding landscape.
Roads/access/utilities	Secure access gates were utilized to minimize illegal access to lands resulting from the development of new roads. Cattle guards were provided at fence crossings to minimize cattle loss if a gate is inadvertently left open. Electric power lines were buried to the extent feasible. Remaining overhead electric lines were located to avoid flight corridors (i.e. riparian areas) wherever possible. Roads were laid out taking landowner and operator design considerations into account as well as the avoidance of sensitive habitat and cultural sites. Dust was managed during construction by applying water to roads and construction areas when bare soil was present.
Cultural and/or paleontological sites	An archeological survey was conducted in areas with federal rights. This included 10-acre block surveys around well locations and linear surveys along road/utility corridors. The project scope was then adjusted to avoid sites discovered by the survey.
Wildlife and vegetation habitat	An annual wildlife survey was conducted in areas with federal rights. In addition to the annual survey, the operator conducted an aerial bald eagle survey along the Powder River during the roosting/nesting season for several miles in either direction of the project to determine how the riparian corridor was being utilized and to avoid disturbing bald eagles and ferruginous hawks.
Reclamation requirements	In areas where reclamation to pre-existing conditions was either not possible or not practicable, the operator chose to either avoid those areas or prepare a site-specific reclamation plan to address the issues.
Conditions of Approval	On federal lands various COAs were set in place for the operator to follow during construction and operations. Following these COAs provides additional mitigation against disturbances to wildlife habitat.

regulations and public concern. The first case study presented here is from a Barnet Shale project in a rapidly growing suburb of the Dallas-Fort Worth (DFW) metroplex. The city has annexed much of the adjacent rural land with long-term plans for mixed-use developments, including high end residential, with set-back requirements that provide challenges to gas development. The second case study presented here is from a dewatering project in an older field in Oklahoma City (OKC) where a neighborhood has grown up around a declining oil field, only to have the field experience resurgence in activity in recent years, including drilling of additional wells.

EXPANDING SUBURBAN CASE STUDY

The city in question is an affluent suburb of the DFW metroplex. The city's charter was designed to protect the surface resources available for growth of the community, so as not to detract from the land value or sense of community in anticipation of additional future high end residential and commercial developments. In this case study, a large ranch property recently annexed by the city was to be developed with multiple Barnet Shale gas well locations, each with multiple horizontal laterals.

An analysis of the entire ranch determined that only a small percentage of the ranch could be developed without the need of a variance request. The municipal set-back requirements originally were established with buildings and parking structures in mind, not gas wells and pads. Therefore, in many cases the set-back requirements were counterintuitive to what normally would be considered a "desirable" location for a gas well. Several of the wells required variance requests due to these set-back requirements. A discussion of three of those well locations is included here.

In the process of requesting set-back variances, several low impact surface disturbance solutions were developed to demonstrate to the city that gas drilling activities can be compatible with suburban residential and commercial developments. The operator worked with city staff and landowners to identify well sites that would minimize disturbance to potentially desirable residential building sites. This was accomplished first by identifying features of the property that are undesirable for building, such as proximity to power lines, floodplains, and drainage features. Potential well locations were then placed near these features.

One location was placed near an overhead high-power electrical line; this lot would not have been desirable for residential development. The well-head was placed in this area with horizontal drilling utilized to reach the subsurface target. The variance request for set-back to overhead electrical and property lines was approved. Upgrades were made to the well perimeter including chain-link fences

with painted slats to reduce visual impacts of the well head and appurtenances.

The second location was near an intermittent stream, just downstream from a pond. A detailed floodplain analysis with modeling was performed on the drainage since existing FEMA floodplain models were insufficient to determine the impact of a well location on the floodplain backwaters. The shape and orientation of the pad was modified to fit with the contours of the land, which prevented additional surface disturbance of a nearby hill. Had the pad been configured in a conventional manner, the hill would have required some cutting, which would have yielded several hundred cubic yards of unnecessary surface disturbance. Through hydraulic and hydrologic modeling accepted by the Army Corps of Engineers, it was determined that the construction of the modified well-pad shape would not adversely affect the floodplain. However, a comparison of existing conditions versus a proposed floodplain model indicated that the well pad was located less than 100 feet from the floodplain edge in the proposed alternative. An erosion control plan that utilized primary (silt fences) and secondary (sock filter berms) erosion control during construction was proposed, but this variance request was denied because the City Council believed this was a dangerous precedent to set (allowing any construction within 100 feet of a floodplain).

The third location was near a wet-weather pond spillway/drainage feature in a highly vegetated portion of state-designated sensitive habitat. The goal was to protect vegetation and significant trees by locating the pad to avoid the large trees, and to develop a revegetation plan for the disturbed areas. In addition, compensation to the city's tree preservation fund (established to plant new trees and maintain existing trees in public places) would be made. Compensation was determined through the performance of a tree survey by a certified arborist who calculated the caliper-inch (at chest height) of each tree in the area. The size of all trees proposed for removal were summed to arrive at the total caliper-inches removed; a $/caliper-inch rate, established by the city's tree preservation fund, was used to determine how much the operator would pay into the fund. Also, an existing headcut in the stream bed, followed by a drop in the channel elevation, had led to scouring and erosion of the channel to an unsteady state. In response to this, a design was proposed to improve the drainage feature by lessening the slope of the channel, which, in turn, would lower the velocity of storm water, providing a more stable, long-term drainage feature.

EXISTING URBAN CASE STUDY

An abandoned oil field in Oklahoma City has experienced a re-birth through an operator's use of a proprietary method for recovering additional oil and natural gas. The operator worked with neighborhood, city, and state officials in developing the project because many of the old wells had been plugged and the area had become a dense residential/commercial community. As a result, there was limited available land to drill from.

The operator used off-shore drilling technology, which allowed workers to cluster wellheads on a common pad, in close proximity to one another, allowing for the use of common flow lines for oil, gas, and produced water. This minimized pipeline corridor disturbance; multiple wells were tied together at a single location rather than connecting them to a trunk line with multiple feeder lines. One well pad allowed placement of eight multi-lateral horizontal wells on a 6-acre location that included power stations, flowlines, and proprietary three-phase separation technology for each well. The separation technology was designed specifically to enhance the efficiency of the project with direct flow-through of fluid while minimizing the footprint of disturbance by not requiring surface storage

tanks. The absence of a saltwater storage tank at each well location minimized the volume of fluid that could be released if a spill occurred. Instead of having an oil tank at each well, the development was designed so that the oil flows to a central tank complex with a Lease Automatic Custody Transfer (LACT) unit, which also reduces oil tanker traffic.

An additional benefit of the flow-through concept is a reduction in electrical power requirements; the downhole electric submersible pump (ESP) provides all the horsepower (HP) necessary to move the liquid through the pipeline. The only additional HP required is at the saltwater disposal (SWD) wells to increase injection capacity. Multiple deep injection wells permitted to dispose of up to 60,000 barrels per day were completed as multi-lateral horizontal disposal wells in the lower Arbuckle formation (over 8,000 feet total depth).

Pipelines were buried in existing right of way corridors. Gas venting was reduced during operations since no fluid is exposed to the surface, and multiple gas sales points were eliminated and replaced with a central gathering and custody-of-transfer point that can be closely and accurately monitored through the use of supervisory control and data acquisition (SCADA). Overall, SCADA was utilized to implement real-time monitoring of the entire field to reduce the amount of truck traffic to

Table 3-9. Surface Disturbance Issues and Solutions Utilized in Urban Population Centers

Surface Disturbance Issues	Solution Implemented
Public safety	Fences were placed around all wellheads, pipe runs, and surface facilities. Direct flow of water to injection well and oil to a central facility versus onsite tank storage at each wellhead minimized the amount of fluid stored on the surface.
Well pad spacing, size, and on-site waste management	Use of offshore technology and horizontal drilling provided less surface disturbance and allowed the use of flow-through three-phase separation technology instead of on-site storage of liquids.
Noise, light, traffic, and odor	Use of SCADA with a central monitoring point reduced traffic and noise during operations. Wells located at central locations minimized light pollution and odor.
Property values and visual aesthetics	Placement of attractive fences visually screened the surface facilities to minimize visual impacts. Where possible, wells were sited at locations that otherwise would have been undesirable for home building.

the well sites. The drilling location was fenced-in to minimize visual impacts as well as to prevent trespass entry to the site. The field consists of several such drill pads with multiple horizontal laterals to reach the pay zones. Steps that were taken to minimize surface disturbances are included in **Table 3-9.**

3.3.3 RECOGNIZING AND MINIMIZING IMPACTS IN CATEGORIZED AREAS

Impacts in categorized areas, such as wetlands, might not be as easily assimilated or reclaimed. These impacts, if not properly mitigated and/or minimized, can lead to a ripple effect with regional-scale ramifications over time (Allord, et. al, 1997). The case study selected to demonstrate steps that can be taken to minimize impacts in categorized areas is focused primarily on wetlands in the Sabine River floodplain of Eastern Texas.

WETLANDS CASE STUDY

This case study included more than 90 proposed undeveloped (PUD) locations in various proximity to jurisdictional wetlands. The primary goal of the project was to realize zero wetland disturbances through wetland avoidance and/or horizontal drilling. Wetland inventory data sets were analyzed, along with aerial photography and NRCS soil data to determine where jurisdictional wetland areas are most likely to occur. This provided a focus of the project by narrowing the field effort to PUD locations most likely to be in/near jurisdictional wetlands. A wetland biologist visited each PUD site to determine 1) whether the site was located in or near a jurisdictional wetland and 2) if it was, to find a nearby and suitable upland habitat to relocate the well pad to.

The Fort Worth Army Corps of Engineers (COE) is responsible for permitting wetland disturbance in

View of typical categorized wetlands near the Sabine River with a high water mark evident on the trees excess of 1/10th of an acre in jurisdictional wetlands through Clean Water Act (CWA) Section 404 regional general permit (RGP) #11. In the event there is no choice but to construct well pads/roads in a jurisdictional wetland area (i.e. avoidance is not an option due to proximity of location to wetlands), then it will be necessary to apply for a Section 404 RGP #11 . The overall process of the RGP can follow two paths:

1) No Preconstruction Notification (PCN) is required if the following criteria are satisfied: the project causes the loss of less than 1/10-acre of waters of the United States; the construction does not result in adverse effects to forested wetlands; it does not require stream alignment, or does not occur within sensitive areas as described in the RGP (wetlands, cypress-tupelo swamps, Caddo Lake "Wetland of International Importance", critical habitat of the Concho water snake, Houston toad, or the Arkansas shiner).

- *Construction may commence when the applicant can ensure that all terms and conditions of the RGP can be met. No written approval is necessary from the COE (i.e. no Section 404 permit is required).*

2) A is required if any of the above criteria are not satisfied. The PCN consists of: project maps, descriptions of work, detailed engineering on cuts/fills and soil volume calculations, discussion of alternatives that were not pursued, drilling termination/well abandonment plan, and compensatory mitigation plan, etc.

- *Construction may not commence until written notification of approval (i.e. an approved Section 404 permit) is received by the applicant from the COE. Special conditions can be imposed by the COE depending on the site.*
- *For all Section 404 permits (in Texas), the Texas Railroad Commission (RRC) is required to perform a Section 401 water quality certification. However, the RRC has certified water quality for all regional general permits for oil and gas. Therefore, Section 401 water quality certification is not necessary if the construction specifications for RGP #11 are adhered to.*

One potential disadvantage to the RGP is that the required specifications might limit facility designs. If the required specifications for RGP #11 cannot be met, then it would become necessary to submit an individual 404 permit, which could have a much longer approval time (potentially up to 2.5 years) and is contingent upon a public approval process. To obtain an individual permit, the applicant must follow, as closely as possible, the requirements set forth in the RGP and provide an explanation for why the specifications in the RGP cannot be met. Any variance from the RGP likely will be scrutinized during review; therefore, it is possible that an application with merit might still be rejected.

Utilizing existing roads/well pads to drill new locations is another option, and the Fort Worth COE indicated that directional drilling from an existing well pad could be done without completing a regional general permit as long as construction activities do not cause fill material (soil) to enter waters of the United States (jurisdictional wetlands).

ENDANGERED SPECIES HABITAT CASE STUDY

A Conservation Bank under development in Kern County, California, (CERES, 2008) is being established by the operator to promote conservation of San Joaquin Valley saltbrush scrub, which is habitat for a number of endangered wildlife and vegetation species, including: Bakersfield saltbrush, Bakersfield cactus, San Joaquin kit fox, blunt-nosed leopard lizard, Tipton kangaroo rat, and Swainson's hawk. The conservation bank will allow for 3 acres of preserved habitat for every acre of permanent oil and gas disturbance and 1.1 acres of preserved habitat for every acre of temporary impacts. The conservation bank was established in cooperation with the California Department of Fish and Game and the U.S. Fish and Wildlife Service. This conservation bank fits into a larger collection of land protection programs designed to help meet recovery planning goals for listed species in the San Joaquin Valley (IPIECA, 2007).

Steps that were taken to minimize surface disturbances in categorized and sensitive areas are included in **Table 3-10**.

3.3.4 REDUCING IMPACTS: VINTAGE VERSUS EMERGING FIELDS

The case studies discussed above have dealt with specific land use/demographic categories irrespective of the ages of the oil or gas fields.

Table 3-10. Surface Disturbance Issues and Solutions Utilized in Categorized or Sensitive Areas Case Studies

Surface Disturbance Issues	Solution Implemented
Disturbance of sensitive habitat area may cause irreparable damage	A wetland determination was made on all PUD locations prior to construction activities. Sensitive habitat was avoided as upland habitat and/or existing disturbances were targeted for development, coupled with horizontal drilling.
	A conservation bank was established to allow for proper mitigation and preservation of sensitive habitat to offset temporary and permanent impacts in the area.
Timing of disturbance can be a problem	Construction and operational activities were coordinated with local FWS to avoid impacting migration, breeding, and foraging patterns of wildlife in the area.
Spill prevention is always a priority in developments; however, in sensitive areas the need for spill prevention receives even greater emphasis	The PUD locations were primarily natural gas wells; oil was not a major consideration. However, steps such as hay bales, silt fences, erosion socks, etc., were taken to prevent storm water runoff pollution into sensitive areas.

There are distinct differences between what is commonly referred to as a "vintage" field versus an "emerging" field, and the approach to reducing impacts from each must be tailored to suit the specific project situation. Two case studies are presented here to demonstrate this contrast; they are separated geographically by the Bighorn Mountains of Wyoming and Montana. The vintage field case study involves several fields in the Bighorn Basin with more than 90 years of production history and hundreds of oil and gas wells in place. These Bighorn Basin fields are now engaged in secondary and tertiary recovery efforts; reducing impacts is an important aspect of current development at these fields, as they are in many other vintage fields across the country. In contrast, the coal bed natural gas play in the Powder River Basin provides an example of an emerging field faced with numerous challenges related to reducing surface impacts such as construction of roads, pipelines, and well locations.

VINTAGE FIELD CASE STUDY

The Bighorn Basin fields, located in north-central Wyoming, are typical of historical oil and gas fields. In one case, some of the earliest producing wells in the area are involved. These early wells were drilled using cable tool drilling technology and wells were pumped using historic central power and rod-line pumping units. The old central pumping units had a powerhouse and cables or rods running out to drive pump jacks or to connect counter balances. Evidence of this and other historic equipment is present throughout fields. Small concrete pads and other remains reflect this history.

The approach for reducing impacts, where years of surface impacts are already in place, might seem counter-intuitive in the short-term; however, considered from a forward-looking perspective they are undeniably logical. There are several temporarily abandoned (TA) wells, some of which occupy suitable locations for secondary and tertiary recovery efforts that are either ongoing or planned. Plugging and reclamation of these TA wells at this time could result in additional impacts in the future as secondary and tertiary efforts progress. By keeping these TA wells and the infrastructure surrounding them in place, the operator can utilize existing disturbance corridors in the future without having to 1) disturb the area during reclamation efforts, which could cause ancillary surface impacts like erosion and invasive weed issues and 2) prevent new disturbances from occurring by re-utilizing the existing disturbed areas. This approach promotes the delay of reclamation rather than plugging wells

Table 3-11. Surface Disturbance Issues and Solutions Utilized in Vintage Production Fields

Surface Disturbance Issues	Solution Implemented
Premature plugging and reclamation of TA locations	Existing TA locations are analyzed for potential re-use prior to plugging and reclamation of the area. Overall, this contributes significantly towards minimizing cumulative disturbances.
Revegetation	Seeding with a mix of native species, watering, and fertilizing problem areas routinely aids in reclamation and revegetation activities.
Infill drilling	Infill drilling was planned and designed to utilize existing disturbances, to the extent practicable, and duplicate roads were reclaimed to minimize the total disturbance.

and reclaiming disturbed areas as soon as a well is taken out of production. However, in a vintage field where secondary and tertiary recovery is feasible such a plan is quite effective at reducing overall, cumulative surface impacts. Steps that were taken to minimize surface disturbances are included in **Table 3-11**.

EMERGING FIELD CASE STUDY – POWDER RIVER CBNG

The Power River Basin CBNG development has met with multiple challenges over the last 25 years. Some of these have arisen from public interest group misinformation; initial operator insensitivity and inability to properly communicate intentions and resource impacts/benefits to the public; and political controversy stemming from specific public issues such as the greater sage grouse or effluent discharges into sensitive water systems. Produced water management has become the focus of many debates over how to best reduce impacts to the surface, including a statewide development moratorium in Montana on public lands until the issue of managing produced water without impacting surface water quality is resolved. Landowners and homesteaders have mixed views on CBNG development. Some are calling for it to move forward at a quicker pace while others want it to stop . More often than not these arguments are born from split estate issues that have been the catalyst for numerous lawsuits and complaints by surface owners.

Many CBNG companies have established low impact practices, such as those noted in the Cabin Creek case study earlier in this section. Other practices noted in the basin include:

- *Adding a supply of water to farm and ranch operations in the southeast portion of the basin. Several ranchers have testified to CBNG water as the salvation of their ranch during the recent extreme drought conditions.*
- *Screening and hiding roads, facilities, and overhead electric lines in a manner that utilizes natural landforms, vegetation, color, line, and form to minimize contrast with visual resources.*
- *Design and construction of roads to a safe and appropriate standard based on traffic volume and intended use. Roads servicing a few locations are often left as simple two-tracks whereas roads that service large areas are engineered with a crown and ditch to support the additional traffic load.*
- *Initiating interim reclamation on well pads and along borrow ditches in newly constructed roads to enhance revegetation and reclamation efforts and minimize habitat fragmentation to the extent possible.*
- *Control of noxious/invasive weeds with pesticides, employee training in the prevention of weed transport and introduction, wash stations, and inspections.*

EMERGING FIELD CASE STUDY – WILLISTON BASIN BAKKEN FORMATION

North and east of the Powder River Basin is the Williston Basin, which straddles Montana, North and South Dakota, and Canada. The Williston Basin is home to one of the most recent emerging plays, the exploitation of the Bakken Formation. The Bakken is a success story of horizontal drilling, fracturing, and completion technologies in an area that has been producing from other formations for decades (EIA, 2006). A recent USGS assessment of the Bakken stated that Montana and North Dakota alone have an estimated 3 billion to 4.3 billion barrels of undiscovered and technically recoverable oil reserves, 25 times the amount (151 million barrels) previously estimated in 1995. About 105 million barrels have been produced from the Bakken from 2000 until the end of 2007 (USGS, 2008). Success in the Bakken has been predicated primarily on horizontal drilling and completions with hydraulic fracture stimulations. Many drilling locations have included multiple laterals in various directions. An ancillary benefit to this approach is a dramatic reduction in surface impacts compared to that necessary if the wells were closely spaced vertical completions. In some instances, the well pad spacing is as little as 1 pad per 1280 acres (2 sections) with two horizontal wells in either direction. The Bakken Formation has not received the criticism regarding surface impacts that the Powder River Basin has. This is partially due to the fact that it is in an area with well established oil and gas development (production from other formations), but also because the horizontal drilling results in minimal surface disturbances. Steps that were taken to minimize surface disturbances are included in **Table 3-12**.

3.3.5 ADDITIONAL IMPACTS AND POTENTIAL SOLUTIONS

In addition to the case studies outlined above, **Table 3-13** summarizes additional impacts not addressed in detail in the case studies. Potential solutions are offered for these impacts. Most importantly, references are provided to direct the reader to more comprehensive texts on the particular issue.

Table 3-12. Surface Disturbance Issues and Solutions Utilized in Emerging Production Fields

Surface Disturbance Issues	Solution Implemented
New technologies	Water Treatment – Powder River Basin.
	Horizontal Drilling – Bakken.
Visibility	Screening and hiding roads, facilities, and overhead electric lines in a manner that utilizes natural landforms, vegetation, color, line, and form to minimize contrast with visual resources.
Infrastructure, improved access, minimizing illegal use of land in remote areas	Secure access gates were utilized to minimize illegal access to lands resulting from the development of new roads. Cattle guards were provided at fence crossings as well to minimize cattle loss if a gate is inadvertently left open. Electric power lines were buried, to the extent feasible. Remaining overhead electric lines were located to avoid flight corridors (i.e. riparian areas) wherever possible. Roads were laid out taking landowner and operator design considerations into account as well as the avoidance of sensitive habitat and cultural sites. Dust was managed during construction by applying water to roads and construction areas when bare soil was present.

Table 3-13. Additional Surface Impacts and Potential Solutions

CATEGORY/IMPACT	POTENTIAL SOLUTION	REFERENCE
Agricultural Uses Incompatibility		
Disruption of agricultural activities	Drilling operations can be timed, with landowner input, to avoid seasonal agricultural needs/events. The establishment and maintenance of good landowner relations has a win-win benefit.	
Loss of available acreage		
Damage to standing crops		
Damage to soil quality	Avoid surface discharge of produced water with water quality characteristics incompatible with the local soil type.	ALL, 2003
Increased public access to land	Landowners should be consulted about the locations and security of planned roads including the use of locked gates and cattle guards.	
Cultural, Historical and Paleontological Resources		
Identification and preservation of cultural/ paleontological sites	No Surface Occupancy (NSO) buffer zones.	
Drilling		
General	Modern exploration technologies have contributed to improved drilling success rates. Fewer dry holes equates to less environmental disruption or impact.	DOE, 1999
	Advances in drilling technology (directional drilling, closed-loop drilling, coiled tubing drilling, modular rigs, pneumatic drilling, slimhole drilling, etc.) allow for smaller well pads creating less environmental impact. The use of light modular rigs also reduces transportation impacts, fuel use, and exhaust emissions. Coiled tubing drilling also generates less waste (drilling muds, etc.), creates less noise, and reduces fuel use and exhaust emissions.	DOE, 1999
	More efficient production technology now allows fewer wells to be drilled, which results in less environmental impact. In some instances it may be possible to commingle production from different stratigraphic zones, thus minimizing the number of wells and the need for dedicated infrastructure	DOE, 1999
	In some cases it may be possible to mow or brush-beat instead of clearing and grading for pads	BLM, 2006

Table 3-13. Additional Surface Impacts and Potential Solutions (continued)

CATEGORY/IMPACT	POTENTIAL SOLUTION	REFERENCE
Development plans	Drilling should be designed through engineered plans of development (POD). The use of PODs provides for a critical examination of the engineering requirements of the field development. Through this strategic planning task, opportunities to avoid or minimize environmental impacts can be identified and solutions engineered for implementation. In some cases, phased development might be economical and also serve to minimize environmental impacts over time.	BLM, 2007
	High density drilling can sometimes be accommodated via directional drilling of multiple wells from a single well pad. However, such an approach can be highly sensitive to feasibility issues including: depth and location of target horizon, engineering and geological considerations, optimal completion methods, prospect economics, etc. Not all oil or gas prospects lend themselves to directional drilling.	
	In some cases, temporally staggered drilling plans (often referred to as phased development) may be appropriate. However, such an approach can be highly sensitive to field conditions and economics. The latter often is a limiting factor because developing reserves from a limited area or a limited number of wells throughout a large area might not be capable of economically supporting the construction of the full complement of infrastructure required.	BCA, 2003b
	In an effort to maintain good relations and arrive at a win-win scenario, the input of the surface rights owner should always be considered when preparing a POD.	
Hydro-fracturing stimulations	Hydro-fracturing stimulations can require large volumes of water, create large volumes of waste, require large well pads, and create significant noise and traffic. In some instances, CO_2 – sand fracturing can minimize these issues.	DOE, 1999
Erosion Control		
Surface disturbance creates the possibility of increased erosion	Follow U.S. EPA storm water BMPs. Also see: "Guidance Document, Reasonable and Prudent Practices for Stabilization (RAPPS) of Oil and Gas Construction Sites".	HES, 2004
Noise		
Mid to high frequency noise	Use engineered noise barriers including sound-insulated dog houses / buildings to house equipment. Also take advantage of distance, vegetation, and topography.	OGAP, 2005

Table 3-13. Additional Surface Impacts and Potential Solutions (continued)

CATEGORY/IMPACT	POTENTIAL SOLUTION	REFERENCE
Low frequency noise	Low frequency noise tends to travel greater distances and is harder to insulate against. Take advantage of distance and topography.	OGAP, 2005
Production/equipment – well pumps	Electric pumps generate less noise than diesel- powered equipment. Progressive cavity pumps create less noise than pump jacks. Also take advantage of distance, vegetation, and topography	
Production/equipment – compressors	Use of hospital-grade mufflers is sometimes appropriate	
Noxious/Invasive Weeds		
Noxious/Invasive Weed Prevention	Weeds are introduced by vehicular traffic (and cattle); therefore, minimize traffic to the extent possible. Use vehicle wash stations to wash or air spray equipment whenever leaving areas of noxious/invasive weed infestation.	BLM, 2006
	Control weeds during occupation using an integrated approach: cultural (education of resource users), chemical (spray treatment), biological (prevent over-grazing and animal transport of seeds), physical (vehicle wash stations, transportation of seeds)	BLM, 2006
	Practice prompt reapplication of topsoil and/or use of weed-free topsoil along with reseeding using native, weed-free seed and weed-free mulch.	BCA, 2003b
Produced Water		
General	The reader is directed to numerous texts specifically focusing on this subject including:	ALL, 2003 ALL, 2004 ALL, 2005 ALL, 2006

Table 3-13. Additional Surface Impacts and Potential Solutions (continued)

CATEGORY/IMPACT	POTENTIAL SOLUTION	REFERENCE
Reclamation		
General issues	Stockpile topsoil (from well pads, pipelines, etc.) for use in future reclamation efforts. This salvaged topsoil should be re-spread over as much of the entire disturbed area as soon as possible and revegetated with native plants. Even low traffic roads should be reclaimed as two-tracks as soon as usage patterns allow.	BLM, 2006
	Practrice prompt reapplication of topsoil and/or use of weed-free topsoil along with reseeding using native, weed-free seed and weed-free mulch. Seed mixtures should be designed to replace the pre-existing biota as closely as possible. Because of variations in soil and topography, more than one seed mixture may be required for larger areas. In addition to grasses and forbs, shrubs may need to be a component of the revegetation effort.	BCA, 2003b
Brine scars	Plant halophytic vegetation in areas that have received historic releases of saline waters.	KCC, 2006
Road and utility corridor reclamation	Relieve roadway compaction – ripping and seeding alone may not be sufficient for final reclamation.Roads typically need to be re-contoured to blend back into the landscape. Water-bars, boulders, and dead trees need to be placed across reclaimed roadways to prevent use by un-authorized ATV traffic that will discourage revegetation of the roadway.	BLM, 2006
Timing – interim, annual progress, or final reclamation	Interim reclamation should be used to reduce pad size and access road footprint after drilling is complete and the project moves into production phase.	OGAP, 2005
Visual resource reclamation	Reclaim areas as soon as possible by returning land to natural grade and contour. Reseed with native groundcover.	BLM, 2006
Road and Utility Corridors		
General	Avoid off-road travel during wet conditions particularly on steep or unstable soils. Limit use of two-track roads during wet weather or spring thaw. Soft, boggy areas in roadways need to be repaired as soon as possible; do not allow contractors to drive around the soft spot, thereby expanding the disturbance.	BLM, 2007 WGA, 2006

Table 3-13. Additional Surface Impacts and Potential Solutions (continued)

CATEGORY/IMPACT	POTENTIAL SOLUTION	REFERENCE
Design standard	Access roads for energy projects should be designed and constructed to a safe and appropriate standard, but not greater than that necessary to accommodate their contemplated use (i.e.: two-tracks are preferred whenever possible).	BLM, 2005 BLM, 2006 BLM, 2007
	Drainage adjacent to roads must be addressed in the design stage through the use of culverts, bridges, water bars, turnouts, wing ditches, etc.	ALL, 2007 HES, 2004
Locating roads	Whenever possible, co-locate roads and utility corridors to minimize surface disturbance. Also, existing roads/utility corridors should be used as much as possible rather than creating new disturbances. Landowners should be consulted about the locations of planned roads; they may have current or future uses that are compatible with specific locations.	BLM, 2006
	Roads, particularly two-tracks, and utility corridors should follow topographic contours as much as possible. Trench utilities alongside roads rather than striking out across country. This will limit cut and fill requirements as well as limit the presence of visually disruptive straight-line features. It also serves to minimize erosion problems.	BLM, 2006
	Gas production is often measured at the well site; therefore, in compatible circumstances, flow lines and compressor stations could be shared by different operators, thus reducing surface disturbance and development costs by minimizing infrastructure redundancy.	NPRC, 2001
Construction timing	Schedule construction during dry or frozen weather conditions if working in wet areas. Use of oak mats can facilitate driving and working on saturated ground as well as minimizing and accelerating reclamation.	BLM, 2006
	Any necessary crossings of wetlands, riparian, and other sensitive habitat should be perpendicular to the feature to minimize the area affected.	BLM, 1984
	Trench all lines in a corridor at the same time and use wheel trenchers rather than excavators.	WGA, 2006
	Use silt fences, hay bales, rock berms, diversion dikes, etc. to control storm water run-off during construction.	HES, 2004
Reclamation of roads	See reclamation section. Access roads should be left in the condition desired by the surface owner.	WGA, 2006

Table 3-13. Additional Surface Impacts and Potential Solutions (continued)

CATEGORY/IMPACT	POTENTIAL SOLUTION	REFERENCE
Sensitive Lands – alpine, arctic, riparian, wetlands, etc.		
Arctic	Work should be conducted in the winter when the ground is frozen and wildlife is less active or not present. The use of ice pads for drilling and ice roads may be advantageous. ATVs should be outfitted with balloon tires to decrease compaction of roadways.	DOE, 1999
Riparian and wetlands	Cross riparian and wetland areas using the shortest distance possible (perpendicular to channel). This will minimize grading or trenching disturbance or the number of utility poles required.	BLM, 2007
	If possible, disturb these areas only during dry periods or winter freeze.	
	Design project to prevent continuous inundation, if that is not the normal situation.	
	Stream crossings (including culverts) and near stream roads lead to more siltation of streams. Provide proper grading to divert storm water run-off away from streams. Also use hay bales and silt fences during construction.	BLM, 2007
Riparian reclamation	Begin reclamation as soon as possible. Reshape disturbed channels to their original configuration/ geomorphology and ensure proper bank stabilization.	WGA, 2006
Wildlife	Trenched utilities are preferred to above ground lines, particularly in areas supporting greater sage grouse where utility poles can serve as perches for predators.	WGA, 2006
	Any production pits intended for long-term use should be fenced and netted.	WGA, 2006
Traffic		
General issues	Minimize traffic by limiting access and using telemetry for monitoring activities allowing fewer visits to well or production sites.	
	Centralized production facilities also serve to reduce traffic to individual well sites.	
	Consider car pooling/busing work crews during periods of intensive activity.	
	Speed limits on lease rods make traffic less invasive, but effective enforcement is problematic. Education of field hands and appealing to their "outdoorsmen's" nature could help to elicit voluntary compliance.	

Table 3-13. Additional Surface Impacts and Potential Solutions (continued)

CATEGORY/IMPACT	POTENTIAL SOLUTION	REFERENCE
Viewshed – form, line, color, and texture		
General issues	Begin with a plan of development designed to reduce the overall acreage of surface disturbance as much as possible; minimize equipment and well pads, roads, and utility corridors.	BLM, 1984 BLM, 2006
	Minimize top soil removal/disturbance by limiting sizes of pads and utility corridors. When possible mow or brush-beat instead of clearing and grading for pads.	BLM, 1986b BLM, 2006
	Remote monitoring via telemetry provides for a reduction in traffic allowing vegetation to return and roads to be less visually prominent.	
Site selection	First identify the public's key observation points – both linear viewing areas (roads, trails, etc.) and point views (scenic overlooks, etc.).	BLM, 1984 BLM, 2006
	Maximize distance between surface disturbances and these publicly accessible viewing areas. Avoid locating equipment near prominent features.	BLM, 1984 BLM, 1986b BLM, 2006
	Co-locate multiple wells, tanks, and equipment on a limited number of well pads to reduce the number of roads, etc. Locate these centralized facilities out of lines of sight.	BLM, 2006
	Locate equipment on the well pads to occupy a minimum footprint, thus allowing maximum opportunities for re-contouring and reclamation.	BLM, 2006
	Avoid siting well pads on steep slopes; cut and fill is typically more difficult to reclaim. Minimize side-cast of materials.	BLM, 1986b BLM, 2006
Design	Consider the cumulative effects of multiple visual disturbances. A lone disturbance is more easily "accepted" in the visual landscape than is a cluster of disturbances.	BLM, 2006
	Orient equipment to minimize profile/visibility from key observation points.	
	Use vegetative screening by planting trees around equipment. Use topographic screening by locating behind hills or constructing earthen berms around well pads or equipment.	BLM, 1986b
	Use walls or enclosures for visual screening in urban areas.	BLM, 2006
	Minimize clearing and cut and fill modifications to the landscape.	BLM, 1986b
	Utilize existing roads and infrastructure whenever possible.	BLM, 1984 BLM, 2006
	Use low-profile pumping units, tanks, etc. Bury wellheads if feasible.	BLM, 2006

Table 3-13. Additional Surface Impacts and Potential Solutions (continued)

CATEGORY/IMPACT	POTENTIAL SOLUTION	REFERENCE
Presence of oil field equipment - color	Choose paint colors to minimize contrast with the local landscape. When selecting colors to "camouflage" equipment, first consider the season of greatest use. Select a color that is one or two shades darker than the predominant background during that season – typically this will be the color of vegetation rather than that of soil. Paint all equipment the same color; semi-gloss paint (fade and stain resistant) is preferable to a flat finish. An exception can be made for moving equipment; edges may be painted safety red, yellow, or orange as required by OSHA, etc.	BLM, 1986b BLM, 2006
Presence of oil field equipment – texture	Disguise equipment by placing it inside structures compatible with the local cultural landscape. Some drilling and production equipment locations have been disguised by surrounding with a façade structure that blends into the local architectural landscape of the area.	BLM, 2006
	Feather sharp edges of vegetation cut in order to soften visual impact.	BLM, 1984
	Housekeeping - keep equipment and well pads clean and free of extraneous equipment or debris.	BLM, 2006
Presence of oil field equipment - form and line	Avoid locating equipment on or disturbance of ridgelines.	BLM, 1986b BLM, 2006
	Follow the contour of topography or lines of vegetation with roads to minimize visual impact. Avoid straight lines in visually sensitive areas. Avoid siting linear features on steep slopes; the cut and fill required is likely to create significant visual impact.	BLM, 2006
	Bury pipes and flow lines - exposed lines have high visual contrast.	BLM, 2006
	Use two-tracks rather than engineered roads whenever possible.	BLM, 2006
Reclamation timing	Interim reclamation should be used to reduce the amount of bare ground. Interim reclamation is critical to reducing visual impact.	BLM, 2006
Wildlife Habitat – fragmentation and loss		
General issues	Fence or net the tanks, ponds, etc. to prevent access by wildlife (depending on water quality) or install safe egress for wildlife.	NMGF, 2007
	Seasonal timing of activities and No Surface Occupancy (NSO) stipulations.	
Increased levels of human activity	Minimize on-site presence for monitoring (human presence) through use of telemetry.	NMGF, 2007

Table 3-13. Additional Surface Impacts and Potential Solutions (continued)

CATEGORY/IMPACT	POTENTIAL SOLUTION	REFERENCE
Habitat fragmentation and migratory pathways	Develop and implement a plan of development to help minimize equipment, roads, and utilities.	NMGF, 2007
	Locating multiple wells or equipment on a single well pad reduces the number of pads and roads and utility corridor infrastructure needs, thus minimizing habitat fragmentation.	BLM, 2006
	Use lower class roads (i.e.: two-tracks) wherever possible.	BLM, 2006
	Initiate interim reclamation as soon as possible.	BLM, 2006
Habitat loss	Minimize disturbance and footprint using the methods noted above.	BLM, 2006
	Minimize noise using the methods noted above.	
	Provide habitat improvements where practicable. Use habitat improvement offsets if disturbance will be long-term or if reclamation is likely to be difficult or of limited success. In the latter case, it may be more sensible to provide habitat improvements to offset properties than to excessively attempt reclamation of habitat that was unsuitable in the first place.	
Birds – electrocution	Install raptor safe utility poles or retrofit existing equipment.	BLM, 2006
Birds - collision with utility lines	Install diverters.	
Birds – predation	Above-ground power lines may concentrate raptor predation on nearby prey populations. Bury cables whenever possible, such as near greater sage grouse leks and nesting areas.	BLM, 2006
Fish and aquatic invertebrates	Maintain minimum flow, particularly in cold-water systems.	
	Maintain naturally fluctuating flow regimes, particularly in warm-water systems.	
	Manage produced water discharge, only if of suitable water quality for the receiving water body, through a NPDES permit.	

3.4 SUMMARY AND RECOMMENDATIONS

Low impact oil or natural gas projects require careful planning, from the initial exploration phases through to final site reclamation, to minimize the adverse effects of surface disturbing activities. Such surface disturbances include a wide range of issues, with an even wider array of potential solutions; furthermore, various stakeholders may have differing viewpoints on how surface disturbances should best be managed. There is an underlying common approach that can be used to develop and implement management practices appropriate to any given situation. By following a general, yet organized, process focused on avoiding impacts, then minimizing unavoidable impacts, and finally remediating the unavoidable impacts, a plan that is mutually acceptable to all stakeholders often can be developed. This process is generally outlined and described below.

Planning – Potentially costly or time-consuming changes to a project can be avoided if appropriate steps are taken during planning.

- *Due Diligence – Project due diligence is an often underutilized planning tool. Prior to purchasing or leasing mineral rights, the operator is advised to consider the various aspects of the contemplated project that will result in environmental impacts. Once those issues are conceptually identified, the operator should evaluate the financial impact, including time delays, of potential solutions. This information can then be used to make more informed business decisions prior to committing resources to a mineral lease. Unfortunately, often this is not done, perhaps in part because of the highly competitive nature of the industry and the current high-rolling oil and gas commodities markets.*
- *Communication – Effective communication with stakeholders is critical to the success of a project. Perhaps at no time is this more crucial than in the initial planning phases. It is at this time that relationships with landowners, regulatory agencies, and the public are established and the positive or negative "tenor" of those relations set. That said, not all "good" relationships mean that all stakeholders will agree on all fronts, rather, a "good" relationship is one where all stakeholders understand the goals and objectives held by their counterparts. This will serve to foster effective negotiations when concessions are required during the design, construction, operations, or reclamation phases of a project.*
- *Negotiation with and Commitment to Surface Rights Owner – Surface use agreements (SUA) should be negotiated in good faith to gain the landowner's long-term trust and cooperation. Typically it is best for each stakeholder to have a single point of contact to ensure consistent and informed negotiation. It is wise to solicit the surface-rights owner's input to the development plan and consider how the energy project might complement future intended land uses – roads, water supplies, etc. could have preferred locations and utility long after the energy project lifespan. Timely and proactive reclamation and attention to unforeseen issues will help ensure that the trust gained from the landowner is not lost (WGA, 2006).*

Design – Project design can often occur simultaneously with planning. When conducted concurrently, design challenges that were perhaps not fully appreciated during the planning process can be addressed in a more timely and efficient manner. Design should be focused on areas of concern identified during the planning process. For example, if a landowner is adamant about where a road should (or should not) be placed, then the operator can utilize the design phase of the project to incorporate the landowner's request prior to construction and in time to effectively incorporate those wishes, if practicable. Throughout the design process the project team must work to identify challenges posed by environmental impacts and innovative or creative solutions to avoid, minimize, and mitigate those surface impacts during construction.

Construction – Perhaps one of the most critical elements of a successful low impact project is to ensure that construction proceeds according to the design and plan; that deviations do not occur without justifiable cause supported by appropriate documentation. Occasions might arise during construction that might not have been readily apparent during the design phase, but which present opportunities for further impact reduction. As noted above, the three key elements of a low impact construction project consist of avoidance, reduction, and mitigation:

- *Avoidance – The most effective means to reduce impacts is to avoid the activity or situation that would cause the impact. Avoidance is not, however, always possible. Oil or gas projects create some disturbances that are unavoidable. Typically avoidance is most effective in situations involving cultural or paleontological resources, sensitive habitat, or categorized areas. These are often among the most difficult resources to reclaim and, hence, are best avoided whenever possible. In many instances it can be a regulatory requirement that needs to be avoided.*
- *Minimization – If avoidance of an impact is not possible, then reduction of the impact through the implementation of reasonable and prudent practices is warranted. In addition to the several case studies presented herein, there are multiple handbooks, manuals, and documents from state, federal, and local agencies that provide guidance and recommendations for various field conditions.*
- *Mitigation – Also commonly referred to as interim reclamation, mitigation activities can commence as the project transitions from the construction phase to the operations phase. Mitigation can include revegetation and reclaiming borrow pits, ditches, roads, and portions of well locations, and repairing incidental damages such as erosion.*

Final Reclamation – Timely completion of final reclamation is as important as the initial planning. Incomplete or improperly executed final reclamation can result in the complete loss of a low-impact project opportunity. Reclamation becomes significantly more difficult, more expensive, and less effective if sufficient topsoil is not salvaged, interim reclamation is not completed, and if proper care is not taken to construct pads and roads in locations that minimize reclamation needs (BLM, 2006). Reclamation should account for re-grading the disturbances to the original contour, or a contour that blends with the surrounding landform (BLM, 2006). According to BLM's Gold Book (2006), "a reclamation plan is included in the Surface Use Plan of Operations and should discuss plans for both interim and final reclamation. Reclamation is required of any disturbed surface that is not necessary for continued production operations." The reclamation plan should address the following surface disturbances:

- *Pit Reclamation – All pits must be reclaimed to a safe and stable condition and restored to an attitude that blends in with the reclaimed pad area.*
- *Revegetation – Disturbed areas should be revegetated after the site has been satisfactorily prepared; site preparation should include re-spreading topsoil to an adequate depth. Native perennial species or other plant materials specified by the surface management agency or private surface owner are required on federal lands.*
- *Pipeline reclamation – Reclamation of pipelines includes re-contouring to the original contour, seeding, and controlling for noxious weeds.*
- *Well site reclamation – To achieve final reclamation of an abandoned well site, the area should be re-contoured to blend into the contour of the surrounding landform, stockpiled topsoil evenly redistributed, and the site revegetated.*
- *Road reclamation – Reclamation of roads includes re-contouring the road to the original contour, seeding, and controlling for noxious weeds.*
- *Reclamation of other infrastructure – Other facilities and areas of surface disturbance associated with federal oil and gas lease development, including water impoundments, power lines, metering buildings, compression facilities, and tank batteries, must be removed and reclaimed unless the surface lessee or owner requests that items such as impoundments, water wells, etc. be kept.*

Following these procedures is not a catch-all solution for avoiding environmental impacts and conflict during an oil and gas project. However, by reviewing and understanding the various case studies presented herein, and applying the knowledge gained in a manner consistent with the processes outlined, many issues can be avoided or substantially minimized.

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SECTION 4

Wildlife

4.1 INTRODUCTION

ENERGY DEVELOPMENT WITHIN WESTERN NORTH AMERICA AND THE GREATER SAGE-GROUSE

Resource extraction for energy development historically has been widespread throughout greater sage-grouse habitats (Scott and Zimmerman, 1984; Braun, 1987 and 1998; Braun *et al.*, 2002). Development of mines and energy resources in western North America was initiated prior to 1900 (Robbins and Wolf, 1994) and oil and gas development in the sagebrush biome began in the late 1800's with the discovery of oil in the Interior West (Connelly *et al.*, 2004). In Wyoming, which is dominated by sagebrush habitat, the first coal mine was opened in 1868 while the first oil well began producing in 1884. In Colorado, oil and gas development began at least in the early 1920's. Since the 1960's, development of natural gas resources has increased across the region; most recently coal bed natural gas (CBNG) development has emerged as a frequent associate of the greater sage-grouse. CBNG drilling first began in the Wyoming portion of the Powder River Basin (PRB) during the late 1980's and early 1990's; in 1997 the CBNG well drilling rate accelerated substantially and has continued to increase (BLM, 2003).

To date, there are more than 15,000 active CBNG wells within the PRB of northeastern Wyoming, and 10,000 kilometers (km) of overhead power lines (Braun *et al.*, 2002). CBNG development is also ongoing in other portions of the sage grouse range including Utah, Montana, and Colorado (Rowland, 2004). Oil production and exploration in the Rocky Mountain region is expected to remain constant or decrease slightly (National Petroleum Council, 2003) whereas natural gas development within those basins is expected to increase for the next 15 to 20 years. Although the oil and gas industry has been held largely responsible for the declining population trends observed in the greater sage-grouse, in fact, the extent of the impact directly attributable to oil and gas industry activities remains relatively uncertain (Holloran, 2005). However, the discovery and subsequent development of gas and oil fields throughout the western United States has been identified as one potential causative agent (Braun, 1987; Connelly *et al.*, 2004).

4.1.1 DISTRIBUTION, HABITAT REQUIREMENTS, AND NATURAL HISTORY

Currently, greater sage-grouse inhabit suitable sagebrush habitats in central Washington through southern Idaho, much of Montana, extreme southeastern Alberta and southwestern Saskatchewan, south to the southwestern corner of North Dakota, northwestern and southwestern South Dakota, most of Wyoming, western Colorado, and portions of Utah, and west to Nevada, extreme eastern California, and southeastern Oregon (Schroeder *et al.*, 1999 and 2004). Approximately 99 percent of the current population is found in the United States, while the remaining 1 percent is located in Canada (Stiver *et al.*, 2006). Federal lands make up about 72 percent of the total range of the species (Connelly *et al.*, 2004) making federal land management agencies primarily responsible for habitat management. However, privately owned lands provide critical seasonal habitats for many populations and their importance to conservation may greatly exceed the percentage of ownership within a population's range (Stiver *et al.*, 2006). Sage grouse populations typically inhabit large, unbroken expanses of sagebrush and are characterized as a landscape-scale species (Patterson, 1952; Wakkinen, 1990); however, definitive data are unavailable on minimum patch sizes of sagebrush needed to support populations of sage grouse (Rowland, 2004).

Sage grouse are native to the sagebrush steppe of western North America, and their distribution closely follows that of sagebrush, primarily big sagebrush (*A. tridentata*). The greater sage-grouse is a sagebrush obligate species because of the bird's year-round dependence on sagebrush habitat (Patterson, 1952; Braun *et al.*, 1976; Braun and Beck, 1996; Paige and Ritter, 1999; Schroeder *et al.*, 1999). However, the greater sage-grouse can also use a variety of other native habitats, especially during non-breeding times, including low sagebrush types such as, little sagebrush (*A. arbuscula*), black sagebrush (*A. nova*), antelope bitterbrush (*Purshia tridentata*), as well as riparian and upland meadows and sagebrush grasslands (Patterson, 1952; Dalke *et al.*, 1963; Wallestad, 1971; Nisbet *et al.*, 1983; Klebenow, 1985; Connelly *et al.*, 1991; Gregg *et al.*, 1993; Musil *et al.*, 1994; Braun, 1995; Apa, 1998; Schroeder *et al.*, 1999; Aldridge and Brigham, 2002; Crawford and Davis, 2002; Danvir, 2002). In addition, greater sage-grouse also have been shown to use human-modified habitats, such as croplands (alfalfa), when adjacent to sagebrush sites (Schroeder *et al.*, 1999).

Sage grouse are polygamous and exhibit similar breeding behaviors each year on ancestral strutting grounds known as leks (Patterson, 1952; Wiley, 1978). Breeding habitats are sagebrush-dominated rangelands, typically consisting of large, relatively contiguous sagebrush stands (Connelly *et al.*, 2000; Leonard *et al.*, 2000). Males display on leks that are characterized by low, sparse vegetation or bare ground (Patterson, 1952; Gill, 1965; Klebenow, 1985). Leks can be occupied for years, with reported use exceeding 25 years (Dalke *et al.*, 1963 and Wiley, 1978). Nesting habitat is often a broad area within or adjacent to leks, winter range or between winter and summer ranges (Klebenow, 1969; Wakkinen, 1990; Fischer, 1994). Productive nesting habitat includes sagebrush with horizontal and vertical structural diversity (Wakkinen, 1990; Gregg, 1991; Schroeder *et al.*, 1999; Connelly *et al.*, 2000) with moderate sagebrush cover, typically ranging from 15 to 25 percent (Connelly et al., 2000). During winter, sage grouse rely on exposed sagebrush for both forage and shelter (Batterson and Morse, 1948; Patterson, 1952; Schroeder *et al.*, 1999; Rassmussen and Griner, 1938; Patterson, 1952; Remington and Braun, 1985; Robertson, 1991). Sage grouse have shown a preference for large, intact expanses of sagebrush and an avoidance of conifer and topographically rugged habitats (Doherty et al., 2007).

4.1.2 HISTORIC AND CURRENT POPULATION TRENDS

Sage-grouse currently occupy 670,000 km2, or 56 percent, of their potential pre-settlement range, which once covered approximately 1,200,000 km^2 (Schroeder *et al.*, 2004). Population estimates from the Fish and Wildlife Service indicate at least two million birds occupied their natural range in the mid-19th Century, significantly more than the 100,000 to 500,000 the USFWS estimates to be present today. Historically, population dynamics of sage grouse have been defined by strong cyclical behavior; however available data and reports suggest this species has observed long-term population declines because of habitat loss, with range-wide decline rates estimated from 17–47 percent (Connelly and Braun, 1997). Research suggests breeding populations have declined by 45 to 80 percent since the 1950s (Braun, 1998); more recent data from 1985 to 1995 indicates declines have averaged 33 percent (Connelly and Braun, 1997); the slowing rate of decline is likely attributable to the ending of broad use chemical applications to remove sagebrush, as well as cessation of certain predator control programs.

In more recent studies, analysis of sage grouse populations by Connelly *et al.* (2004) has indicated negative population trends from the 1960's to the mid-1980's with some stabilization afterwards. In the past 15-20 years, most areas have exhibited relatively stable or minor population declines. An exception to this took place in 1991-1995 when, for unknown reasons, many leks disappeared in the PRB during a region-wide population decline (Connelly et al. 2004). In other regions however, between 1989 and 1994 Connelly *et al.* (2004) observed that some areas demonstrated population increases (2004). Recent data for 2005 also indicates potential population increases within some areas of the grouse's range, such as the PRB in Montana. However, it is evident the overall greater sage-grouse population has been declining at various rates for some time; the estimated rate of decline often being dependent on the analyzed time frame. For example, the rate of decline from 1965 to 2003 has been estimated at an overall annual rate of 2.0

percent; 3.5 percent from 1965 to 1985; and 0.4 percent from 1986 to 2003. That level of decline led to a population that was estimated to be 5 percent lower than the 2003 population (Connelly *et al.*, 2004).

4.1.3 PURPOSE

Current research has suggested that the energy industry is having an effect on sage grouse populations in areas such as the Powder River Basin or Pinedale Anticline areas of Wyoming where development is expanding. For example, Walker et al, (2007) in a recent study reported leks in areas of CBNG development (>40 percent developed within 3.2 km of lek) exhibited declining population trends in comparison to leks in an area of minimal or no CBNG development. His findings also indicated that leks adjacent to natural gas fields (10-40 percent developed) exhibited increasing population trends in comparison to leks located farther from development. This has been interpreted to suggest that sage grouse could be avoiding developed areas by moving into nearby habitat (Walker et al., 2007). In another study, Holloran (2005) reported male lek attendance decreased with physical distance to the nearest drilling rig and the number of males also declined when the lek was located downwind from a drilling rig, indicating that noise from energy development was likely a contributing factor (Holloran, 2005).

However, no single factor has been identified as the cause of declines in sage grouse populations (BLM, 2004). The current effect the oil and gas industry is having on the birds overall population size and habitat is becoming better understood as focused, well-designed research provides valuable information on the subject. Historic effects on the other hand are poorly understood because of a lack of quality research (Braun, 1998). Additional study is needed to fully understand how and what facets of energy development affect the grouse, the subsequent long-term effects on the overall population after land reclamation, and what life history characteristics are most susceptible.

Considering the national importance of federal land access for energy development and supply, it is critical to accurately understand the effect the industry is having on the greater sage-grouse so that appropriate conservation strategies and adaptive management practices can be implemented. The primary aim of this document is to assess methods that are commonly used to estimate greater sage-grouse population sizes or trends, as well as methods that are used to determine the presence or absence of leks within active oil and gas development areas. Furthermore, an analysis of the Montana and Wyoming greater sage-grouse databases was conducted to evaluate their quality since, they are commonly used to analyze the effect the oil and gas industry is having on the greater sage-grouse. Lastly, data analysis recommendations are presented that not only account for current data, but historical data as well. The intent of this report is not to discredit previous findings or conclusions by researchers, but simply to generate additional information to help further explain, clarify or validate the affects the energy industry is having on the bird.

4.2 REVIEW OF NON-ENERGY RELATED LAND USE IMPACTS

Sagebrush habitat has experienced extensive alteration and loss (Connelly, 2004), which likely is a primary reason for the long-term declines observed in many sage grouse populations. Land managers have used prescribed fires, mechanical treatments, biological agents, and herbicides to remove sagebrush from vast areas on federal and private lands for reseeding with non-native grasses, primarily to provide forage for livestock (Pechanec *et al.*, 1965; Vale, 1974; BLM, 1991). Although no single historic, or current, land use is likely the sole cause for the observed declines, the alteration and range-wide quality reduction of the sagebrush biome generally is recognized as a causative factor (Connelly *et al.*, 2000; West and Young, 2000). This section will provide a synopsis of common historic and current non-energy related land practices, as well as the West Nile Virus, to help explain or further define the grouse's current negative population trend.

4.2.1 LIVESTOCK GRAZING

During the late 1800's a series of legislative acts were passed to regulate grazing on public lands. Legislation delegated responsibility to the U.S.

Forest Service in the Department of Agriculture and the Grazing Service in the Department of Interior for administrating public land grazing (Connelly *et al.*, 2004). The Taylor Grazing Act, which was passed in 1934, authorized the Secretary of Interior to establish grazing districts of "vacant, unappropriated, and unreserved land from any parts of the public domain" (Connelly *et al.*, 2004). By the 1930's, greater sage-grouse habitat had been fragmented or severely reduced in many areas (Braun, 1998) and by the early 1960's, elimination or reduction of sagebrush (to increase grass production) became a common practice on public and private rangeland (Martin, 1970). During this time frame the greater sage-grouse experienced two major population declines.

Currently, much of the sagebrush biome is managed for livestock grazing (Knick *et al.*, 2003, Klebenow, 1982; Call and Maser, 1985; Beck and Mitchell, 2000; Connelly *et al.*, 2004; Crawford *et al.*, 2004). For instance, in 2001, 15,000 permits were issued for 10.2 million animal unit months of forage consumption on lands managed by the BLM (2002). Because the impact grazing pressure has on sage grouse populations is poorly understood, it is a senstive management issue for many (Brussard et al., 1994; Noss, 1994; Wambolt *et al.*, 2002; Crawford *et al.*, 2004). One reason for this lack of understanding is due to experimental research deficiencies (Braun, 1987; Beck and Mitchell, 2000; Connelly *et al.*, 2000). For example, many studies infer negative effects on sage grouse habitat by noting that grazing systems require appropriate design to adequately address nesting and brood rearing habitat needs (Gregg *et al.*, 1994; DeLong *et al.*, 1995; Sveum *et al.*, 1998). However, adequate research to optimize grazing plan designs to minimize specific negative impacts on greater sage-grouse populations is still needed.

4.2.2 AGRICULTURE

Agricultural activities, such as plowing and the subsequent introduction of cultivated crops, have been reported as a major factor leading to the long-term loss of sage-grouse habitat (Montana Sage Grouse Work Group, 2005). Plowing for instance is detrimental to sage grouse because it affects suitable terrain on which the grouse winter; also sagebrush is not likely to recover from continuous cultivation (Montana Sage Grouse Work Group, 2005). The first significant loss of sagebrush habitat due to agriculture likely occurred in the 1880's with the advent of irrigation projects, which expanded and intensified development of croplands formerly thought to be marginal for crop production (Todd and Elmore, 1997). Starting in 1862, settlement of western rangelands within the sagebrush biome was encouraged by a series of Homestead Acts (Todd and Elmore, 1997). Most land with agricultural potential was homesteaded and in private ownership by 1930 (Braun, 1998). This resulted in the conversion of approximately 1.2 million km^2 (296 million acres) of public lands. The federal farm program further encouraged conversion of private rangeland to cropland affecting large tracts of sagebrush steppe during the 1970's and 1980's (Montana Sage Grouse Work Group, 2005). Currently, more than 70 percent of the sagebrush dominated rangeland that provided suitable grouse habitat has been converted to cropland in some states (Braun, 1998).

4.2.3 HARVESTING/HUNTING

Harvesting of the greater sage-grouse occurs in 10 of the 11 western states within its range; the State of Washington being the only exception (Connelly *et al.*, 2004). As far back as the 1800's, hunting has negatively impacted many populations of this species (Patterson, 1952) and may have had some role in the bird's current population trend. In sagebrush habitats, sage grouse often were (and are) the only upland bird available for sporting harvest, providing a specific recreational and economically opportunity that would otherwise be unavailable. In Idaho for example, the Idaho

Department of Fish and Game estimated that in the early 1990's about 17,000 hunters pursued the bird each year, with a value of more than $2 million to Idaho's economy. There is some disagreement concerning the effects hunting might have had, or is having, on sage grouse populations. Braun (1998) reported he believed hunting had minimal affects on the bird's population because hunting is thought to help with population replacement and be compensatory. However, Connelly *et al.* (2003) reported areas closed to hunting showed increases to breeding populations and that moderate levels of harvesting slowed population recovery.

4.2.4 HERBICIDES

Historic herbicide treatment of the sagebrush biome to increase grazing efficiency was primarily implemented following unrestricted grazing in the late 1800's and early 1900's (RangeNet Project, 1964). It is conservatively estimated that at least 50 percent of all western rangelands have been treated with herbicides at least once (Braun, 1998). Estimates of treated sagebrush habitat vary and from 200,000- 240,000 km^2 treated over a 30-year period (Schneegas, 1967) to 400,000 to 480,000 km^2 treated by the 1970's (Vale, 1974; Pechanec *et al.*, 1965). Other estimates indicate that since the early 1960's, treated areas probably exceed 20-25 percent of the total remaining sagebrush-dominated rangelands and by some accounts no areas used by sage grouse are known to have escaped treatment. Spraying of herbicides primarily degrades habitat for sage grouse by increasing fragmentation and removing shrubs used as nesting cover. Until the early 1980's, herbicide treatment (primarily with 2,4-D) was the most common method to reduce sagebrush on large tracts of rangeland (Braun, 1987).

4.2.5 WEST NILE VIRUS

The effect of West Nile Virus (WNV) on the greater sage-grouse is a surging issue that until recently was not actively studied. Although further research is required to accurately reflect the impact of this virus on the grouse, available data suggest concerns voiced by resource managers might be warranted. In 2003, known sage grouse mortalities attributed to WNV included 19 in Wyoming, but only three in Montana and five in Alberta. However, in a study by Naugle *et al.* (2004), mortality associated with WNV infection decreased survival of female greater sage-grouse by 25 percent across four populations in Wyoming, Montana, and Alberta in 2003. In one population, mortality was as high as 75 percent due to WNV (Naugle *et al.*, 2004).

In a study by Naugle and others in Montana, researchers reported that some sage grouse hens survived WNV infection. Two adults and four yearlings out of 68 females captured in the fall of 2004 and the spring of 2005 tested seropositive for antibodies to WNV indicating that they had been infected previously but survived the winter. Despite regular spring and summer precipitation, researchers confirmed only two WNV mortalities in 2005. The low rates of WNV-related mortality and low seroprevalence (<10%) suggests that WNV impacts may be limited by low rates of exposure to the virus rather than to high levels of resistance.

4.3 REGULATORY REVIEW

Federal lands make up approximately 72 percent of the total range of the greater sage-grouse (Connelly *et al.*, 2004), as well as a large portion of remaining grouse habitat. As such, federal land management agencies are primarily responsible for the management of greater sage-grouse habitat. Three federal agencies, the U.S. Bureau of Land Management (BLM), the U.S. Fish and Wildlife Service (FWS) and the U.S. Forest Service (FS), are engaged in implementing range-wide greater sage-grouse conservation policies and planning. Currently, FWS lists the greater sage-grouse as a candidate species, which by definition is a species of concern where sufficient information on their biological status and threats is available to propose them as endangered or threatened under the Endangered Species Act, but for which development of a listing regulation is precluded by other higher priority listing activities. In 2005 the FWS completed a "status review" of the greater sage-grouse for listing and protection under the Endangered Species Act. From this process the FWS, under considerable controversy, determined the greater sage-grouse did not warrant special protection under the Act because the overall natural distribution and population of the birds was not considered to be in significant jeopardy.

The BLM manages more federal land than any other agency --- approximately 261 million surface acres and 700 million sub-surface acres of mineral estate. Because of this, the BLM's role in implementing the Energy Policy Act of 2005 is critical. In addition, the BLM has the management responsibility for the majority of that portion of greater sage-grouse range that exists on federal lands, including those lands that define the Powder River Basin. Therefore, the BLM has a critical role in ensuring that the energy needs of the United States are met

while balancing the protection and conservation of sensitive resources, such as the greater sage-grouse. The aim of this section is to review those BLM policies and strategies that are pertinent to the greater sage-grouse and energy development, as well as discuss conservation plans that have been developed by Montana and Wyoming.

4.3.1 CURRENT STATUS AND CONSERVATION STRATEGY

The BLM (and the FS) characterizes the sage grouse as a sensitive species and provides specific guidance and policy for this species within BLM's Manual 6840, Special Status Species Management. The authority for this policy and guidance comes from the Endangered Species Act of 1973, as amended; Title II of the Sikes Act, as amended; the Federal Land Policy and Management Act (FLPMA) of 1976; and the Department Manual 235.1.1A., General Program Delegation, Director, Bureau of Land Management. The BLM's Instruction Memorandum IM 97-118 Guidance on Special Status Species Management (6840 Manual) was issued on April 30, 1997 in response to USFWS's "Notice of Review of Plant and Animal Taxa That Are Candidates For Listing as Endangered or Threatened" (61 FR 7595).

By definition the sensitive species designation includes species that could become endangered or extinct. The intent of the sensitive species designation is to ensure that actions on BLM-administered lands consider the welfare of these species and do not contribute to the need to list additional Special Status Species under the provisions of the ESA. Management requirements that apply to the species on the BLM Sensitive Species List are to avoid or minimize adverse impacts and maximize potential benefits to species whose viability has been identified as a concern by reviewing programs and activities to determine their potential adverse effects on sensitive species.

Currently, BLM is the only federal agency to develop a conservation strategy specific to the greater sage-grouse, the *National Sage Grouse Habitat Conservation Strategy*. Its purpose is "to guide future actions for conserving sage grouse and associated sagebrush habitats and to enhance BLM's ongoing conservation efforts" (BLM, 2004). Fundamental to BLM's habitat strategy are guidance documents or land use plans that mandate or recommend that certain sage grouse conservation measures be incorporated into all ongoing BLM programs and activities, including oil and gas development. The direction of the strategy revolves around identifying "Guiding Principals", such as cooperative integrated approaches, land use plans, use of scientific study, etc., and serves as the umbrella for BLM state-level strategies. The strategy identifies efforts or "action items", delineates responsibility, establishes time frames for completion, and stresses the importance of local and state coordination.

4.3.2 POLICY APPLICABILITY TO THE GREATER SAGE-GROUSE

Existing management direction for land and mineral resources administered by BLM are contained within regional Resource Management Plans (RMP). Within RMP's there are mitigation guidelines that are used to determine the types and levels of mitigation needed to protect important resources from actions involving surface-disturbing and other human-presence disturbance or disruptive activities. These guidelines are used in the RMP process for developing and analyzing alternatives for Environmental Impact Statements (EIS). They constitute the planning criteria for developing the alternatives and for determining mitigation requirements to be included in an approved RMP; and in planning and developing project proposals.

Specific to the Powder River Basin, assessment of associated oil and gas impacts to the greater sage-grouse are addressed by Wyoming's *Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project* and *Montana's Final Statewide Oil and Gas EIS and Proposed Amendment of the Powder River and Billings RMPs* (Supplemental EIS in draft).

Wyoming's EIS details oil and gas related impacts to the greater sage-grouse as:

- *Increased direct mortality (including legal hunting, poaching, and collision with power lines and vehicles).*
- *The introduction of new perches for raptors and thus a potential change in rate of predation.*
- *Direct loss or degradation of habitats.*
- *Indirect disturbance resulting from human activity (including harassment, displacement, and noise).*
- *Habitat fragmentation (particularly through construction of roads).*
- *Changes in population.*

Within the *Mitigation Monitoring and Reporting Plan* (Appendix D) of the EIS, documentation of clearance surveys for greater sage-grouse breeding activity and loss of sagebrush shrub lands and their reclamation success are required. Montana's Statewide Oil and Gas EIS addresses the same impacts to grouse as Wyoming's EIS, but details more specific management approaches within the EIS's associated *CBNG Programmatic Wildlife Monitoring and Protection Plan,* such as survey requirements. The impact reduction strategy for the greater sage-grouse and other wildlife species in Montana's EIS revolves around an adaptive management scheme. The aim of which is to allow for evaluation of new information based on changing conditions and the close monitoring of population data to determine the effectiveness of mitigation measures and stipulations. Mitigation measures and timing stipulations to protect greater sage-grouse breeding grounds (leks) are common in both impact statements and are further detailed (and administered) in either BLM's Application for Permit to Drill (APD) or Plan Of Development (POD) process, depending on the development proposed.

4.3.3 ADPs AND PODs

Under the APD or POD process for oil and gas development, the BLM has the authority and discretion to condition its approval of proposed actions with reasonable measures to reduce the effect of actions on other resource values and uses, consistent with the lease rights granted (see 43 CFR 3101.1-2). The National Environmental Policy Act of 1969 and amendments (NEPA) record associated with an APD or POD must document the effects of the development and explain the effects on other resources under consideration in the planning process. In completing NEPA analyses for an APD or POD, BLM must make a determination on plan conformance. Site-specific NEPA analysis may include cumulative impact analysis, especially where impacts projected from Reasonably Foreseeable Development (RFD) scenarios, are or will be exceeded. It should be noted that an APD can include a plan for development of only a single well; whereas, a POD is organized around large parcels of land that will contain multiple wells.

In Wyoming, conditions of approval for the conventional oil and gas APD, as they relate to the greater sage-grouse, include performance of lek surveys, set-back stipulations (if applicable), data collection, and mitigation and monitoring efforts. In Montana, however, the conditions of approval for a conventional oil and gas APD differ. For instance, the performance of greater sage-grouse surveys technically are *not* required by the conventional oil and gas industry because the *Programmatic Wildlife Monitoring and Protection Plan* contained in the Statewide EIS and SEIS is applicable only to CBNG development. Although BLM-Montana can enforce timing or surface occupancy stipulations that might limit development during certain times of the year where leks are present, formal regulations mandating surveys (or survey protocols) by conventional oil and gas operators do not exist. BLM's proposed adaptive management approach (subject to approval) and changing greater sage-grouse conservation strategy will likely address this issue. Consequently, this may result in requiring the conventional oil and gas industry to expand their greater sage-grouse management strategies in the near future. Further discussion of this evolving subject, although critical to the oil and gas industry, is considered beyond the scope of this report.

For CBNG, development approval is contingent on completion of the APD and POD; both Montana and Wyoming provide guidance documents for completion of these submittals: Wyoming's Coal Bed Natural Gas Well Application for Permit to Drill and Plan of Development Preparation Guide and Montana's Coal Bed Natural Gas APD and Project POD Guidance Manual. Both documents provide detailed survey protocol, survey time frames and reporting and stipulation requirements for the greater sage-grouse. **Table 4-1** provides a comparative list of survey, mandatory lease stipulations and surface occupancy requirements for the greater sage-grouse within the Powder River Basin for both states. Note: the Montana Department of Fish, Wildlife and Parks has proposed new oil and gas stipulations that expand the protective buffer distance for breeding and nesting activities. However, at the time of this report, these proposed stipulations were under consideration and; therefore, are not included in the table.

4.3.4 GREATER SAGE-GROUSE CONSERVATION STRATEGIES: MONTANA AND WYOMING

Greater sage-grouse work groups, typically cooperative members of state, federal, tribal, and private entities, as well as individuals from the public, have prepared conservation and management plans for sage grouse in Montana and Wyoming: Wyoming's *Greater Sage Grouse Conservation Plan* and Montana's *Management Plan and Conservation Strategies for Sage Grouse*. These plans establish a process to achieve sage grouse management objectives and provide a framework to guide local management efforts and coordinated management across jurisdictional boundaries. The overall goal of these plans is to "provide for the long-term conservation and enhancement of the sagebrush steppe/mixed-grass prairie complex…" in a manner that supports sage grouse and a healthy diversity and abundance of wildlife species and human uses.

Table 4-1: BLM Greater Sage-Grouse Survey Requirements and Stipulations in Montana and Wyoming

NSO-No Surface Occupancy CSU-Controlled Surface Use TLS-Timing Limitation Stipulation

State	Survey Dates	Survey Frequency	Surface	Stipulation Distance (lek)	Surface Occupancy (nest)	Stipulation Distance/Time (nest)
Montana	April	Prefer 3 (aerial or ground)	NSO	1/4 mile	2 miles (if within 2 miles of known lek)	NSO: March 1st – June 15th
Wyoming	April 7th – May 7th	Require 3 (ground only)	CSU	1/2 mile	2 miles	TLS: March 1st – June 15th

4.3.5 APPLICABLE NEPA METHODS USED TO DETERMINE LEK IMPACTS FROM OIL AND GAS DEVELOPMENT-IN MONTANA AND WYOMING

Impacts to the greater sage-grouse, as discussed in both Wyoming's Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project and Montana's Final Statewide Oil and Gas EIS and Proposed Amendment of the Powder River and Billings RMPs, primarily focus on qualitative discussions of known oil and gas related disturbances that might affect regional or local population levels. Relative to the greater sage-grouse, these disturbances include direct loss of wildlife habitat, shifts in vegetation, habitat fragmentation, predation from raptors (power lines) and wildlife mortality from collisions with power lines. In addition, noise and the presence of humans also are addressed. Quantifying direct or indirect impacts to greater sage-grouse, or for any wildlife species is difficult because of the grouse's dynamic behavior and complex seasonal migration needs, as well as limited funding to study impacts resulting from specific disturbances.

For instance, a typical oil and gas evaluation of the effects power lines will have on greater sage-grouse typically includes a qualitative assessment of what could happen. That is, additional power lines within greater sage-grouse habitat could provide raptors with new opportunities for hunting and capturing prey, and at a higher success rate. As such, this could increase local or regional levels of raptors and subsequently, reduce the number of greater sage-grouse in the area. Although this type of impact analysis is not necessarily incorrect, since quantifiable analysis options are largely not available, it does bring to light the need for additional research that examines specific oil and gas related disturbances and the resulting effects on the greater sage-grouse.

Estimates of oil and gas related surface disturbance is the one exception found within the NEPA analysis process that allows for a quantifiable approximation of impacts. Typically, the number of well pads and length or roads/utility corridors and other infrastructure can be calculated and then extrapolated to estimate impacts to various resources such as habitat biomes (fragmentation) or air quality (dust emissions). Such an analysis can provide an overall magnitude of impact and further define or facilitate development of necessary mitigation that will reduce avoidable impacts. However, in the case of habitat obligate species, such as the greater sage-grouse, this type of analysis is somewhat limited because the level of disturbance to crucial habitat, *i.e.* sagebrush, is nearly impossible to quantify accurately. For this reason, an integral component of the analysis process involves the development and implementation of prudent management actions aimed at habitat avoidance or activity minimization and surface restoration. These topics are further addressed in Section 4.6 of this document.

4.4 ANALYSIS OF POPULATION ESTIMATE METHODS AND IMPACTS IN AREAS WITH ENERGY DEVELOPMENT

Consistent and comparable methods for estimating populations of greater sage-grouse are vital when evaluating the effectiveness of current conservation strategies and BLM-implemented surface stipulations. To date, the primary method used to estimate population size and trends of the greater sage-grouse is done by conducting lek counts. The use of this method to monitor populations was standardized by Batterson and Morse (1948), and Patterson (1952) based on the premise that male sage grouse annually attend leks during the breeding season. However, concerns of this method have been expressed since the early 1980's by Beck and Braun (1980) and more recently by Walsh *et al.* (2004). The use of this method requires the formulation of data assumptions, that when coupled with varying population estimate parameters, often can lead to discrepancies and, in some cases, inconsistent results. Some attempts to standardize estimating techniques have been made (Connelly *et al.*, 2003), but given the large scale complexity of the issue and the involvement of multiple states and stakeholders, standardizing methods has been slow to come to fruition.

Despite the questions surrounding the validity of lek counts to monitor population trends, counting sage grouse on leks appears to be the most reliable method (Connelly *et al.*, 2004). The aim of this section is to further address the strengths and weaknesses of this method, as well as other commonly used population estimate methods. It should be noted that the collection and/or performance of independent data or research was not conducted as part of this report. Therefore, conclusions associated with the analysis of current population estimate methods are based solely on available literature and, in some cases, might not be empirically supported.

4.4.1 LEK SURVEY METHODS

Various greater sage-grouse monitoring procedures are employed by state and federal agencies to establish attendance numbers, which are subsequently used to estimate population size. These monitoring procedures should be performed in the spring (mid-March to early May) in the early morning (1/2 hour before to 1 hour after sunrise) or in some cases in the evening just before sunset, when weather conditions are conducive to visual observations (Connelly *et al.*, 2003). Furthermore, for lek counts to be considered reliable, leks need to be counted ≥3 times annually and the counts, when feasible, separated by ≥5 days (Connelly *et al.*, 2003). Presented below is a brief description of the three primary monitoring procedures used for breeding populations of greater sage-grouse, and their advantages and disadvantages.

LEK SURVEYS

Lek surveys are likely the most widely used and most basic form of lek monitoring. With this method, leks are identified and monitored on an annual basis over time for occurrence in an area and are normally classified within a given year as active or inactive. The general use of this method is based on Emmons and Braun's 1984 study that indicated the number of active leks is directly proportional to population size. The advantage of performing lek surveys is that they are simple and can be conducted by air or on the ground in a relatively short amount of time. However,

because this method does not involve performance of bird quantification per lek, it may be less sensitive than other lek survey approaches, especially when considering short-term changes in population size (Connelly *et al*., 2003).

LEK COUNTS

The lek count method is a tally of greater sage-grouse males per lek, or group of leks, with no assumption that the leks represent all or part of a single breeding population (Connelly *et al.*, 2004) and is used to quantify changes to individual lek attendance over time. The performance of lek counts typically requires more effort than lek surveys, because counts should be conducted more than once per breeding season to sufficiently estimate the largest number of male sage grouse attending a lek for any given year (Jenni and Hartzler, 1978; Emmons and Braun, 1984). With this approach, and assuming leks are monitored accurately over the course of several years, population trends can be estimated more accurately than with the lek survey method. However, because lek size may be density dependent, and counts can be affected by weather, time of day, winter survival, nest success, proximity of predators, livestock grazing, agriculture and other factors, some researchers have expressed concerns that the counting method may yield biased estimates of population trends (Stiver *et al.*, 2006).

LEK ROUTES/CENSUSES

Lek routes or censuses are counts of male sage grouse on a group of leks that are relatively close and represent all or part of a single breeding population (Connelly *et al.*, 2004). Performance of this method minimizes bias associated with counts of individual leks by quantifying the number and size of leks in a given area (Stiver *et al.*, 2006). This approach may not account for male migration to other leks or other regions and also might be affected by certain variables as addressed in lek counts.

LEK DESIGNATION CRITERIA

During the process of evaluating greater sage-grouse lek occurrence data for population trend analysis, data assumptions typically are employed to account for the high variability in reporting methods and results (counts), various disturbance factors (*e.g.:* livestock grazing, human encroachment, oil and gas development, etc.), and the complex and changing migratory or movement patterns of the birds. Although the formulation of pre-defined assumptions is necessary to calibrate and organize survey data, establishing and implementing them as part of the overall analysis process lacks empirical support (Walsh *et al.*, 2004) and is relatively subjective because the quality of data may vary or research objectives and individual interpretations might differ.

To further understand monitoring efforts to classify leks, Connelly et al (2004) conducted a survey among various state agencies within the grouse's range to ascertain survey methods. The survey found:

- *Ten agencies (77%) reported having started monitoring programs in the 1940's or 1950's; whereas, two (15%) started programs in the 1960's or 1970's, and one agency started monitoring in the 1990's.*
- *All of the surveyed state and provincial fish and wildlife agencies reported they conducted annual surveys for sage grouse breeding populations; however, they use varying methodologies.*
- *Three of the surveyed agencies use lek counts and lek routes; one uses lek counts and lek surveys; and four use lek counts, lek routes, and lek surveys.*
- *Most agencies indicated they attempt to replicate lek counts over a period of several weeks (more than three monitoring efforts per year), but at least two agencies complete counts within a one week period where only one lek count is performed.*
- *Results of the survey suggested that some agencies were performing counts during inappropriate time frames, possibly leading to inaccurate lek designations or attendance counts.*
- *Lastly, the survey indicated discrepancies were found among information submitted by the agencies versus data obtained from the agencies' lek database, an issue that could directly affect population estimates.*

Current lek designation practices typically use one field observation to surmise the "active" status of the lek while three observations are necessary to classify the lek as "inactive". Informal findings have found one field observation in some cases is not sufficient to accurately characterize a lek's active status because many variables can affect the count. As described in the Western Association of Fish and Wildlife Agency's Greater Sage-Grouse Comprehensive Conservation Strategy, the accuracy of survey efforts is affected by many unknowns that include:

- *The attendance rates of males.*
- *The attendance rates of females.*
- *Variation in attendance due to age, time of day, time of year, weather conditions, and relationship with the peak of female nesting.*
- *Variation in the technology used to capture and mark birds for monitoring.*
- *Observational biases associated with observer, habitat, region, and topography.*

To further examine the "accuracy" issue, the Montana Fish, Wildlife & Parks conducted an informal, unpublished study to examine the accuracy of survey results for 12 known lek sites. As part of the study each of the 12 lek locations were surveyed on three separate occasions by ground and by air. Although specific data were not available at the time of this report (*e.g.:* attendance, weather, time, etc.), results of the study indicated only three of the 12 (25%) surveys yielded comparable data, whereas survey results for the remaining leks indicated high variability among attendance counts. To further support this premise, Walsh *et al.* (2004) suggested that male lek attendance and visibility of males on leks might be considerably lower than previously thought.

In addition to inaccurately characterizing active leks, the same may hold true for the designation of inactive leks. That is, has the lek truly become inactive or has the lek moved or shifted to other areas containing more suitable habitat or have the males simply dispersed and incorporated themselves into other functional leks, or even established new leks? Although more research is needed to fully understand this issue, Emmons and Braun (1984) demonstrated extensive inter-lek male movements and Dunn and Braun (1986) found this movement was typically less than 8 km, suggesting that an awareness of the number of leks within a given region may be equally as important as accurately assessing male attendance at a given lek (Stiver *et al.*, 2006).

4.4.2 METHODS TO ESTIMATE POPULATION TRENDS

To assess greater sage-grouse population (breeding) trends within a particular region, the minimum level of information required is the number of active leks in an area over a period of years (Connelly *et al.*, 2004). The use of lek data to ascertain greater sage-grouse populations across the species range is relatively problematic because the quantity, quality, and methods used to obtain the data often vary among agencies , as well as the necessary, yet varying data assumptions or inferences which are employed during the analysis process (Connelly *et al*., 2004). In addition, although the three primary lek monitoring procedures (surveys, counts and routes/censuses) mainly focus on the male grouse to extrapolate population size and trends, little empirical information is available to detail the relationship that exists among male lek attendance versus the proportion of females (or possibly juveniles) in the population (Walsh *et al.*, 2004). Resulting assessments of sage grouse population trends are likely dependent on the monitoring approaches used to acquire the data, which in themselves are problematic. to perform because of the of the birds large range (which may cross jurisdictional boundaries), and because of their potential inability to reflect actual population conditions due to the birds unpredictable movements.

To examine the use of lek surveys to estimate population trends, Connelly *et al.*, (2004) simulated greater sage-grouse populations to further validate the method. Results of the simulated study supported findings from Emmons and Braun (1984), which indicated the proportion of males observed and the number of leks surveyed contribute more to the analysis of trends than do the number of years monitored and the size of the leks. In terms of long-term population trends however, lek counts when performed in conjunction with lek surveys may provide more pertinent trend data versus lek surveys alone. Lek count data is the most widespread approach for assessing population trends and will likely continue as such, at least for the near future, since the method is easy to perform and it facilitates compilation of more specific data due to the quantification of males (and females) per lek.

However, the use of lek counts to assess greater sage-grouse populations is controversial (Walsh, 2002; Walsh *et al.*, 2004), because of a lack of supporting data on actual population parameters (Anderson, 2001; Walsh *et al.*, 2004) and the method's inherent assumption that the probability of detection of birds remains constant through the years. A gradual shifting of a lek's location over time can directly influence lek counts (Stiver *et al.*, 2006) and can be further complicated by the formation of satellite leks that may develop near a large lek during years with relatively high populations (Connelly *et al.*, 2004) or in some cases when male sage-grouse do not attend a lek or may attend two or more different leks (Jenni and Hartzler 1978, Walsh 2002).

Furthermore, conflicting grouse attendance data, as reported by Connelly *et al.*, (2004), have been reported in previous publications. Emmons and Braun (1984) found the mean lek attendance was 86% for yearling males and 92% for adult males; whereas, Walsh *et al.* (2004) reported that adult male sage-grouse and yearling daily attendance rates were 42% and 19%, respectively. The problem of movement of male birds from one lek to another (attendance), or geographical shifting of leks is minimized when leks are close together and represent a significant portion of the breeding population for that region. As such, lek routes are preferable to lek counts because they can improve the chances of male grouse detection (Connelly *et al.*, 2004) and, therefore, are more useful for assessing population trends than information on the simple number of active leks (Connelly *et al.*, 2003).

Additional biases associated with each of these monitoring techniques relate to individual state priorities and possibly a lack of overall manpower on the part of state agencies to sufficiently monitor range-wide populations. For instance, greater sage-grouse inhabit certain areas of Nebraska but because the bird is not controversial or considered sensitive in that State, monitoring of leks is not performed. To expand on the above premise, sampling of leks is typically not performed in marginally-occupied areas or more specifically, may be disproportionately conducted in areas where human related surface disturbances are not expected versus areas where disturbance practices are ongoing or are expected. In this situation the sampling of leks may be disproportionately conducted in regions where disturbance (*e.g.*, energy development) is an over-riding concern. Furthermore, many states when employing lek monitoring efforts often focus on a select group of leks, which were originally selected because of size, and rely on observations from these leks to extrapolate information pertaining to a given regions population trend (Stiver *et al.*, 2006). As such, inherent bias resulting from the available population data is likely present.

4.4.3 THE PRESENCE OF LEKS WITHIN OIL AND GAS AREAS AND A SUMMARY OF RESEARCH FINDINGS

Resource extraction for energy development historically has been widespread throughout much of the greater sage-grouse range (Scott and Zimmerman, 1984; Braun, 1987 and 1998; Braun *et al*., 2002). CBNG development is fairly recent (primarily since 1997). The increasing rate of CBNG development in particular has emerged as a growing concern for sage-grouse. For example, to date there are more than 15,000 active CBNG wells within the Powder River Basin of northeastern Wyoming, and 10,000 km of overhead power lines (Braun *et al*., 2002). CBNG development is ongoing in other portions of the sage grouse range, including Utah, Montana, and Colorado (Rowland, 2004). Oil production and exploration in the Rocky Mountain region is expected to remain constant or decrease slightly (National Petroleum Council, 2003), whereas natural gas development within those basins is expected to increase for the next 15 to 20 years.

Potential impacts of gas and oil development on sage grouse include habitat loss and fragmentation from well, road, and pipeline construction, and increased human activity causing the displacement of birds through avoidance behavior (Holloran, 2005). Direct mortality also occurs from collisions of sage grouse with fencing (Call and Maser, 1985; Danvir, 2002), which is typically needed for livestock grazing, and vehicles on roads (Patterson, 1952). The effects of energy development thus far indicate a negative impact on sage grouse populations, although the overall industry affect, or its magnitude relative to other widespread activities such as agriculture, on the population range-wide still is relatively uncertain (Holloran, 2005).

Stakeholders, public agencies, and members of the academic community have been providing management guidelines to the energy industry to help in the conservation of the species. Specific to many of these guidelines are the establishment of protective buffer zones around critical breeding, nesting, and wintering habitats that either limit or prohibit new surface disturbance activities (*e.g.:* road and well pad construction, drilling, utility corridors, etc.) during specific seasonal time frames coincident with the grouse's seasonal use of specific habitats. One central question has arisen: what buffer size is adequate to insure the protection of the species?

Studies of greater sage-grouse specific to the oil and gas industry, although limited in number, primarily have focused on the first question by examining the effects of development (disturbance) on leks within set distance categories. To further examine this, several studies were reviewed to determine if relatively consistent findings are being reported. The second question has yet to be thoroughly examined. Section 4.5 of this paper examines the available data from the PRB and attempts to begin to address these and other questions.

John Connelly of the Idaho Department of Fish and Game has conducted extensive study on the greater sage-grouse. The results of his studies are regarded highly within the greater sage-grouse academic/scientific community. From Connelly *et al.*, (2000), *Guidelines to Manage Sage Grouse Populations and their Habitats*, he recommended energy related facilities be placed a minimum distance of 3.2 km (2 miles) from active leks. For non-migratory grouse, he recommended the same distance applied near lek sites also be used to protect critical habitats. For migratory grouse, however, he recommends a protective zone of 18 km to protect breeding habitats (nesting habitats may be as far as 18 km from lek sites utilized by migratory sage grouse populations). This particular recommendation was based on findings from Wakkinen *et al.* (1992); Lyon (2000) and Lyon and Anderson (2003) indicating that protection of habitat within 3.2 km of leks might not protect most of the important nesting areas and that oil and gas development influenced the rate of nest initiation of sage grouse located more than 3 km from construction activities.

Braun *et al.* (2002) examined the effects of 200 CBNG-related compressors (noise) on active greater sage grouse leks in Campbell County, Wyoming. His findings suggested leks within 1.6 km of compressors exhibited consistently lower male attendance rates than leks located at greater distances from the compressors. His findings also suggested that active greater sage-grouse leks within 0.25 miles (0.4 km) of CBNG wells had fewer males per lek and lower annual rates of population growth when compared to less disturbed leks. To further expand on noise impacts, Holloran and Anderson (2005) reported that lek activity by sage grouse decreased downwind of CNBG drilling activities suggesting that noise had measurable negative impacts on the species. Similarly, Connelly *et al.*, (2004) reported no active sage grouse leks within 2 km of a major Wyoming interstate highway and only 9 leks were known to occur between 2 and 4 km from that highway.

Holloran (2005) evaluated potential CBNG impacts to the greater sage-grouse in the upper Green River Basin based on 5 km (3.1 mile) buffers near active lek locations. For the study, leks located within 5 km of producing CBNG wells were categorized by level of impact based on well densities. Known leks within 6.4 km of the study boundary were used for the lek count; the 6.4 km likely represents Connelly's (2000) recommended 3.2 km distance to protect critical habitat with a multiplier of two. The effects on lek activity of three principal energy-related surface disturbances --- drilling rigs, producing wells and main haul roads --- were examined.

Based on results of the study, drilling rig activity appeared to have no influence on overall male lek attendance at distances greater than 5.0 km. For producing gas wells, results suggested no influence on leks more than 3.0 km from a well and for roads, no influence was observed from main haul roads greater than 3.0 km from a lek. the number of males occupying leks within 5 km of a drilling rig declined; as did the number of males occupying leks within 3 km of a producing well and within 3 km of a road. The study also indicated a relationship between well density and male lek attendance: in terms of well density, the number of males occupying leks declined in cases when there were more than 5 wells within 3 km of the lek. The average annual change in the number of males on leks with 1-3 producing wells within 3 km did not differ significantly.

Most recently, Walker et al., (2007) used a 350-meter (m) buffer to estimate CBNG-=related surface disturbances (*e.g.:* well pads) around leks. Based in part on this calculation, a lek was defined as being within CNBG development if >40% of an area within 3.2 km was developed, or if >25% was developed and development overlapped the lek center. Furthermore, a lek was considered to be on the edge of CBNG development if 10-40% of the area within 3.2 km was developed and development did not overlap the lek center. Leks with <10% development were considered outside of CBNG development. Results of the study suggest leks within CNBG development (>40 percent developed within 3.2 km of lek) showed lower population trends than leks with minimal or no development. In addition, findings indicated leks adjacent to natural gas fields (10-40 percent developed) showed increasing population trends compared to leks further away from development, suggesting that sage grouse might be avoiding developed areas by moving into adjacent undeveloped habitat in a "donut" of higher density occupancy (Walker et al., 2007). It should be noted that the methods used to calculate disturbance were not clearly stated in the report. For instance, was the 350 m well buffer used solely to estimate disturbance, or were other land surface disturbance factors such as roads, utility corridors, compressors, etc., also used to estimate a disturbance percentage?

Research focused on the impact the oil and gas industry is having on greater sage-grouse populations indicates these effects are greater during pre-development construction activities versus post-construction operations. Some research suggests there is a degree of greater sage-grouse population recovery following initial development and subsequent surface reclamation of the affected area (Eng et al., 1979; Tate et al., 1979; Braun, 1986). To take the initial premise a step further, it can be inferred that areas with new development likely are having more of an effect on populations in comparison to established areas where new development has not taken place for some time (*e.g.*: portions of the Cedar Creek Anticline with conventional oil and gas). Although more empirical data to support this idea is needed, prior research does, to a certain extent, validate this premise. For instance, in North Park Colorado, coal mining and oil field development activities resulted in decreased greater sage-grouse lek attendance on leks within 2 km of energy related activities compared to leks located more than 2 km from these activities (Braun, 1986 and 1987; Remington and Braun, 1991). However, once development activities ceased, greater sage-grouse populations returned to their pre-disturbance levels (Braun, 1987; Remington and Braun, 1991)

4.4.4 ANALYSIS/OVERVIEW OF AVAILABLE GREATER SAGE GROUSE POPULATION DATA: AN EXAMPLE FROM THE PRB

DESCRIPTION OF STUDY AREA

For the purpose of this project, the study area is defined as regions within the Powder River Basin (PRB) consisting of oil and gas development, as well as those regions *not* consisting of oil and gas development. The PRB extends from east-central Wyoming northward into southeastern Montana. It is bound by the Black Hills Uplift to the east, the Bighorn Uplift to the west, the Miles City Arch and Cedar Creek Anticline to the north, and the Casper Laramie Arch and the Hartville Uplift to the south. Throughout the PRB there are federally owned and managed, state owned, and private (Fee) mineral estates.

COAL GEOLOGY

The PRB basin is a geologic basin of sedimentary rocks including sandstone, shale, coal, and limestone of Paleozoic through Tertiary age (ALL, 2001). These strata form the source and reservoir rocks for fossil energy reserves – crude oil, natural gas, CBNG, and coal. Of particular interest for CBNG in the PRB is the Tertiary Period, Paleocene Epoch sedimentary units, comprising the Tongue River member of the Fort Union Formation. Current CBNG production in the Wyoming and Montana portions of the PRB are focused on several coal seams present within the Wyodak Anderson Coal beds of the Tongue River Member.

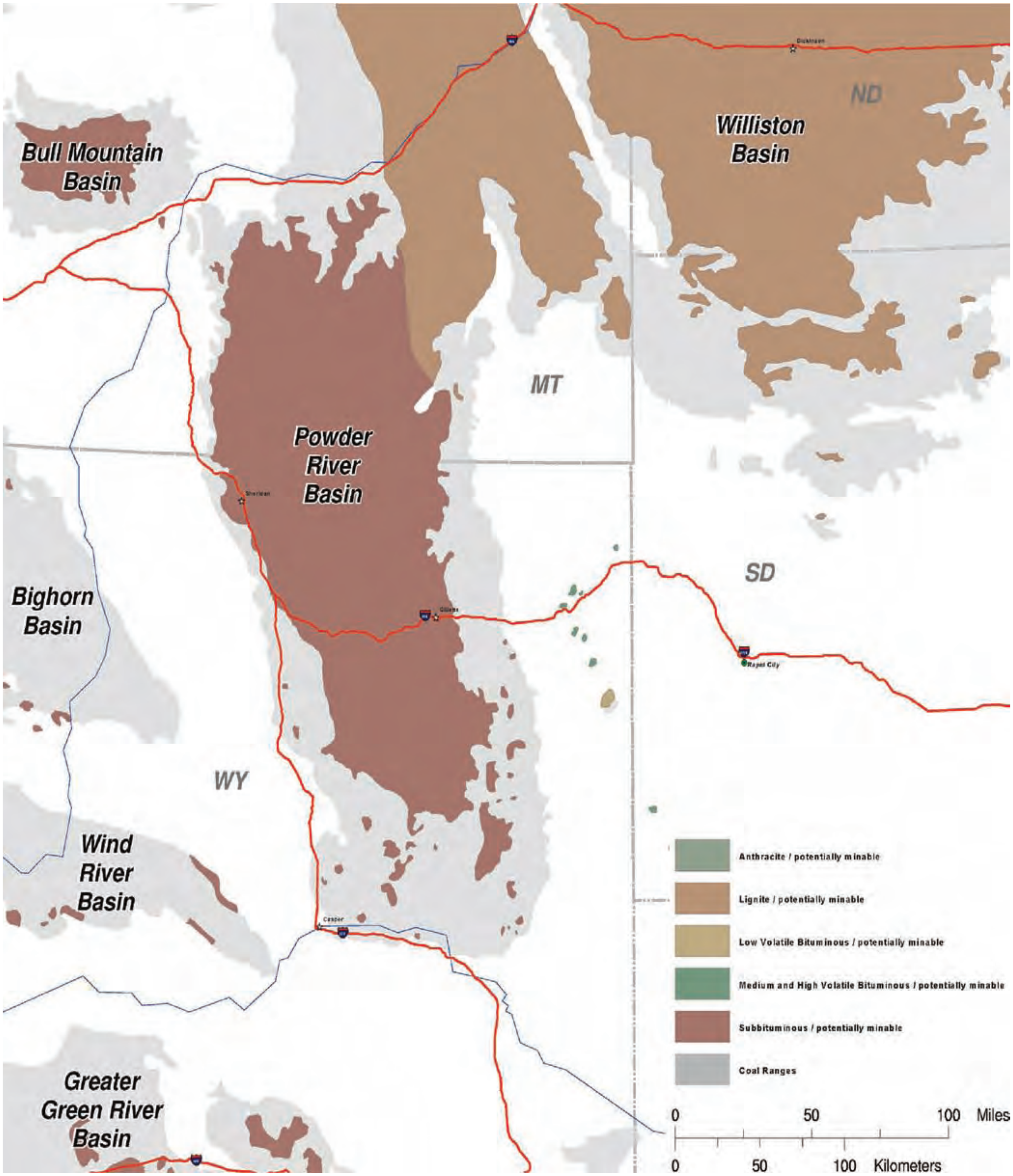
Mining of coal first began in the PRB in 1883; however, it was not until the 1970's and early 1980's that this region emerged as a major coal-producing area. More than 90% of the PRB coal production occurs from federal leases; since 1982 coal mine expansion has been managed on a lease-by-application process. Of the 20 mines in the PRB, three are in the final stages of reclamation, one has been reclaimed, and one is inactive. The reasonably foreseeable development scenario for coal mining in the PRB projects up to 710 million tons per year (mmtpy) from 2010 to 2020 compared to current production estimated at up to 525 mmtpy (ENSR, 2005)--- an increase of approximately 35% over the next decade (based on maximum estimated extraction rates).

CBNG DEVELOPMENT AND GAS RESERVES

CBNG drilling first began in the Wyoming portion of the PRB during 1987; in 1997 the CBNG well drilling rate accelerated substantially and has continued to increase (BLM, 2003). The estimated methane gas reserves to be produced from the coal beds within the PRB have been estimated to be as much as 90 TCF in the Montana portion of the PRB (ALL, 2001). The USGS has estimated the total reserves within the PRB at 30 TCF (Rice and Finn, 1995). CBNG developments on both the Montana and Wyoming sides of the basin are expected to continue to grow. Wyoming's *Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project* is projecting as many as 60,000 CBNG wells to be drilled in the next 10 to 20 years, while Montana's *Final Statewide Oil and Gas EIS and Proposed Amendment of the Powder River and Billings RMPs* (Supplemental EIS in draft) projects as many as 27,000 CBNG wells will be drilled over the same time period.

Figure 4-1: Powder River Basin Coal Bearing Area

Powder River Basin showing coal types and CBNG potential



4.4.5 DISCUSSION OF AVAILABLE DATA-MONTANA AND WYOMING DATABASES

Greater sage-grouse count data used for the analysis portion of this study were obtained from the Wyoming Game and Fish Department (WGFD) and the Montana Department of Fish, Wildlife, and Parks (MDFWP). In addition, publicly available count data from regional Wyoming and Montana BLM offices with jurisdiction in the PRB was compared to the Wyoming and Montana state data to identify data discrepancies and to augment the data to generate the most comprehensive lek count database possible for the PRB.

Data accumulated for Wyoming consisted of count data from 1948 to 2006 and included 70,023 lines. Data accumulated for Montana consisted of count data from 1954 to 2006 and included 5,365 lines of data. The initial lek count data received from WGFD contained 65,536 lines of data, the maximum number of rows permitted in an Excel™ spreadsheet. Approximately 5,000 lines of data were missing from the spreadsheet because of this limitation. Those conducting similar studies using publicly available information should be aware of this limitation; according to WGFD previous researchers had not recognized that data was missing from the data sets provided to them.

The analytical aspects of this project focused primarily on evaluating the limitations inherent to greater sage-grouse lek count data quality. Therefore, this review focuses on a simple analysis of the data quality that underlies this and all similar studies of greater sage-grouse in Montana and Wyoming.

The combined data set contains 75,388 lek count observations from 3,805 individual leks in Montana and Wyoming (see **Table 4-2** and **Table 4-3**). A series of filters were applied to the data set to reduce it to data sufficiently detailed to allow an evaluation of greater sage-grouse population trends in respect to oil and gas development history within the PRB. The data filters consisted of the following:

- *Null data such as place-holders and other entries into the raw data sets which that were not recordings of actual lek counts were removed; actual observations of zero birds observed were retained.*
- *Data pertaining to leks without sufficient location information were eliminated from the data set. Because the ultimate objective is to evaluate the influence oil and gas development might have on greater sage grouse populations over time it is necessary to be able to locate the leks specifically to identify proximity to wells. While leks with specific latitude and longitude data are preferred for this task, all leks with location information sufficient to post a location within a quarter-quarter section were retained for analysis. Holloran (2005) has suggested that leks within 5 km of oil and gas development*

Table 4-2: Sage Grouse Data Summary by Male Count Observations

Data Elimination Issue	Montana	Wyoming	Total	Cumulative Qualified Data
Raw data set	5365	70023	75388	75388
Filtered data*	-1164	-52210	-53374	22014
April 1 - May 7 data only	-560	-8431	-8991	13023
April 1 - May 7 data only, Peak Count	-818	-6698	-7516	5507
PRB Study Area only, Peak Count	-1341	-2175	-3516	1991
PRB Study Area only, Lek Complexes, Peak Count	-224	-34	-258	1733

*Notes: * = Filtered data represent the total number of data points removed for the following reasons:*
Null data including place-holders and other non-entries (legitimate zero counts and actual counts were retained)
No location information was provided in the state database for that lek
Insufficient location information (leks with location information to quarter-quarter section or better were retained)
No date, or an invalid date, was recorded for the observation
Duplicate data

Table 4-3: Sage Grouse Data Summary – by Lek

Data Elimination Issue	Montana	Wyoming	Total	Cumulative Qualified Data
Raw data set	1659	2146	3805	3805
Filtered data*	-763	-1103	-1866	1939
April 1 - May 7 data only	-80	-437	-517	1422
PRB Study Area only	-303	-505	-808	614
PRB Lek Complexes	-136	-8	-144	470

*Notes: * = Filtered data represent the total number of data points removed for the following reasons:*
Null data including place-holders and other non-entries (legitimate zero counts and actual counts were retained)
No location information was provided in the state database for that lek
Insufficient location information (leks with location information to quarter-quarter section or better were retained)
No associated observation data

may be affected by that activity. Adopting a minimum quarter-quarter section level of accuracy for lek locations is expected to provide sufficient balance between an exact location and the retention of as much of the greater sage-grouse data as possible.

These filters resulted in a reduction of 53,374 lek observations and 1,866 leks in Montana and Wyoming combined (see **Table 4-2** and **Table 4-3**). This is equal to approximately 71% of lek observations and 49% of lek data that were insufficient for further evaluation. The majority of this data loss was from the Wyoming portion of the data set which contained a great many null data lines (no data recorded in the original database's bird count or location fields) in the raw data base.

The early data entries in each state database typically are silent regarding the type of survey or count conducted. In more recent years the study of the birds has advanced such that it is now recognized that ground lek counts conducted between April 1 and May 7 provide the most meaningful data. This date range matches the BLM's guidelines for lek counts in Wyoming (BLM, 2002b) as well as the general date recommendations made by Connelly *et al.*, 2003.

Because aerial surveys often do not include detailed counting of male birds, typically they are not regarded as reliable. Montana and Wyoming databases specify the survey/count method conducted in more recent years; in earlier years it was often the case that no survey/count method was noted. However, because the reduction in useful data has been significant to this point and because of a desire to retain as much of the historical data as possible, no database filter was applied to account for survey/count methods. Therefore, aerial survey data is included. As a consequence, the data evaluated herein may be biased towards lower (incomplete) count numbers as a result of "dilution" by lower magnitude aerial counts (compared to potentially higher ground count data had it been acquired at the same time). It is anticipated that the use of peak counts for lek complexes will minimize, as much as is practicable, any adverse result.

Therefore, an additional filter limiting the retained data to that acquired during the April 1 to May 7 time frame further reduced the combined dataset by 8,991 lek observations and 517 leks (see **Table 4-2** and **Table 4-3**). This demonstrates that the vast majority of data were from the desired time frame.

To this point, results of the database filtering process indicate that of the original 75,388 lek observations in the Montana and Wyoming data bases, only 13,023, or approximately 17% of the data, are of sufficient quality to support further analysis. Likewise, of the original 3,805 leks in the Montana and Wyoming data bases, only 1,422, or approximately 37% of the data, are of sufficient quality to support further analysis. A review of this refined dataset indicates that:

- *The number of leks visited per year increased gradually from one in 1948 to 124 in 1997, but thereafter increased 7-fold to 869 in 2006 (Figure 4-3). Of the total number of leks visited in the database, 5,696 of the 7,847 total visits occurred in 1997 through 2006 (73% of the database was acquired in the last 10 years).*

Figure 4-2: Observations by Month (Montana and Wyoming)

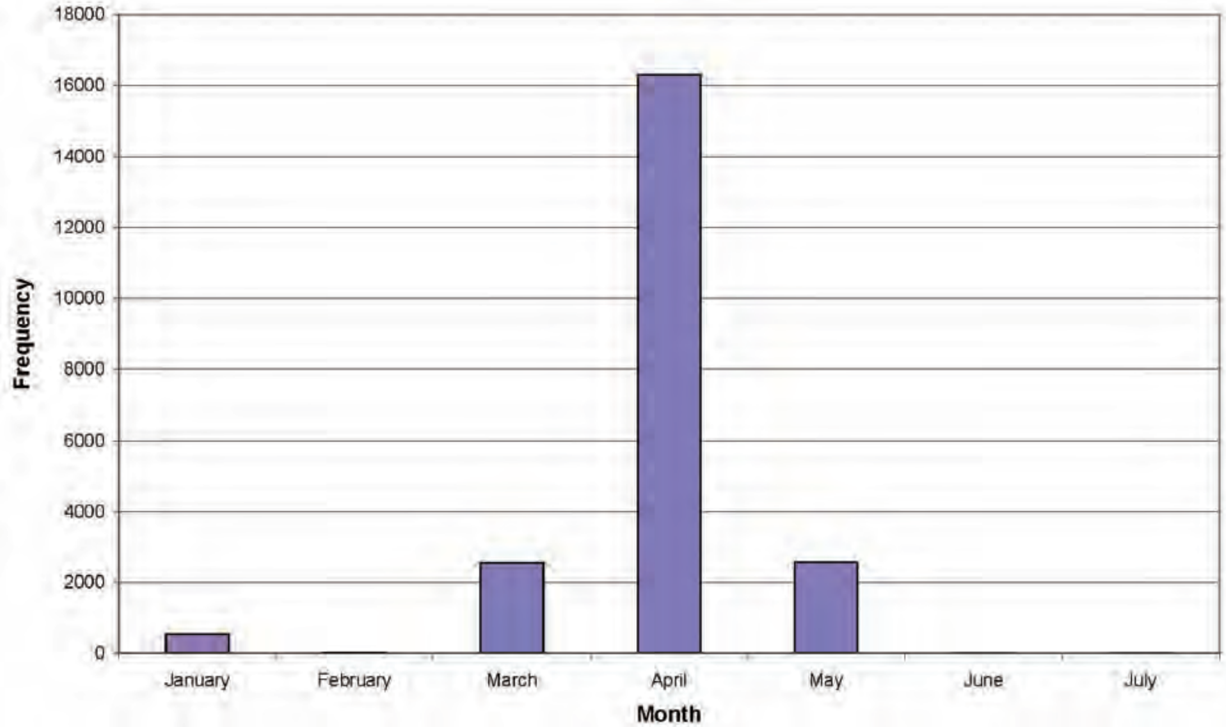


Figure 4-3: Number of Leks Visited by Year (Montana and Wyoming)

Figure 4-3: Shown: onset of WY CBNG in 1987, onset of MT CBNG in 1999

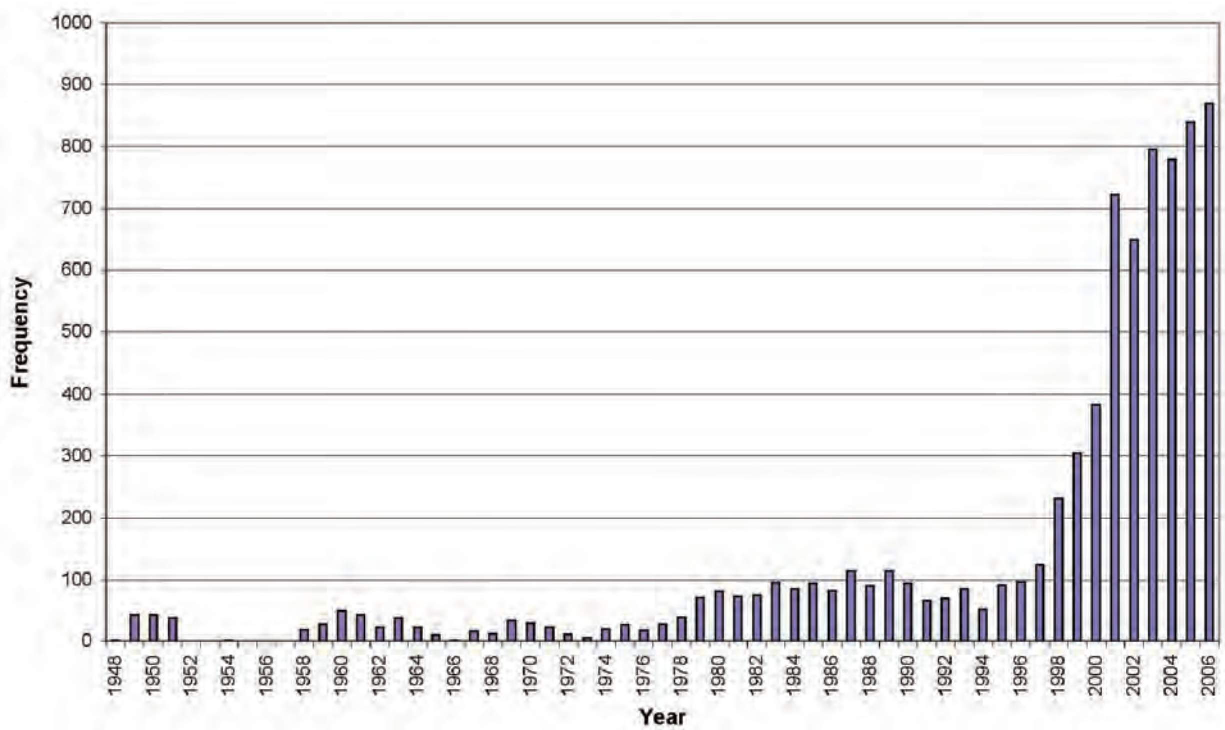


Figure 4-4: Number Of Lek Observations by Year (Montana And Wyoming)

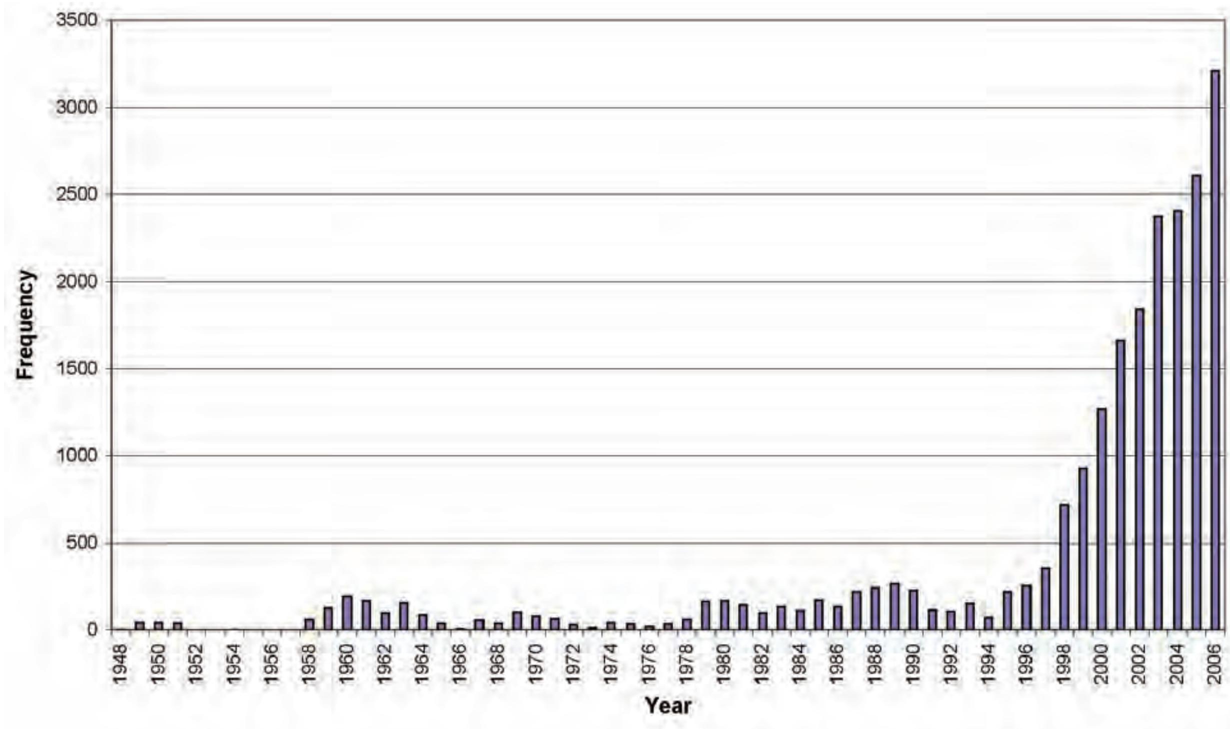
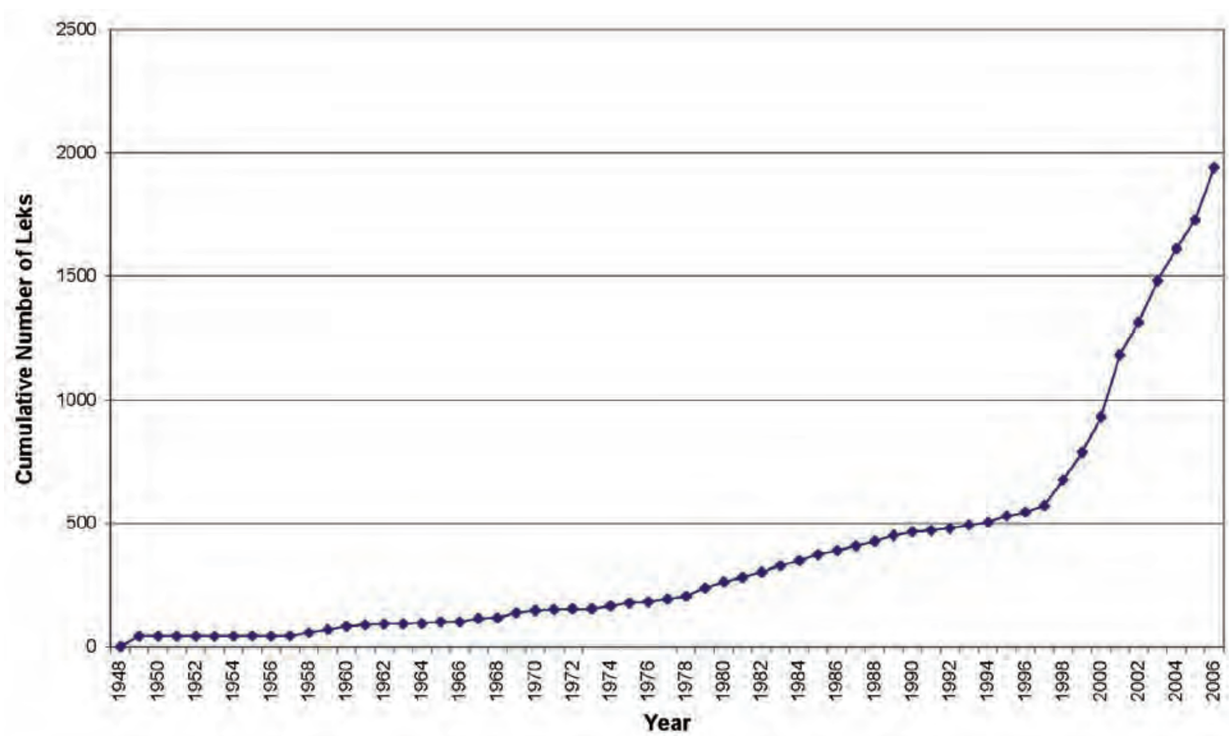


Figure 4-5: Cumulative Number Of Leks by First Discovery (Montana And Wyoming)



- *The number of lek observations conducted per year also increased gradually from one in 1948 to 357 in 1997, but similarly thereafter increased almost 10-fold to 3,212 in 2006 (Figure 4-4). Of the 22,014 total observations, 17,373 occurred from 1997 through 2006 (79% of the database was acquired in the last 10 years).*
- *A cumulative graph of the first observation (or "discovery") of each lek in the combined Montana-Wyoming database clearly shows a gradually increasing trend from one in 1948 to 571 in 1997 --- and thereafter a dramatic increase to 1,939 leks in 2006 (Figure 4-5).*

These data clearly indicate that since the uptick in CBNG drilling activity beginning in 1997 there has been an unprecedented increase in effort to gather data on the greater sage-grouse in these two states. Any interpretation of long term population trends must keep in mind the simple fact that the majority of the data, and the vast majority of the highest quality data, has been collected only recently. Insightful and reliable interpretation of population trends over the long term may be severely limited by the relative lack of historical (pre-1997) data.

Peak male counts for each lek were defined as the maximum male count from that lek for the April 1 to May 7 time period (see **Table 4-2**). The combined Montana-Wyoming data set was then reduced to the area occupied by the PRB. A total of 1,991 lek peak male observations from 614 leks within the PRB meet the criteria necessary to allow further evaluation of population trends over time and the possibility of adverse impact attributable to oil and gas industry activities (see **Table 4-2** and **Table 4-3**).

One of the interesting questions is whether there are any observable trends in lek size (number of males in attendance) over time. As noted by Connelly *et al.* (2004):

"If all the individual lek locations were considered separately, without regard to their inter-dependence with adjacent sites, the overall count of males would not be affected. However, the continuity of data between years would be dramatically influenced. For example, many more leks would be considered to have become 'vacant' even though the males merely changed locations."

Therefore, to facilitate this analysis and to account for the known tendency for greater sage-grouse to display within a diffuse area of suitable habitat rather than at a single specific location, the data set was examined for the presence of satellite leks. For the purposes of this investigation, satellite leks were defined as those leks located within 2.5 km (Connelly et al. 2004) of each other and without a significant intervening habitat structure (such as a topographic drainage feature) that might physically isolate the displaying areas in question. Maps for the qualified leks within the PRB were plotted using ArcGIS© software and each was evaluated for inclusion into lek complexes. A total of 470 lek complexes (with 1,733 associated peak male observations) were identified within the PRB study area (see **Table 4-2**). In creating the lek complexes, the following logic was employed:

- *The name and location of each lek complex is based on the location of the largest, most consistently attended, lek in the complex grouping.*
- *Associated satellite leks within a 2.5-km radius of a primary lek were summed to derive a lek complex count.*
- *A peak male count for each complex for the April 1 to May 7 time period was derived by summing the peak male counts among primary and satellite leks in the complex for that year. This count was thereafter used as the peak male count for the lek complex for that year*
- *Isolated leks with no associated satellites for complexing, regardless of count size, were treated the same as lek complexes for further evaluation.*

A review of the lek complex dataset indicates that:

- *The number of lek complexes visited per year increased gradually from one in 1954 to 54 in 1983; then dropped off to 10 in 1997, but thereafter increased more than 20-fold to 237 in 2001 (Figure 4-6).*
- *The total number of male greater sage-grouse counted summed over all lek complexes within the PRB study area per year also shows a more than 20-fold increase after 1997 (Figure 4-7).*
- *Figures 4-6 and 4-7 reiterate the dramatic increase in data acquisition effort for greater sage-grouse population information collected after 1997.*

Figure 4-6: Number of Lek Complexes Visited by Year (PRB: April 1-May 7)

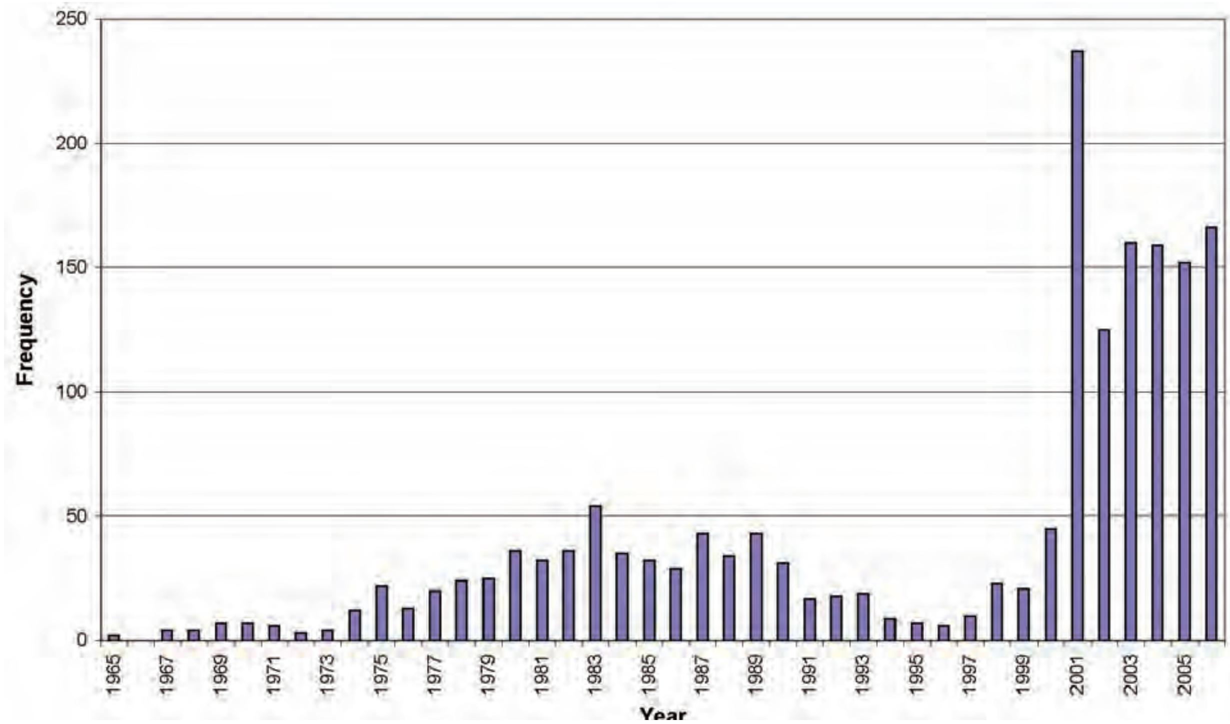
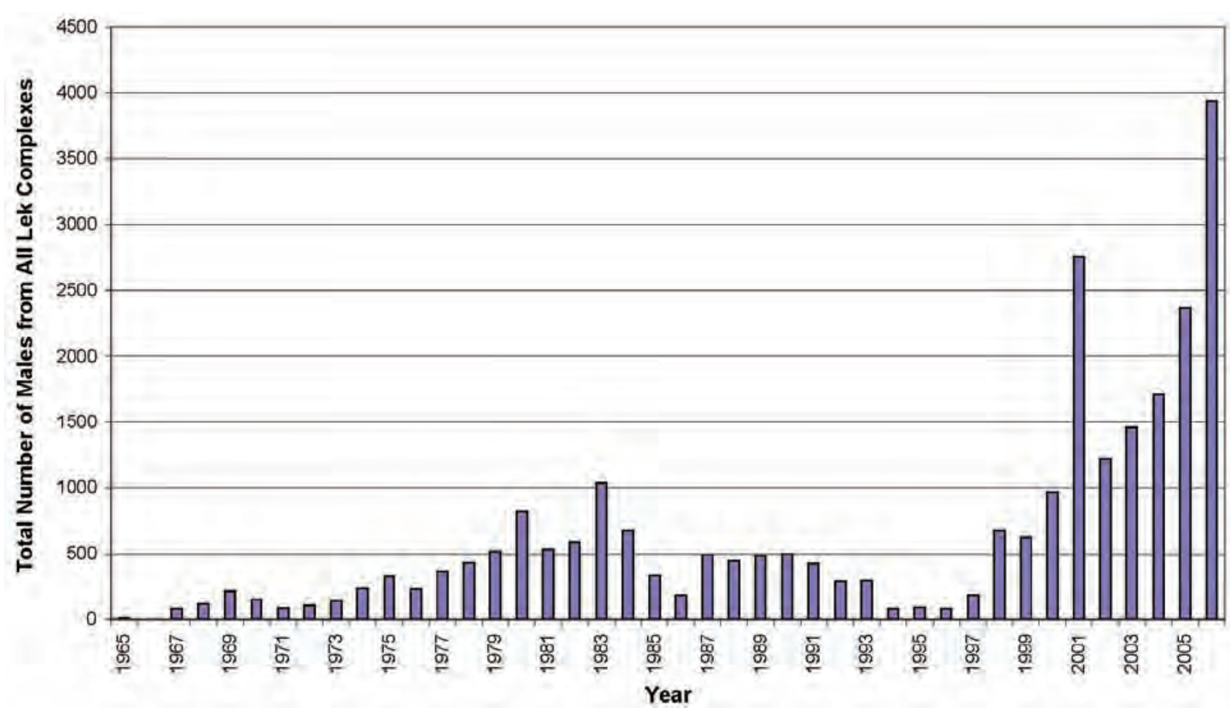


Figure 4-7: Total Number of Males Counted from All Lek Complexes by Year (PRB: April 1-May7)



- *To scale this data by lek visit over time, Figure 4-8 provides a graph of average lek complex size over time. Comparison of Figure 4-8 to Figure 4-6 indicates that during the 1960's through early 1990's, the period of generally poorer quality data, the years in which larger average lek complex sizes are observed (e.g.: 1968, 1969, 1972, 1973, and 1991) coincide with low numbers of counts (decreased data collection effort). Therefore, these apparent peaks likely are a result of only a limited number of prominent, larger, lek complexes being surveyed in those years; any fluctuations observed from the graph may be artifacts of the database rather than representative of actual fluctuations in the greater sage-grouse population.*

Again, the data indicates that interpretation of long-term greater sage-grouse population trends is limited severely by the relative lack of historical data upon which to document such trends.

A question to pose of the data is that if greater sage-grouse are being pressured by oil and gas development or other anthropogenic influences, are lek complexes being vacated at an increasing rate over time? To examine this question the following graphs were prepared:

- *The frequency of lek complexes with male counts equal to zero by year (Figure 4-9) and those with positive counts (Figure 4-10) indicate that the number of zero count lek complexes per year roughly follows the data acquisition trends noted previously. As zero count lek complexes increase, so do the number of positive count lek complexes*
- *To normalize this, and remove the influence of data acquisition trends to the degree possible, a plot was constructed of the percentage of zero count lek complexes by year (Figure 4-11). This too mimics the overall data acquisition trend of heightened level of effort in the late 1980's, lower level of effort in the early 1990's, and increased level of effort since 1997. It is interesting that the 1990 peak is roughly equivalent to the post 1997 peak. From data acquisition trends alone one might have predicted a lower peak in the 1980's. It is possible that Figure 11 suggests the presence of a trend in the relative frequency of zero count lek complexes; potentially suggesting trends in the vacation of lek complexes. Further evaluation of this data is warranted. However, the nature of the dataset suggests that demonstrating conclusive trends could be problematic.*

Figure 4-8: Average Lek Complex Size by Year (PRB: April 1-May 7)

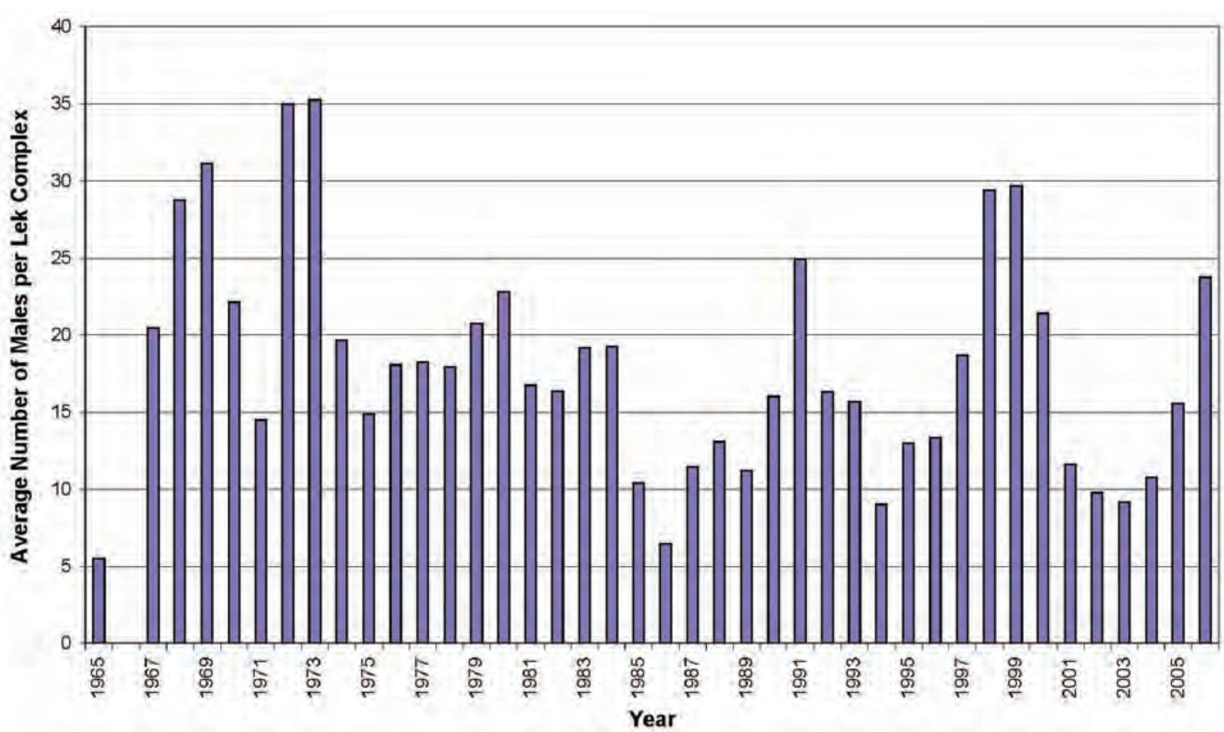


Figure 4-9: Number Of Lek Complexes With Male Count = 0 by Year (PRB: April 1-May 7)

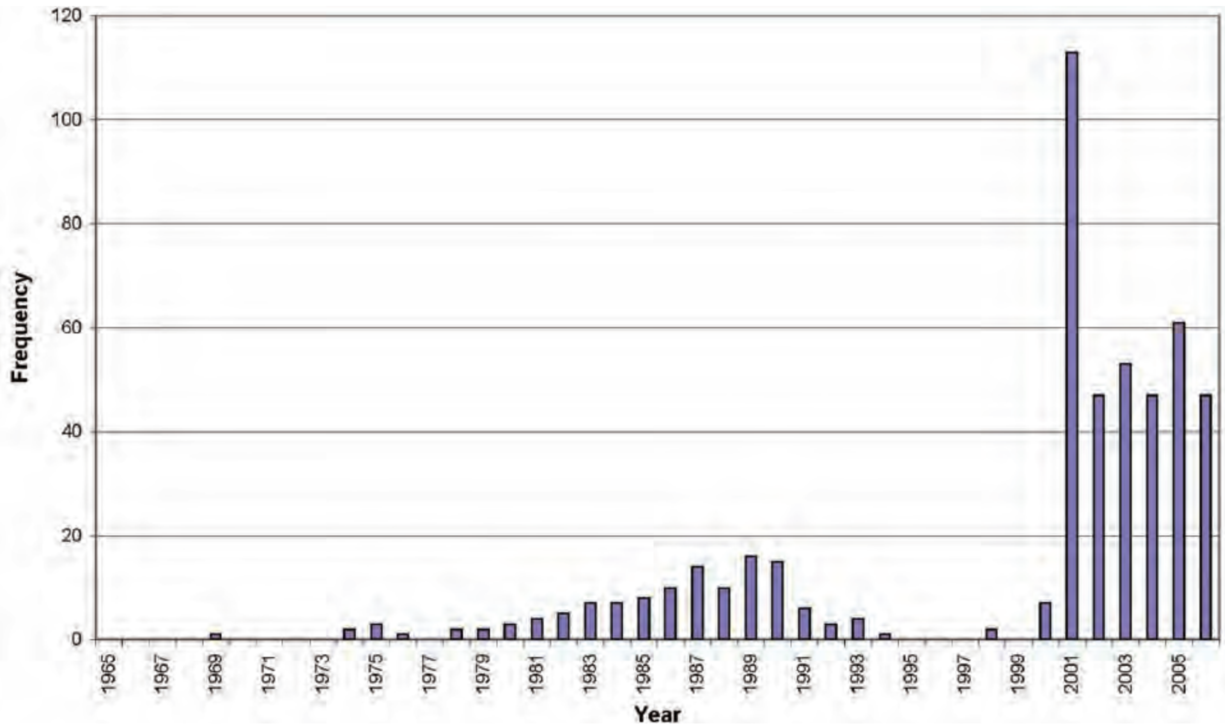
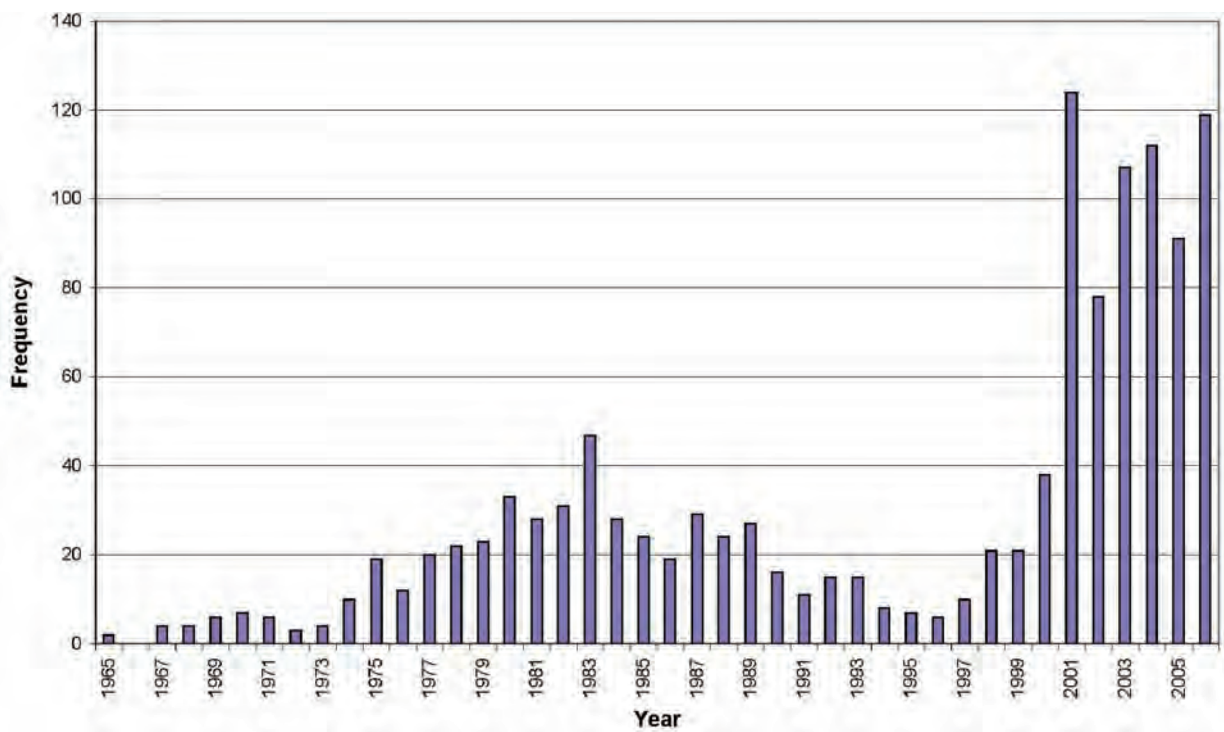


Figure 4-10: Number Of Lek Complexes With Male Counts ≥ 1 by Year (PRB: April 1-May 7)



Another interesting question to pose to the data is whether there is an increase in the number of smaller lek complexes and a concomitant decrease in the number of larger lek complexes over time. Such a trend might suggest that habitat fragmentation is leading to the fragmentation of large lek complexes. Or, if the reverse trend is observed, that pressures on the grouse are leading to consolidation of lek complexes. To examine this and following the example set by Connelly *et al.* (2004), lek complexes were first grouped into three size categories as follows:

- *Small lek complex = 1 to 19 males*
- *Medium lek complex = 20 to 49 males*
- *Large lek complex ≥ 50 males*

Figure 4-12 presents the frequency of each lek complex size category by year. Simple trends of increasing or decreasing frequency by lek size category are not readily apparent. This graph also mimics the overall data acquisition trends elaborated on previously. To normalize this, and remove the influence of data acquisition trends to the degree possible, a plot was constructed of the relative percentage of each lek complex size category by year (Figure 4-13). Note that the percentage was calculated using only the sum of positive count complexes; rather, the zero count complexes were not factored into the calculation of relative category abundance. Again, it is not clear if discernable trends in lek complex size category exist. Further evaluation of this data is warranted.

The authors have drawn the following conclusions from the analyses of the raw data and the qualified PRB database:

- Although Montana and Wyoming have accumulated a seemingly large database on greater sage-grouse over the years, the quality and usefulness of that data is severely limited.
  - *Of the original 75,388 lek observations in the Montana and Wyoming databases, only 13,023, or approximately 17% of the data, is of sufficient quality to support detailed analysis.*
  - *Of the original 3,805 leks in the Montana and Wyoming databases, only 1,422; or approximately 37% of the data, is of sufficient quality to support detailed analysis.*
  - *Of the original 13,023 qualified lek observations in the Montana and Wyoming databases, only 1,733 peak male counts are available for lek complexes located within the PRB.*

Figure 4-11: Percentage of Lek Complexes with Male Counts = 0 by Year (PRB: April 1-May 7)

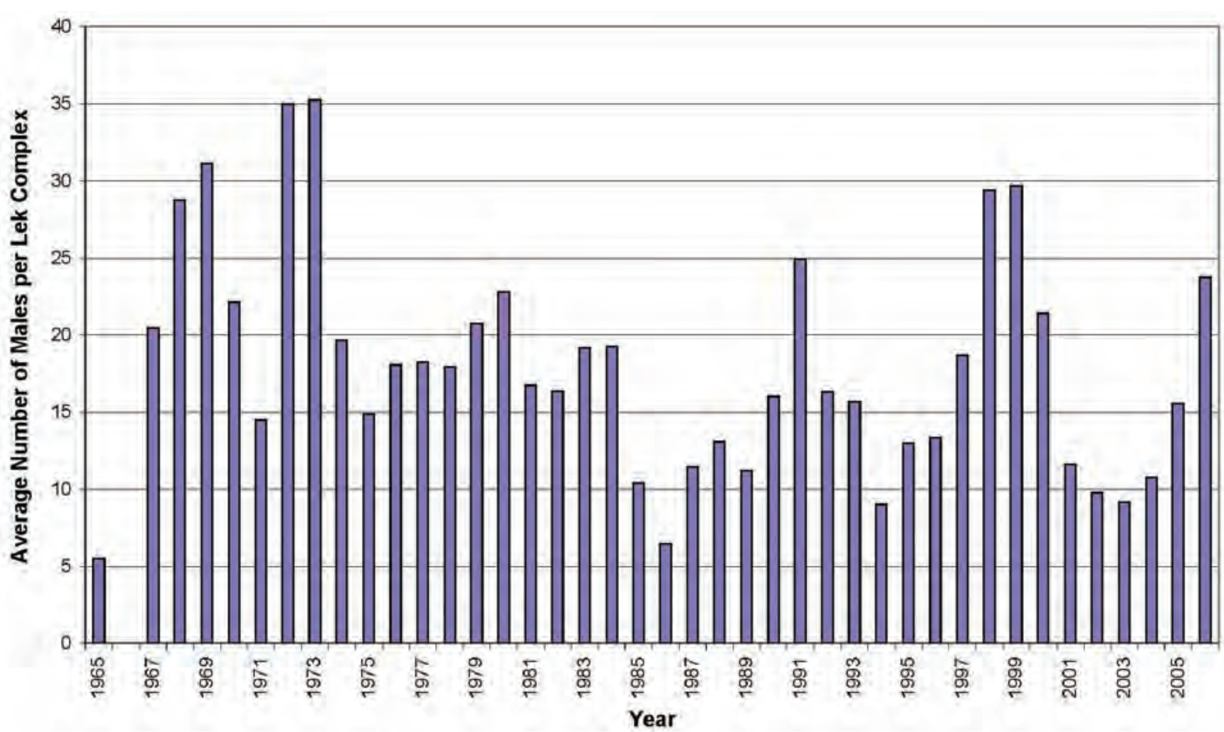


Figure 4-12: Complex Size Distribution by Year (PRB: April 1-May 7)

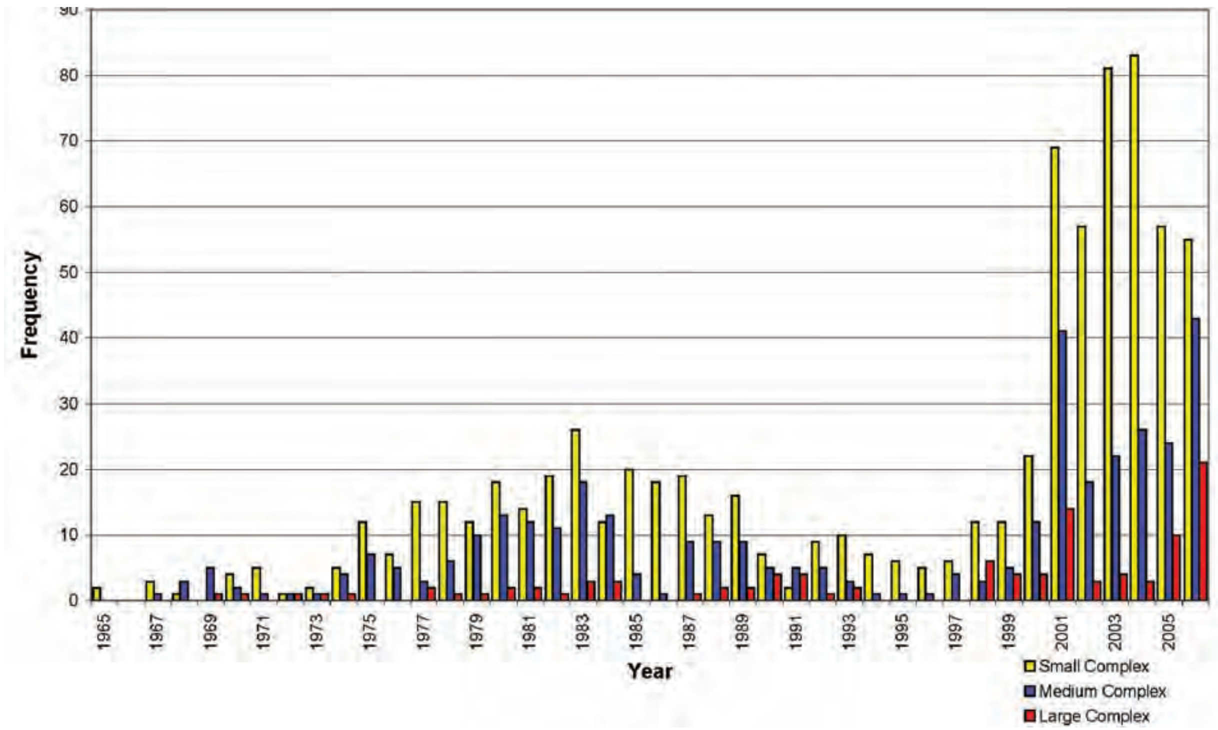
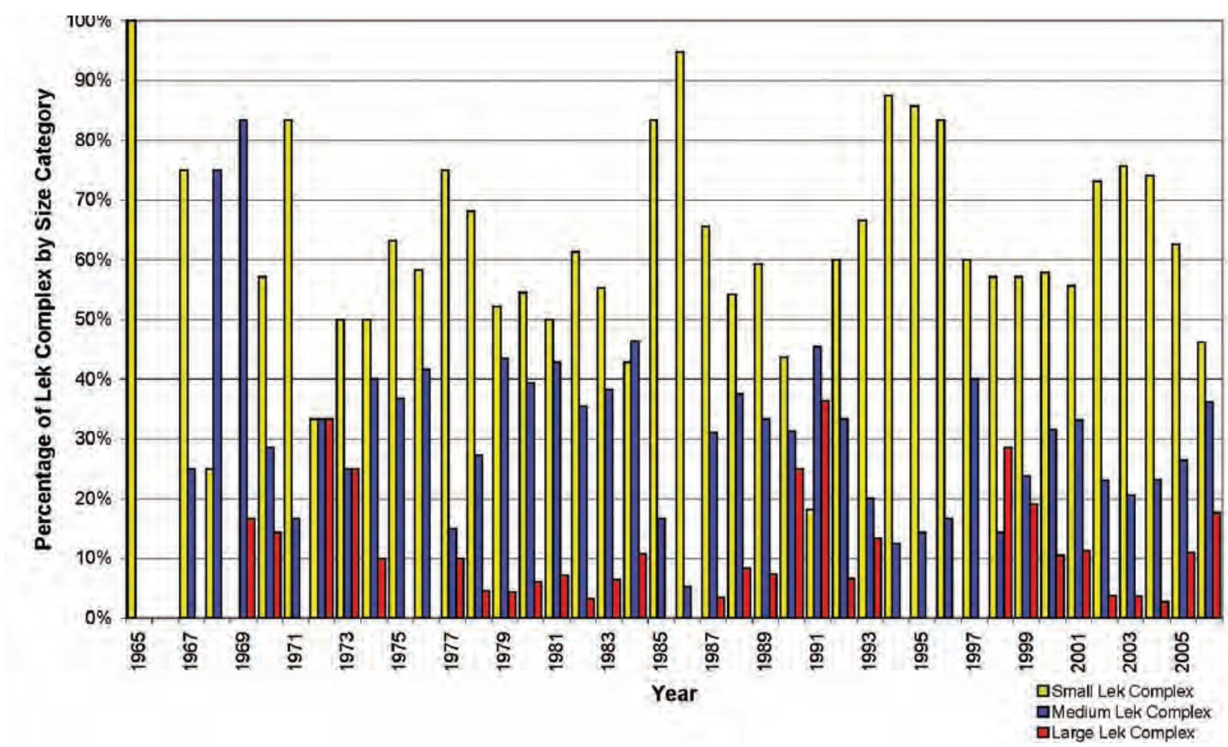


Figure 4-13: Relative Lek Complex Size Distribution by Year (PRB: April 1-May 7)



- *Of the original 1,422 qualified leks in the Montana and Wyoming databases, only 470 are for lek complexes located within the PRB.*
- *Compared to the raw datasets available from the various agencies in Montana and Wyoming, only a limited fraction of the data has qualified utility in the analysis of greater sage-grouse population trends within the two states (not surprisingly, an even smaller fraction is applicable to the PRB study area).*

• Since the uptick in CBNG drilling activity beginning in 1997 there has been an unprecedented increase in effort to gather field data on the greater sage-grouse in Montana and Wyoming and in the PRB in particular.

• Any interpretation of long-term population trends must keep in mind the simple fact that the majority of the data, and the vast majority of the highest quality data, has been collected only recently.

- *Seventy-two percent of all known leks in the two states have been "discovered" since 1997 (545 leks were first identified prior to 1997; 1,394 leks were first identified in 1997 or subsequent years).*
- *Seventy-nine percent of the qualified observation data has been gathered since 1997.*

• Insightful and reliable interpretation of population trends over the long term may be severely limited by the relative lack of historical (pre-1997) data.

• Further evaluation of the PRB database, with particular focus on the post 1997 data, is warranted.

The analytical aspects of this project focused primarily on evaluating the limitations inherent to greater sage-grouse lek count data quality. It is recommended that additional analysis of the qualified PRB database consider the following questions:

• What if any trends are seen in the overall population data?

- *Are greater sage-grouse populations increasing or decreasing over time?*
- *Do lek complex size categories indicate any trends towards fewer or greater numbers of the three size categories over time?*
- *Active and inactive definitions for lek complexes should be developed and tracked for trends over time by lek complex size category. A scheme for active-inactive definition is offered herein.*
- *Can an approach utilizing an instantaneous rate of change calculation provide more readily interpretable results?*
- *Can individual lek complexes be tracked over time in the database to examine trends towards eventual extirpation?*
- *Is there any cyclicity to the greater sage-grouse population size over time?*
- *Does any such cyclicity correspond to drought intervals or other climatological factors?*

• Is oil and gas development in the PRB having an adverse impact on greater sage-grouse populations over time?

- *The qualified lek complex database should be compared, using a geographic information systems (GIS) approach, to oil and gas activities. Information to examine includes:*

  - *Trends in oil and gas well activity within the PRB over time.*
  - *Proximity of greater sage-grouse lek complexes to active oil and gas wells.*

- *Do these data indicate any population trends potentially attributable to oil and gas development such as:*

  - *Are greater sage-grouse lek complexes at distances greater than existing stipulations from active wells adversely affected by the oil and gas activities?*
  - *Are greater sage-grouse lek complexes at distances less than existing stipulations from active wells adversely affected by the oil and gas activities?*
  - *Does analysis of the qualified PRB database support existing setback stipulations or does it suggest that alternative stipulations might be appropriate?*

• Can similar analyses be performed to examine the potential influence of other growth and industrial activities on greater sage-grouse populations in the PRB? For example:

- *Agricultural conversion of sage steppe biome.*
- *Grazing.*

- *Establishment of irrigable crops.*
- *Highway and major utility corridors.*

Clearly, the concerns surrounding greater sage-grouse management and its potential listing as a threatened and endangered species have a significant bearing on the Western United States. Not only is there a potential to significantly impact oil and gas activities in these states, but also agriculture, grazing, and sport hunting, all of which are inextricably tied to the local economies. While the latter activities may share deeper socio-cultural ties to the Western United States than does oil and gas, all of these activities must be examined if management of the greater sage-grouse is to be optimized in balance with potential uses for public lands. Effective management of the species also requires that the outcomes of these activities on non-federally managed lands be considered.

4.4.6 SOLUTIONS AND PRUDENT MANAGEMENT PRACTICES FOR HABITAT RESTORATION OR ENHANCEMENT

Decreasing range-wide population trends for the greater sage-grouse has placed considerable pressure on BLM resource managers and varying industrial stakeholders to aggressively develop protective measures and strategic management plans aimed at conserving critical resources for the bird. Loss of sagebrush habitat and/or fragmentation due to various land disturbance activities (e.g., livestock grazing, agriculture, oil and gas development) is of special concern because this grouse species is so highly dependent on it. For this reason, emerging research and resource plans are placing greater emphasis on habitat restoration as a viable conservation approach to insure the bird's success on lands altered by human actions. In addition, previous research in Montana, Wyoming, and Colorado have indicated some recovery of sage-grouse populations after initial development and subsequent reclamation of mine sites, roads, etc. (Eng *et al.*, 1979; Tate *et al.*, 1979; Colenso *et al.*, 1980; Scott and Zimmerman, 1984; Braun, 1986).

As stated earlier, Federal lands make up approximately 72 percent of the total range of the greater sage-grouse (Connelly *et al.*, 2004), BLM has responsibility for the multi-use management of much of this land. The future success of habitat restoration efforts undoubtedly will require collaboration among regulatory and non-regulatory entities, but may ultimately dependent on BLM's ability to incorporate and implement scientifically sound habitat restoration techniques and guidelines into their Land Use Plans. The Federal Land Policy and Management Act of 1976 requires that:

"...public lands must be managed in a manner that protects the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archaeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; that will provide for outdoor recreation and human occupancy and use; and that recognizes the nation's need for domestic sources of minerals, food, timber, and fiber from the public lands by encouraging collaboration and public participation throughout the planning process." (BLM, 1996)

In terms of sagebrush restoration, information contained within land use plans may include delineation of available habitat, patch size (habitat heterogeneity) and vegetative structure, patch disturbance restrictions, seeding guidelines and specific restoration research references pertinent to local landscapes, as well as regional objectives. To further protect against the loss of sagebrush habitat, BLM has instigated a three-tiered habitat restoration program referred to as the *Great Basin Restoration Initiative*. The first step in the Initiative is aimed at prioritizing specific greater sage-grouse areas for conservation and restoration by use of spatial data (Pyke and Knick, 2003). Secondly, the Initiative establishes collaboration efforts for restoration plans that do not cause unnecessary hardship to local land users, and thirdly; focuses conservation activities on specific landscapes that have been predominately unaltered to ensure these areas remain intact.

Greater sage-grouse habitat can be restored on disturbed lands by reclaiming the affected area with diverse plant communities that include native forbs, grasses, and shrubs. According to Connelly *et al.* (2004), the methods employed to restore sagebrush habitats will depend on the severity of land alteration(s) and in general, will be performed by either active or passive techniques. Passive techniques to restore habitat are viable when native plants are present on the disturbed lands in the form of plants or seeds and thus, do not require active re-vegetation (Connelly *et al.*, 2004). With this approach, habitat or ecological community structures are restored through time by allowing for the natural successional process to take place.

One emerging passive technique for restoring sagebrush habitat involves the utilization of livestock management. Although this particular management approach has been used in the past to improve rangeland conditions, not until recently has it been applied to improve habitat for greater sage-grouse (Evans, 1986, as reported in Beck and Mitchell, 2000). The general premise of this approach is to improve the structure and function of sagebrush habitat in areas with intense livestock grazing by continually adjusting grazing seasons and animal unit months (AUM) (Connelly *et al.*, 2004). (One animal unit is defined as a 1,000 lb. (450 kg) beef cow with or without a nursing calf with a daily requirement of 26 lb. (11.8 kg) of dry matter forage. Therefore, an AUM is equal to 780 lb. (355 kg) of dry matter forage (30 days x daily forage requirement). Although obvious, it is important to note that adjusting grazing seasons to benefit grouse will succeed only when pre-grazing vegetation consisted of a sagebrush-grassland mix biome. It is also important to note that this approach might yield immediate results, but that appropriate vegetative structure might take 3-5 years to form and overall community function could take 10-15 years to form (Connelly *et al.*, 2004).

Conversely, active restoration of habitat is necessary when land disturbance practices (e.g., livestock grazing, agriculture, oil and gas) have resulted in a significant loss of critical habitat or in situations when native vegetation is no longer dominant in the area but has been replaced by invasive plant species (Connelly *et al.*, 2004; Lambert, 2005). Typically, planting native vegetation or seeding the affected area with approved, region-specific big sagebrush seed mixes restores the area. The use of "seeding" in greater sage-grouse habitat restoration efforts is an important issue as it relates to proper management of the bird. It has been proven to be successful (Stiver *et al.*, 2006; Connelly *et al.*, 2004), but requires special attention and knowledge of local vegetative communities and seed characteristics for successful application. For instance, big sagebrush is composed of three primary subspecies, each adapted to different growing conditions based on precipitation levels and soil types (Natural Resources Conservation Service, 2007).

In extreme conditions when the consequences of land disturbance practices (removal of soil horizons due to significant soil erosion or herbicide treatments) or natural phenomenon (wildfires) result in significant impacts to large tracts of land, employment of passive or active restoration methods might not be feasible (Connelly *et al.*, 2004). In such situations, functional improvements to lands require rehabilitation approaches, not restoration techniques. Although active measures to restore or rehabilitate lands are similar, in general, the large-scale nature of rehabilitation projects can require more intense collaboration and financial support among involved parties compared to site-specific restoration efforts within smaller tracts of land disturbed by oil and gas development.

4.4.7 AVOIDANCE, MINIMIZATION AND MITIGATION

Avoiding impacts on the greater sage-grouse requires protecting the integrity of the grouse's seasonal ranges. Previous research has shown the average distances between leks and nests vary from 0.7 to 3.9 miles (Autenreith, 1981; Wakkinen *et al.*, 1992; Fischer, 1994; Hanf *et al.*, 1994; Lyon, 2000), and movements between seasonal ranges may exceed 45 miles (Dalke et al., 1963; Connelly *et al.*, 1988). Furthermore, greater sage-grouse have high fidelity to all seasonal ranges (Keister and Willis, 1986; Fischer *et al.*, 1993). Females return

Table 4-4: NRCS Recommended Seeding Mixes by Two Soil Types

(Represents two Natural Resources Conservation Service (NRCS) recommended seeding mixes that are common to the region, yet require distinctly varying soil types.)

Sandy Loams and Shallow Sandy Loams			**Very Shallow to Very Deep Clays and Loams**	
Native Species	PLS lb/ac		Native Species	PLS lb/ac
big sagebrush	0.10-0.50		big sagebrush	0.10-0.50
little bluestem	0.40		green needlegrass	0.90
needle-and-thread	0.95		Sideoats grama	0.60
western wheatgrass/ thickspike wheatgrass	0.40		western wheatgrass/ thickspike wheatgrass	0.40
prairie sandreed	0.40		blue grama	0.20
bluebunch wheatgrass	1.20		purple prairieclover	0.40
purple prairieclover	0.40		white prairieclover	0.40
white prairieclover	0.40		blanketflower	0.70
shell-leaf penstemon	0.40		western yarrow	0.04
western yarrow	0.04		yellow coneflower	0.10
yellow coneflower	0.10		slender wheatgrass	0.50
Total	4.79-4.19		Total	4.34-4.74

to the same area to nest each year (Fischer *et al.*, 1993) and may nest within 660 feet of their previous year's nest (Gates, 1983). However, other studies by Lyon, 2000; Fischer et al., 1993; and Berry and Eng, 1985 found average distances of 683 meters (2,240 feet), 740 meters (2,427 feet), and 552 meters (1,811 feet), respectively. Therefore, while important, seasonal protective buffers around leks, as specified under BLM's current stipulations in Montana and Wyoming, may be inadequate to avoid impacts on displaying and nesting birds. Furthermore, these stipulations may not provide sufficient protection of the breeding area or any wintering areas.

As additional research emerges for the greater sage-grouse, it can be expected that resulting data will further identify or demonstrate the effectiveness of existing management approaches being applied or that of proposed protective strategies. However, until a well rounded conservation approach based on unbiased, sound empirical data can be developed and implemented by stakeholders, currently applied mitigation measures likely offer the best solution for protecting the bird's future population numbers and critical habitat. Although choosing which measures to implement are typically dependent on site-specific conditions and lek characteristics in the region, protective measures should be focused on improving existing areas, and not simply protecting isolated or local populations (Stiver *et al.*, 2006). In addition, further development of affected lands should not be considered until these lands have been restored to allow for all-season support of local populations (Stiver *et al.*, 2006). Listed below are some of the common practices used to protect greater sage-grouse and their habitat; this list should not be considered all inclusive. Although a discussion of the individual measures is considered outside the scope of work for this report, existing literature on this subject is increasing and is available via numerous public documents.

- *Require transportation corridors and utility corridors to minimize footprint and reduce habitat fragmentation.*
- *Include the reintroduction of sagebrush in well pad and site reclamation plans to restore and improve habitat.*
- *Bury all power lines to avoid increased predation as well as mortality from impacts with power lines.*
- *Implement noxious weed eradication programs to reduce competing plants and improve habitat.*
- *Conduct outreach meetings in the CBNG production areas (SGWG) to inform private*

landowners about greater sage-grouse programs and to solicit feedback.

- *Locate aboveground power lines, where practical, at least 0.5 mile from any greater sage-grouse breeding or nesting grounds to prevent raptor predation and grouse collision with the conductors. Power poles within 0.5 mile of any greater sage-grouse breeding ground should be raptor-proofed to prevent raptors from perching on the poles.*
- *Require gauging and alarm notice by telemetry for all wells to minimize traffic to reduce indirect impacts as well as greater sage-grouse mortality from vehicle impacts.*
- *Require gates and signage restricting access to reduce indirect impacts from disturbance as well as reduce greater sage-grouse mortality from vehicle impacts. Restricted access would apply to OHV as well as recreational use.*
- *Eliminate use of impoundments or require use of construction techniques and or insecticides to control mosquito population to minimize mortality from WNV.*
- *Locate compressor stations so that noise from the stations does not exceed 49 decibels (10 dBA above background noise) at any nearby greater sage-grouse or sharp-tailed grouse display grounds.*
- *Construct power lines to minimize the potential for raptor collisions with the lines. Potential modifications include burying the lines, avoiding areas of high avian use (for example, wetlands, prairie dog towns, and grouse leks), and increasing the visibility of the individual conductors.*

4.4.8 INDUSTRY LEK SURVEY REQUIREMENTS

In recent years BLM has adopted guidelines, originally established by Connelly *et al.* (2000), that could require that greater sage-grouse surveys for oil and gas projects proposed on *public lands* be conducted within a certain annual time frame and by following specific survey protocols. As mentioned earlier, in Wyoming, conditions of approval for the conventional oil and gas APD, as they relate to the greater sage-grouse, include performance of lek surveys, set-back stipulations (if applicable), data collection, and mitigation and monitoring efforts. In Montana however, the conditions of approval for a conventional oil and gas APD differ. For instance, the performance of greater sage-grouse surveys technically are *not* required by the conventional oil and gas industry because the *Programmatic Wildlife Monitoring and Protection Plan* contained in the statewide EIS and SEIS is exclusively applicable to CBNG development.

From a legal perspective lek surveys are not required for proposed oil and gas projects located on private (Fee) or state lands or on public lands in Montana associated only with conventional oil and gas. However, because of the ongoing public concern for the greater sage-grouse and the political nature of the issue, it is recommended that surveys occur on non-public lands as well. Furthermore, because BLM can enforce stipulations on public lands, even in situations when lek surveys are not required, for planning purposes alone, it is highly recommended that surveys occur on an annual basis.

4.4.9 ANNUAL MONITORING PROGRAM

On public lands proposed for oil and gas development, annual surveys of active greater sage-grouse leks (including sharp-tailed grouse) are recommended or required to assure appropriate relations with BLM policy. These annual surveys are also intended to identify undiscovered leks that may have newly formed in a given area and/or migrated from another area. Furthermore, active leks that have become inactive also require annual monitoring. Currently in Montana (for CBNG development), the monitoring of historical (inactive) leks is required for five years before the lek can officially be classified as an inactive lek. In Wyoming, inactive lek monitoring is required for seven years before the lek can be re-classified. Once these monitoring requirements for inactive leks have been satisfied, then annual monitoring is no longer necessary.

Surveys can be conducted by air or on the ground, as deemed appropriate by the BLM. Aerial surveys are used to determine lek locations, whereas ground surveys typically are used to confirm lek locations and more accurately estimate male counts (refer to Section 4.4). Both the aerial and ground surveys should include a two-mile buffer around an area of operations to account for BLM's two-mile nesting timing stipulation. Winter use surveys also are recommended within suitable habitat within two miles of a project area to identify greater sage-grouse wintering concentration areas. Records of survey results and efforts should be maintained at field offices for the duration of development, to include restoration and enhancement related projects.

4.4.10 SURVEYING PRACTICES FOR ACTIVE DEVELOPMENT VERSUS STATIC OPERATIONS

To account for BLM's greater sage-grouse NSO and timing stipulations, it is critical that operators perform surveys on an annual basis; this certainly holds true in areas with active development and in some cases, in areas where development has slowed. Leks may move locations, migrate to other regions or newly form. Knowing where leks are and the wells they affect (based on the stipulations), will aid in the planning of new development and maintenance of existing operations.

For instance, BLM's NSO stipulation, although relatively small in size (1/4-mile), will have the greatest affect on new and active areas and more specifically, on the placement of individual wells, roads and other infrastructure. Under this stipulation, wells are not allowed within ¼-mile of any active lek or inactive lek (until monitoring guidelines have been completed). In addition, the NSO does not allow for normal operation and maintenance of existing production facilities during a certain time frame. As such, understanding during the initial phase of development the areas that need to be avoided can help with the overall design of the project or maintenance of any particular well. The two mile timing stipulation can potentially affect numerous wells when compared to the NSO but with less severity. For instance, wells, roads or other infrastructure are allowed with the two mile zone, but surface disturbance is not allowed during a certain time frame. In addition, normal operations and maintenance of individual wells are not affected by this stipulation. In this situation existing facilities will typically not be affected if proper planning is implemented.

4.5 RESEARCH NEEDS AND RECOMMENDATIONS

4.5.1 RESEARCH NEEDS

The performance of lek counts is the primary method for estimating sage grouse population size. Although, counting sage grouse on leks is likely the most reliable method currently available for determining population trends over time (Connelly *et al.*, 2004); the usefulness and accuracy of this method has been in question for some time (Beck and Braun, 1980; Walsh *et al.,* 2004). These questions suggest a need for development of alternative counting methods to improve current knowledge of sage grouse population dynamics and methods for determining population trends (Stiver *et al.*, 2006). However, available information that may facilitate development of new counting methods is inconsistent and in most cases based on short-term local studies (Stiver *et al.*, 2006). For example, conflicting data have been published on lek attendance patterns. Emmons and Braun (1984) reported the mean lek attendance was 86 percent for yearling males and 92 percent for adult males. Contrary to this, Walsh *et al.* (2004) reported that adult male sage-grouse had an average daily attendance rate of 42 percent whereas; the daily attendance rate for yearlings was 19 percent.

As inferred above, long-term studies are needed to better reflect other factors such as weather and its relationship with reproductive success, and vegetation that might affect population success,. Also needed are more studies based on manipulative field experiments that might reflect real-world scenarios more accurately. The effect habitat fragmentation is having on sage grouse also requires additional attention since the effects of the current level of habitat fragmentation on the grouse are unknown. From a geographic perspective, a better understanding of the spatial extent of suitable habitat patches that will provide seasonal requirements such as nesting, brood rearing, and wintering is needed (Montana Sage Grouse Work Group, 2005). Identifying crucial habitat (core areas) and determining if protection of these areas will sustain acceptable population levels is also needed (Wyoming Game and Fish Department, 2008).

The following bulleted items reflect some of the specific research needs for the greater sage-grouse that could aid in the further understanding population declines or potentially facilitate practices which may lead to increases in population. The list also helps to demonstrate the dynamic level of research topics that are still necessary before a full understanding of the grouse is known, including associated impacts from the oil and gas industry. The following ideas and statements were taken from Connelly *et al.*, 2004; Montana Sage Grouse Work Group, 2005; Holloran and Anderson, 2005; and Stiver *et al.*, 2006.

- *Continue monitoring the number of males on leks as an index of population trends to determine population success.*
- *Develop a monitoring strategy that will measure long-term sage grouse abundance and distribution trends.*
- *Evaluate the consequences of using pesticides and herbicides on the herbaceous understory and insect availability.*
- *Evaluate the effects of hunting on sage-grouse and what would constitute an optimal harvest rate.*
- *Focus on explaining the long-term greater sage grouse population decline.*
- *Establish and compile information on extent and availability of suitable habitat.*
- *Identify current occupancy of existing sagebrush steppe habitat.*
- *Determine behavioral, genetic, demographic and population dynamics ramifications of dispersal.*
- *Research juvenile responses to a developing gas field: What is the spatial extent of the area searched by disturbed juvenile males prior to establishing a territory on a lek? Is territorial establishment timing of juvenile males influenced by displacement?*
- *Investigate the effects on vital rates (e.g., survival, nesting initiation and success probabilities, and chick productivity rates) of the juvenile females displaced from their natal lek, nesting, or brooding areas.*
- *Assess sage grouse mortality rates, factors that influence them, and effectiveness of actions taken to reduce them.*
- *Study the benefits that may occur to the greater sage-grouse when oil and gas is developed in phases.*
- *Evaluate other potential influences on decreasing male counts at lek complexes within areas affected by non-oil and gas disturbance factors such as agriculture, livestock grazing, climate, predator population levels, etc.*

4.5.2 RECOMMENDATIONS

4.5.2.1 POPULATION DATA ANALYSIS METHODOLOGIES WITH FOCUS ON THE OIL AND GAS INDUSTRY

Recent methods to evaluate population trends utilize modern data (post-2000) to assess population levels and then use statistical treatment to extrapolate information necessary to estimate historical trends. Review of greater sage-grouse data for Wyoming and Montana (refer to Section 4.5) further supports and justifies this method because prior to the year 1997, useable or viable data, in general, is largely not available to accurately assess historical population trends.

Incorporation of "pockets" of useable historical data into a trend analysis may provide for a more comprehensive assessment of the data. To better define the historical fluctuating population levels of the greater sage-grouse (based on available data) and perhaps, to provide a more accurate baseline trend that might further explain the birds' current population levels, database rules and population estimate methods are recommended as part of this report to allow for analysis of both historic and current data. The following paragraphs describe additional analytical steps recommended following completion of lek "complexing", as described in Section 4.5 above. These methods are not necessarily new and in some cases represent a combination of techniques utilized in recent studies by other researchers. Performance of these methods was not conducted as part of this report and therefore the validity and success of these methods is yet to be determined. The analytical aspects of this project focused primarily on evaluating the limitations inherent to greater sage-grouse lek count data quality.

4.5.3 THE DATABASE DEFINITION OF AN ACTIVE OR INACTIVE LEK

Upon completion of lek "complexing", as described in Section 4.5, the next step would be to define the active or inactive status of leks within the database by using a combination of filtering rules originally established by Connelly (2000) and Walker *et al.* (2007). The primary objective of defining the active status of leks early on during the analysis process is to track the status of any given lek on an annual basis over time. Such information is important because it might better reflect normal cyclical patterns (historical) to population levels or perhaps detail for instance, the timing of specific surface disturbances (*e.g.*, agriculture, livestock grazing, oil and gas, etc.) or other affects (*e.g.*, precipitation, land treatment, hunting) and the corresponding or associated changes to population trends.

As stated earlier, the definition of an active or inactive lek was defined by using criteria established by both Connelly (2000) and Walker *et al.* (2007). Connelly's (2000) definition uses a relatively simple approach in which a lek is considered active if the lek was visited by three or more male greater sage-grouse during at least one survey event in three or more of the previous 5 years. For the purpose of this study, this definition was problematic given the abundance of relatively new survey data on leks that have been discovered only in the last several years or in cases where 5 years of data is not yet available. It also is problematic in dealing with historical first observations of leks that, for one reason or another, may have declined to fewer than three males rapidly enough to fail the 3 out of 5 year screening criteria.

Walker *et al.* (2007) essentially considers a single strutting male equivalent to an active lek, whereas an inactive lek is defined as a lek when no strutting males are observed in one year (after at least three lek surveys during that year), or if no strutting males are observed at the lek for three consecutive years. A possible drawback to such an approach is that a strutting site truly occupied by a single male grouse for the breeding season does not satisfy the concept that leks are locations where males compete for breeding opportunities with females. Even in cases where this may occur and result in successful breeding, it could be a situation that does not fully and positively contribute to the proliferation of a diverse gene pool among the local greater sage-grouse population. Also, because the observation of male grouse strutting on a lek potentially is dependent on a variety of field variables (time of year, time of day, etc., etc. that a lek is visited for a count observation), the simple presence of an individual male strutting is too problematic to assess and classify lek status.

For the purpose of classifying lek status (and subsequently analyzing historical and current trends of the sage-grouse), this study has developed and is recommending the following database guidelines.

A *location* should be considered an active lek if it is attended by three or more male grouse during at least one count or survey event in a given year (see **Table 4-5**, Example 1). However, if fewer than three males (but greater than zero) are observed in a given year then the following database filters should be applied to define a lek's status:

1. *If this occurs within the span of 5 years (either preceding or succeeding and inclusive of the year in question) and 3 of those 5 years have male counts of three or more male grouse, then the year(s) with fewer than three males within that 5-year time span are also defined as active (see* ***Table 4-5****, Example 2 (top).*

2. *If this occurs in the year immediately preceding, or succeeding, a year defined as active by virtue of a 5-year time span (defined as active in #1 above), then that additional contiguous year is also considered active (see **Table 4-5**, Example 2 (bottom)).*

3. *If fewer than three male grouse are observed in a given year but there is no supporting 5-year grouping to help define the year in question as an active year, then it is considered to be inactive (see **Table 4-5**, Example 3).*

4. *Leks discovered in 2004 or after are not subject to the above logic because they lack 5 years of survey data. Instead, for those leks attended by three or more male grouse in at least one year (2004, 2005, or 2006) then the lek is considered active in that year and any other of those years with a male count greater than zero (see **Table 4-5**, Example 4).*

5. *A count of 0 males is always defined as inactive unless it occurs within (inside, not as outliers) a 5-year grouping of active years, in which case it can be defined as active (see **Table 4-5**, Example 2-bottom).*

The general premise of screening data in this manner is to help minimize the apparent lack of data or low male counts that might result from field counts taken at inappropriate times, etc. It also will ensure identification of active leks whenever the preponderance of data support an active status, but a given field count indicates inactive status. At the same time, it seeks to avoid over-emphasis of zero count data during years following active counts but without resumption in male count.

Table 4-5: Illustration of Applying Database Rules to a Theoretical Lek

"A" implies an active definition • "I" implies an inactive definition.

Lek/Year		Example 1		Example 2		Example 3		Example 4	
Lek #	Year	# Males	Status	# Males	Status	# Males	Status	# Males	Status
53SW	1989	0	I	14	A	0	I	0	I
53SW	1990	3	A	8	A	2	I	0	I
53SW	1991	0	I	3	A	0	I	0	I
53SW	1992	0	I	2	A	0	I	0	I
53SW	1993	0	I	4	A	0	I	0	I
53SW	1994	3	A	2	A	3	A	0	I
53SW	1995	4	A	0	I	4	A	0	I
53SW	1996	0	I	0	I	0	I	0	I
53SW	1997	0	I	0	I	0	I	0	I
53SW	1998	0	I	0	I	0	I	0	I
53SW	1999	0	I	6	A	0	I	0	I
53SW	2000	1	I	4	A	0	I	0	I
53SW	2001	1	I	2	A	0	I	0	I
53SW	2002	0	I	0	A	0	I	0	I
53SW	2003	0	I	3	A	0	I	0	I
53SW	2004	0	I	3	A	0	I	2	A
53SW	2005	0	I	1	A	0	I	1	A
53SW	2006	0	I	0	I	0	I	3	A

4.5.4 CHANGES IN MALE COUNT PER LEK COMPLEX BY YEAR INTERVAL

By following criteria and methods utilized by Connelly *et al.* (2004), mean and median lek complex size by year can be calculated for 5-year intervals starting in 1993. Although not critical to the trend analysis, this task allows one to compensate in cases when incomplete or inadequate sampling or geographic shift of a lek result in a lek's status being incorrectly recorded for any given observation or year. Some data preparation and organizational tasks to complete this effort could include:

- Segregate the lek complex data into the 5-year intervals: 1960-64, 1965-69, 1970-74, 1975-79, 1980-84, 1985-89, 1990-94, 1995-99, 2000-04.
- Estimate missing data (not a count =0) for a given lek complex by:
    - *averaging the year before and the year after the missing year.*
    - *averaging the two preceding years in the case of a missing value at the end of a time period.*
    - *averaging the two succeeding years in the case of a missing value at the start of a time period.*
- Calculate number of lek complexes counted (average number of leks counted per year within each year interval) and tabulate results.
    - *number of active lek complexes counted.*
    - *percentage of active lek complexes.*
- Calculate mean/median
    - *calculate the mean lek complex size for each year interval and tabulate results.*
    - *perform linear regression to evaluate changes in mean lek complex size over time; significant if P≤0.05.*

4.5.5 CHANGES IN LEK COMPLEX CLASS SIZE BY YEAR INTERVAL

By following criteria by Connelly *et al.* (2004), population change by lek complex size class by year can be calculated. As with the task above, this step is not critical to the trend analysis. Leks can be organized into any size class, but the standard established by others is: small (1-19 males), medium (20-49 males), and large (>49 males). From this, temporal changes in size class categories can be evaluated quantitatively by graphing trends. Some data preparation and organizational tasks to complete this effort could include:

- Tabulate:
    - *number of small lek complexes in each year interval.*
    - *number of medium lek complexes in each year interval.*
    - *number of large lek complexes in each year interval.*
    - *for each year interval, which lek complex size category is predominant.*

4.5.6 CHANGES IN LEK COMPLEX POPULATION RATE-OF-CHANGE INDEX BY YEAR

Population trends can be examined by calculating the instantaneous rate of change for leks with *continuous* data; Connelly *et al.* (2004) and Walker et al (2007) used a two-year instantaneous rate-of-change calculation. The significance of this approach is that it reduces the potential influence of sampling variables, as discussed in this report, but it is limited by the need for continuous data. As such, current evaluations of this index have been limited to recent data. By following the recommended rules outlined in this section, it is believed an instantaneous rate of change can be evaluated for certain historical components (time frames) of the database as well.

The instantaneous rate-of-change index is tabulated by following the below formula and using the total number of males summed over the lek complexes in the "current year" (Y_n) and the total number of males summed over the lek complexes in the "previous year" (Y_{n-1}) only for lek complexes with counts in both years. For example, if the same 10 lek complexes were counted in 2006 and 2005, the total male count for each lek complex grouping would be used for the respective years in the calculation. Leks with a zero observation in one of the two years are not be used in the calculation.

- Calculation:
  - *IRCI = Ln (Yn / Yn-1), where: n=the current year and Y = the count for that year (the instantaneous rate of change is a unitless index that represents relative rate)*

The result is then plotted as a percentage of the 2006 year population. The 2006 year data should be taken as the baseline for comparison because it is the most recent annual data set within the database.

4.5.7 EVALUATION OF OIL AND GAS WELL DEVELOPMENT HISTORY

When evaluating the effect(s) the oil and gas industry is having on the greater sage-grouse (historical or current) it is obvious that current and updated well files be used to ascertain accurate well density information. This will allow for the best available assessment of grouse behavior relative to oil and gas development. When assessing a well database, it is recommended that abandoned dry holes and plugged and abandoned producers be accounted for so that these non-active locations do not contribute to the disturbance definition (see below) for dates subsequent to their abandonment. It is also necessary to note an important assumption related to well development that might need to be made. That is, reclamation procedures will return disturbed locations to original condition and in older areas, when formal reclamation practices were not required or recommended, that some degree of natural reclamation would occur over time. Furthermore, and perhaps more importantly, lack of activity in an area would not preclude grouse from using nearby suitable habitats.

4.5.8 DEFINING DISTURBED AND NON-DISTURBED AREAS TO EVALUATE THE EFFECTS ON LEKS

As summarized in this document, it has been recommended by Connelly *et al.* (2000) and supported by Holloran (2005) that producing oil and gas wells be separated from active greater sage-grouse leks by at least 3.2 km (2 miles). Based on Holloran's study (2005), leks ≥ 5 km from an *active drilling* rig were not disturbed at a level significantly different than those from the control leks (leks with less than five wells within 5 km). However, leks closer than 3.1 km from *active drilling* were disturbed at a greater rate than were the control leks. Leks ≥ 3.1 km from a producing well were not disturbed at a level significantly different than those from the control leks. However, leks closer than 3 km from production were disturbed at a greater rate than were the control leks. Following these results, it is believed a lek located ≤ 3.2 km (2 mi) from a *producing* well be classified as occupying a disturbed area. Conversely, a lek location > 3.2 km to the nearest *producing* well should be classified as occupying an area of no disturbance and subsequently, should represent the control.

Within areas defined as disturbed (relative to lek locations), it is recommended that well densities also be evaluated, as conducted by Holloran (2005) to measure the severity of disturbance. The tiered disturbance categories represented below reflect one possible way to organize disturbance severity based on the individual year counts for leks:

- *Control lek-defined as those leks ≥ 3.2 km from the nearest producing oil or gas well*
- *Area of minor disturbance (Holloran, 2005) < 5 wells within 3.2 km*
- *Area of moderate disturbance (Holloran, 2005) 5-15 wells within 3.2 km*
- *Area of major disturbance (Holloran, 2005) >15 wells within 3.2 km*

Upon tabulating the frequency of leks per disturbance category, numerous statistical treatments can be utilized to further examine data trends and impacts.

4.5.9 DATABASE TRANSPARENCY

Currently lek databases for Wyoming and Montana are administered by the Wyoming Game and Fish Department and the Montana Department of Fish, Wildlife, and Parks, respectively. Although not necessarily the fault of the agencies, all data present in the databases likely was not made available for this study. For one reason, because of the current controversy surrounding greater sage-grouse, it appeared from the investigations undertaken for this study that some private land owners are hesitant to publicly divulge lek locations on their property for fear of potential ramifications and as such, may have made requests to these agencies to keep such data private. Another reason likely relates to the transfer of data among agencies, as well as other stakeholders involved with lek surveys. Other reasons may also exist, but at this time to identify reasons would be purely speculative in nature and more importantly, unproductive.

Although it is unclear how much data (and from where) was not made available for this study and why, or if this data would have significantly affected this study or others, the point of this discussion is not to discredit, but to further highlight the importance of cooperation and data sharing among agencies (state and federal) and between agency and private landowners/stakeholders. At the present time, assembling the various lek data for study such as this is inefficient; not knowing what data is being withheld, if any, further complicates the issue.

Significant time and energy was needed as part of this study to acquire a database of greater sage-grouse leks for the states of Montana and Wyoming. It is estimated that approximately six weeks of time communicating with database managers to obtain complete databases and to make them compatible was used for this report.

To facilitate information sharing, it is recommended that a clearinghouse be constructed that includes a common database, built using standard protocols, and when feasible, is accessible to all. Management of the database should include a stringent quality control program to limit input errors and misinterpretation of survey data. Cooperation agreements also should be made with private landowners or other private stakeholders to educate and alleviate certain concerns. Lastly, federal and state sponsored greater sage-grouse programs responsible for acquiring survey data (or performing surveys) should be administered in unison to ease the burden of data transfer and subsequently, to limit database discrepancies.

4.6 CONCLUSIONS AND RECOMMENDATIONS

4.6.1 CONCLUSIONS

The following conclusions from the analyses of the raw data and the qualified PRB database are offered:

- Although Montana and Wyoming have accumulated a seemingly large database on greater sage-grouse over the years, the quality and usefulness of that data is severely limited. Compared to the raw datasets available from the various agencies in Montana and Wyoming, only a limited fraction of the data has qualified utility in the analysis of greater sage-grouse population trends.
- 1997 represents a watershed event in both the development of CBNG resources in Montana and Wyoming as well as in the acquisition of comprehensive greater sage-grouse population field data. Since then there has been an unprecedented increase in efforts to gather field data on the greater sage-grouse in Montana and Wyoming and in the PRB in particular.
- Any interpretation of long-term population trends must keep in mind the simple fact that the majority of the data, and the vast majority of the highest quality data, has been collected only recently.
    - *Seventy-two percent of all known leks in the two states have been "discovered" since 1997.*
    - *Seventy-nine percent of the qualified observation data has been gathered since 1997.*
- Insightful and reliable interpretation of population trends over the long term may be severely limited by the relative paucity of historical (pre-1997) data.
- Further evaluation of the qualified PRB database, with particular focus on the post-1997 data, is warranted.

Clearly, the concerns surrounding greater sage-grouse management and its potential listing as a threatened and endangered species have a significant bearing on the Western United States. Not only is there a potential to significantly impact oil and gas activities in these states, but also agriculture, grazing, and sport hunting, all of which are inextricably tied to the local economies. While the latter activities may share deeper socio-cultural ties to the Western United States than does oil and gas, all of these activities must be examined if management of the greater sage-grouse is to be optimized in balance with potential uses for public lands.

Furthermore, the effective management of the species requires that the outcomes of these activities on non-federally managed lands must be considered. Just as no one sector of industry should be held accountable while others enjoy the benefits of amnesty, it should not be expected that management of the greater sage-grouse on only a portion of its geographic range will be solely successful in its preservation. The expansion of management efforts to state, private (fee), and Tribal lands should be given similar consideration. It is anticipated that such a regional landscape approach to wildlife management will prove most successful. The appropriate management of greater sage-grouse in the PRB, in fact over its entire range, is a difficult and contentious issue that requires mutual stakeholder-based cooperation if a practical solution with a realistic probability of success is to be achieved.

4.6.2 RECOMMENDATIONS

Currently, lek surveys are not required for proposed oil and gas projects located on private (Fee) or state administered lands or as stated above, on public lands in Montana associated only with conventional oil and gas. However, because of the ongoing public concern for the greater sage-grouse and political nature of the issue, it is recommended that surveys occur on non-public lands as well. Furthermore, because BLM can enforce stipulations on federally managed public lands only, even in situations when lek surveys are not required, for planning purposes alone, it is highly recommended surveys occur on an annual basis.

To facilitate information sharing, it is recommended that a clearinghouse be established that includes a common database, built using standard protocols that will be accessible to all interested researchers. Management of the database should include a stringent quality control program to limit input errors that could result in future misinterpretation of survey data. Cooperation agreements also should be made with private landowners or other private stakeholders to educate and alleviate certain concerns such as potential land use or timing restrictions. Lastly, federal and state sponsored greater sage-grouse programs responsible for acquiring survey data (or performing surveys) should be administered in unison to ease the burden of data transfer and, subsequently, limit database discrepancies.

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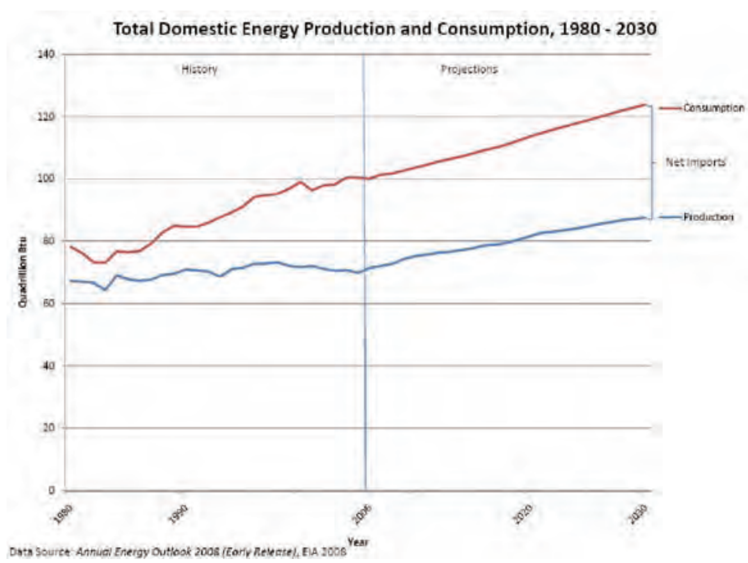
SECTION 5
Air Quality Issues

5.1 AIR QUALITY ISSUES AND OIL AND GAS DEVELOPMENT

Air pollution is a problem for all of us. As early as 1948, smog related deaths were diagnosed in Donora, Pennsylvania, and four years later the London smog disaster occurred. According to the Natural Resources Defense Council, nearly 64,000 people in the United States might die prematurely each year from cardiopulmonary causes linked to air pollution (NRDC, 2007). In an early effort to address this problem, the United States Congress passed the Clean Air Act (CAA). Numerous state and local governments have enacted legislation either implementing the federal programs or passing regulations that were equal to or more restrictive than the federal mandates. Although state and federal environmental agencies traditionally have focused their attention on industry sectors that have emitted greater amounts of air pollution, the continued demand for energy has contributed to a greater amount of regulatory attention on air emissions from domestic oil and gas exploration and production activities.

The oil and gas industry plays an important role in meeting the energy needs of the United States. Petroleum and natural gas supply 65 percent of the energy consumed in the United States, and domestic producers supply approximately 40 percent of the petroleum and 90 percent of the natural gas (EPA Sector Notebook, 2000). Research indicates that current production levels of natural gas and crude oil supplies are unable to keep up with the growing domestic demand. Of the current United States natural gas supply, it has been estimated that as much as 50 percent is provided by wells drilled within the last five years (NMBGMR, 2008). The disparity between natural gas production and consumption in the United States is continuing to grow *(see insert, Source: Energy Information Administration, 2005)*. Oil and gas production is known to contribute to air pollution. As America searches for alternative fuels and pushes fossil fuel producers for new methods to extract more energy, associated air quality issues can be expected to grow as well.



Air quality issues are attracting increasing attention from government agencies, oil and gas companies, and the public. As pressure on domestic operators to meet our growing energy demand is increasing, the number of air quality rules potentially affecting that growth is also expanding. Air quality issues such as ozone, non-attainment areas, and global warming are increasingly in the news. Therefore, a better understanding of these air quality concerns is necessary along with the development of reasonable and prudent practices to prevent, minimize, or mitigate these concerns. Ideally, the best operational scenario would be one that can maximize energy production without unnecessarily compromising the environment.

This handbook is not intended to represent a prioritization of the air quality concerns to the oil and gas industry, or to suggest that the issues discussed herein are the only air quality issues of concern. The air quality topics addressed in the following sub-sections represent important environmental concerns to the domestic exploration and production industry that are the subject of increasing attention from regulatory agencies and a concerned public. The handbook discusses air quality in general; the relationship of the oil and gas exploration and production industry to air quality issues; how certain air issues could represent a barrier to future energy development; reasonable and prudent practices that can be implemented by the industry to avoid, minimize, or mitigate air impacts; and opportunities for future research that will assist in developing our nation's energy resources while remaining environmentally responsible. The document should be of interest to the oil and gas industry and regulators, as well as those members of the public wishing to gain a better understanding of how air quality issues can present challenges to energy development, what measures may be taken to address these concerns and, hence, facilitate energy development.

This section of the handbook is laid out in the following manner:

- *Primer discussing air pollution issues and regulatory programs as they relate to oil and gas development.*
- *Air pollution challenges to oil and gas development.*
- *Solutions and prudent management practices intended to overcome these challenges.*
- *Foreseeable future air developments that could impact exploration and production activities.*

The primer subsection presents a brief overview of air quality terms, regulatory topics, and issues, and how they are important to onshore domestic oil and gas development. It is not intended as an in-depth tutorial of air quality; rather it provides a brief review of selected air quality topics to increase one's understanding of this document.

The air pollution challenges subsection focuses on some of the issues perceived as barriers limiting domestic oil and gas development. The issues presented are considered to be common issues, and are not meant to be construed as the only relevant issues that could impede expansion of energy resources development.

The solutions subsection identifies possible mechanisms to navigate the issues raised in the previous section and presents reasonable and prudent practices that may prevent, minimize, or mitigate the associated air issues.

The last subsection looks at potential future air quality regulations that could affect development of oil and gas resources. Current focal point issues could drive legislation to enact new regulations to limit emissions of regulated pollutants, to identify new pollutants, or to reclassify non-pollutants as pollutants. This subsection will also present opportunities for further research into adverse impacts to air quality during the development of oil and gas resources.

5.2 PRIMER ON AIR QUALITY ISSUES

A primer is provided to enable those who do not deal with air quality on a frequent basis the opportunity to gain a basic level of understanding of the terminology used in regulatory language and by those who work the air quality field. The basic definition of air pollution and key regulated pollutants are provided in the initial portion of this subsection. Following is a brief discussion of where the key pollutants may occur during exploration and production activities. The subsection then looks at the entities responsible for regulating the pollutants and how the pollutants are regulated. Persons already familiar with these topics can skip this subsection and still gain insight on air quality issues related to the exploration and production industry through the other sections in this handbook.

5.2.1 REGULATED AIR POLLUTANTS

While the concept of air pollution is simple to grasp intuitively, how it is defined has been a source of confusion and the topic of much legal discussion. One definition describes air pollution as harmful gases or particles in the outdoor atmosphere in concentrations high enough to be injurious to human health and welfare, plants, and animals, or to unreasonably interfere with the enjoyment of life or property. Indoor air is not included in this definition. Outdoor air is commonly referred to in regulatory language as "ambient" air. Other definitions suggest that air pollution is caused only by man, excluding natural sources such as volcanic events, windstorms, and natural fires. Air pollution can be the result of "primary" pollutants being emitted directly into the air from a variety of sources including process equipment or operations, or formed as "secondary" pollutants through chemical reactions occurring in the atmosphere such as in the formation of ground-level ozone.

Air pollutants are categorized as either single chemical compounds or groups of related compounds. Examples of single chemical compounds generated by exploration and production activities include: carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Groups of related air pollutants are usually based on similar chemical formulation, similar physical properties, or by regulations. Examples of grouped air pollutants based on similar chemical formulation include: oxides of nitrogen (NO_x), oxides of sulfur (SO_x), and volatile organic compounds (VOCs). Particulate matter (PM) is a group of air pollutants based on physical properties that consist of very small diameter solids or liquids that may remain suspended in the atmosphere. Particulate matter is further subdivided based on the particle size, with PM-10 referring to particulate matter having a diameter of less than 10 millionths of a meter (micro-meter) and PM-2.5 being less than 2.5 micro-meters in diameter. Another common group of air pollutants are the six "criteria" pollutants, which include CO, lead (Pb), NO_2, particulate matter (PM-10 and PM-2.5), ozone (O_3), and SO_2. The United States Environmental Protection Agency (EPA) refers to these as "criteria" air pollutants and regulates them by established human health-based and/or environmentally based criteria (science-based guidelines) for setting permissible levels. It is easy to see how confusion can develop when NO_2 is a member of two groups: the oxides of nitrogen and the criteria pollutants, as well as being a single chemical compound air pollutant. Similarly, PM-2.5 is a member of both the PM-10 and PM groups.

Other air pollutant categories include:

- *Volatile Organic Compounds (VOC) -- those compounds of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate) which can form ozone through atmospheric photochemical reactions. In some applications, VOC are defined as those carbon compounds containing three or more carbon molecules.*
- *BTEX (benzene, toluene, ethyl benzene, and total xylenes) -- a group of compounds that also belong to broader categories of regulated pollutants including VOCs and HAPs.*
- *Hazardous Air Pollutants (HAP), -- also called by names such as air toxics, toxic air contaminants, and toxic air pollutants. They are known or suspected to cause cancer or other serious health problems such as reproductive effects or birth defects, or adverse environmental effects.*

Pollutants commonly emitted during exploration and production activities include:

- *CO, which can be emitted during flaring and from the gas produced by incomplete combustion of carbon-based fuels.*
- *PM, PM-10, PM-2.5, which occur from dust or soil entering the air during pad construction, traffic on access roads, and diesel exhaust from vehicles and engines. They also can be emitted during venting and flaring operations.*
- *SO_2, which is formed when fossil fuels containing sulfur are burned. Thus, sulfur dioxide may be emitted during flaring of natural gas, or when fossil fuels are combusted to provide power to pump jacks, compressor engines, or other equipment and vehicles at oil and gas production sites. Sour gas processing units may also emit sulfur dioxide.*
- *NO_2, which is formed during flaring operations and when fuel is burned to provide power to machinery such as compressor engines and other heavy equipment.*
- *O_3, which itself is not released during oil and gas development, but two of its main precursors (e.g., VOCs and NO_x) that react with sunlight to form ground-level ozone can be released during exploration and production operations.*
- *BTEX compounds, which can be emitted from flaring, venting, engine exhaust, and during the dehydration of natural gas.*
- *Hydrogen sulfide (H_2S), which can be released when "sour" gas is vented, when there is incomplete combustion of flared gas, or via emissions from equipment leaks.*

Carbon dioxide (CO2) and Methane (CH4) also are known air pollutants that may be released but are not currently regulated in most states. These pollutants are listed here because they are discussed as key contributors to global climate change, which is addressed in greater detail later in this handbook.

5.2.2 REGULATORY AGENCIES

At the federal level, most air quality regulations are developed, promulgated, and enforced by the EPA. However, certain aspects of air pollution may be regulated by other federal agencies. One example would be worker exposure limits to air pollutants, which is regulated under the Occupational Safety and Health Administration (OSHA), the National Institute of Occupational Safety and Health (NIOSH), and, under specific circumstances, the Mine Safety and Health Administration (MSHA). Indoor air quality, previously excluded from the definition of air pollution, is generally under the jurisdiction of OSHA.

The air quality issues and management solutions of today are larger, more complex and more challenging than ever before. Because the EPA is not large enough to regulate every source of air emissions nationwide, let alone to consider the local and regional differences, the agency typically delegates that role to local, state, other federal, and tribal agencies. This program delegation authority can include rule implementation, permitting, reporting, compliance, etc. In spite of this delegation of authority, the EPA retains the right to intercede, should it see good cause, to amend or add new regulations at the federal and regional levels, and to conduct inspections.

5.2.3 AIR REGULATIONS

The federal government's regulation of air pollution is codified in the Code of Federal Regulations (CFR) Title 40 encompassing 22 volumes covering more than 12,000 pages of regulations (EPA, Laws, Regulations, Guidance, and Dockets). These regulations are then relied upon for developing new regulations by EPA's national and regional offices, state environmental agencies, regional groups of cities and states, local authorities, and other permitting authorities. Many of today's air quality rules were implemented primarily to regulate emissions from single sources of pollution such as a refinery, a chemical plant, an iron and steel manufacturing facility, and individual electrical power generating facilities.

Although the exploration and production industry typically involves much smaller individual sources of pollution relative to the industries noted above, there are operations that may require an air permit (EPA, Sector Notebooks, 2000). Such operations could include: a central tank battery with compressor engines, flares, heaters, and dehydration units; sulfur removal systems having flares and amine units; equipment leaks; regional air pollution problems including acid rain, visibility degradation, and smog in urban areas; and the combined impacts from numerous small emission sources such as venting and flaring. Table **5-1** presents a comparison of air pollution levels emitted by industry sector for the year 1998.

Table 5-1: Air Pollutant Releases by Industry Section (tons/year)

Source: EPA Office of Air and Radiation, AIRS Database, 1997.

Industry Sector	CO	NO2	PM10	Particulate	SO2	VOC
Oil and Gas Extraction	132,747	389,686	4,576	3,441	238,872	114,601
Lumber and Wood Products	139,175	45,533	30,818	18,461	95,228	74,028
Pulp and Paper	584,817	365,901	37,869	535,712	177,937	107,676
Inorganic Chemicals	242,834	93,763	6,984	150,971	52,973	34,885
Organic Chemicals	112,999	177,094	13,245	129,144	162,488	17,765
Petroleum Refining	299,546	334,795	25,271	592,117	292,167	36,421
Stone, Clay, Glass and Concrete	92,463	335,290	58,398	290,017	21,092	198,404
Iron and Steel	982,410	158,020	36,973	241,436	67,682	85,608
Nonferrous Metals	311,733	31,121	12,545	303,599	7,882	23,811
Ground Transportation	153,631	594,672	2,338	9,555	101,775	5,542
Fossil Fuel Electric Power	399,585	5,661,468	221,787	13,477,367	42,726	719,644

CLEAN AIR ACT

In an effort to reduce air pollution, the United States Congress passed the Clean Air Act (CAA) in 1963, the Air Quality Act in 1967, the Clean Air Act Extension of 1970, and the Clean Air Act Amendments in 1977 and 1990. The CAA's basic goals are:

1. *Attainment and maintenance of National Ambient Air Quality Standards (NAAQS).*
2. *Prevention of significant deterioration of air quality in areas of the country where the ambient standards are already being met.*
3. *Preservation of natural visibility in national parks and wilderness areas.*
4. *Avoidance of risk from hazardous air pollutants.*
5. *Protection of stratospheric ozone, and prevention of acid rain.*

Air quality is one of the main issues that the EPA regulates to accomplish its mission of protecting human health and the environment. The CAA is the primary means relied upon by the EPA to regulate air quality. The CAA is hundreds of pages long, and the EPA has written thousands of pages of regulations to implement the CAA requirements, along with thousands more pages of guidance documents that better explain the regulations.

The CAA requires EPA to set NAAQS to limit levels of the criteria pollutants. EPA regulates the criteria pollutants by developing human health-based and/or environmentally based criteria (science-based guidelines) for setting permissible levels. Each pollutant's standard is based upon its acute or chronic properties based on time-weighted average concentrations (*i.e.*, the average concentration of a pollutant that a person can be exposed to over a set period of time with no adverse health effect). Thus, the averaging time for regulating each pollutant can vary from 1 hour for pollutants that have more acute threats to annually for those with more chronic concerns. Geographic areas that do not meet the NAAQS for a given pollutant are designated as non-attainment areas. One example is the ozone non-attainment area in Los Angeles due in large part to the numerous vehicle combustion emissions. Any state with delegated responsibility for a non-attainment area must develop a State Implementation Plan that identifies the pollution sources and the steps that will be taken to meet the standard within a prescribed time frame.

The EPA has established and enforces National Emission Standards for Hazardous Air Pollutants (NESHAP), which are nationally uniform standards to control specific HAPs. Section 112(c) of the CAA directs EPA to develop a list of sources that emit any of the 188 HAPs and to develop regulations for categories of sources that might emit these HAPs. The EPA has listed more than 185 source categories (to include the oil and natural gas industry) and is working to meet a schedule for the establishment of emission standards. The control standards are being established for both new and existing sources based upon the maximum achievable control technology (MACT).

When developing a MACT standard for a particular source category, the EPA looks at the current level of emissions achieved by best-performing similar sources through clean processes, control devices, work practices, or other methods. These emissions levels set a baseline, often referred to as the "MACT floor" for the new standard. At a minimum, a MACT standard must achieve a level of emissions control that is at least equivalent to the MACT floor. The EPA can establish a more stringent standard when it makes economic, environmental, and public health sense to do so.

The MACT floor for existing units is equal to the average emission limitation achieved by the best performing 12 percent of existing sources. In contrast, the MACT floor for new sources is the level of emission control that is achieved in practice by the best-controlled similar source.

While HAPs are commonly regulated across the nation, some states have implemented programs to regulate other air constituents. For example:

- *In Texas, Effects Screening Levels (ESLs) established by a team of toxicologists are used to evaluate the potential for effects to occur as a result of exposure to concentrations of constituents in the air. These ESLs are based on data concerning health effects, the potential for odors to be a nuisance, effects on vegetation, and corrosive effects. They are not ambient air standards; rather they are considered guidelines that are typically evaluated on a case-by-case basis. The Texas ESL list has thousands of air toxics with acute and chronic concerns (TCEQ, 2007).*

- *Oklahoma also regulates several groups of toxic air contaminants. Its program includes ambient air standards with a maximum acceptable ambient concentration typically averaged over a 24-hour period (ODEQ, 2007).*
- *California regulates air toxics through their "Hot Spots" program. The California Air Resources Board (CARB) has compiled a long list of substances that pose chronic or acute threats to public health when present in the air. The "Hot Spots" program includes an emissions inventory, requirements for assessing health risks, and provisions for notifying the public about emissions of toxic air contaminants.*

Therefore, while the regulation of HAPs is fairly consistent across the country, the regulation (or lack thereof) of thousands of other possible air contaminants is dependent on each state's specific rules.

URBAN AIR TOXICS STRATEGY

The Urban Air Toxics Strategy is another EPA program designed to control toxic air pollutants from area sources in urban locations. "Area" sources in this case are those that emit less than 10 tons annually of a single HAP (air toxic) or less than 25 tons annually of a combination of HAPs. The urban air toxics strategy is a framework for addressing air toxics emissions from multiple, relatively smaller sources. This strategy complements national efforts to regulate major source standards, residual risk standards (intended to reduce any health risks remaining after an industrial source category has been implemented), mobile source standards, and indoor activities.

Under this strategy, the CAA required the EPA to identify a list of at least 30 air toxics that pose the greatest potential health threat in urban areas. Of the 30 air toxics identified by the EPA, benzene and formaldehyde (from glycol dehydrators and compressor engines, respectively) are the two most likely to be emitted from oil and gas facilities. The CAA also requires the EPA to identify and list the area source categories that represent 90 percent of the emissions of the 30 urban air toxics associated with area sources and subject them to standards under the CAA. As of 2006, 16 source categories were regulated and the remaining area source standards were under development. In an effort to expedite this process, EPA was put on a court-ordered schedule to issue the area source rules (EPA, 2006a). Two categories common to the oil and gas industry --- oil and natural gas production and stationary internal combustion engines ---were identified previously in a May 2003 court ruling.

The effect of these rulings targeting multiple smaller sources in urban areas is to achieve meaningful emissions reductions of selected HAPs and thus lower the potential public health risk. These standards typically are developed based upon a MACT determination. One recent example is the amended NESHAP for area sources at oil and natural gas production facilities. In this case, the regulation targets benzene emissions from triethylene glycol dehydration units across the country *(EPA, 2006b, Exemptions include dehydrators having less than 3 MMscfd throughout, "black" oil facilities, and dehydrators emitting less than 1 tpy of benzene)*.

NATIONAL ENVIRONMENTAL POLICY ACT

Another federal law of importance to oil and gas operations is the National Environmental Policy Act (NEPA). NEPA requires that all federal agencies prepare detailed statements assessing the environmental impact of, and alternatives to, major federal actions that could "significantly affect" the environment (EPA, NEPA, 2007). A "federal action" related to oil and gas exploration and production is typically a decision to develop federally owned lands or mineral estate. These actions are evaluated under NEPA through the preparation of Environmental Assessments (EA) and/or Environmental Impact Statements (EIS). If an EA determines that significant environmental impact will or may occur as a result of a federal action then an EIS must be prepared. An EIS must provide a fair and full discussion of significant environmental impacts resulting from the proposed federal action and inform both agency decision-makers and the public about alternative actions that could avoid or minimize adverse impacts. The ultimate goal of an EIS is to identify the preferred alternative that best balances the contemplated federal action with environmental preservation. In certain cases, specific activities may not require the preparation of a project specific EA or EIS; these limited opportunities are addressed under categorical exclusions. It is important to understand that the use of a categorical exclusion does not waive the necessity of environmental review; it simply provides an expedited mechanism for a limited range of eligible activities. The interested reader is directed to a more thorough explanation of categorical exclusions than can be addressed herein (ALL, 2008).

NEPA is the cornerstone of our nation's environmental laws and was enacted to ensure that information on environmental impacts resulting from federal actions or federally funded actions is available to public officials and citizens before decisions are made or actions taken. The intent of the Act is also to formulate and recommend national policies to ensure that the programs of the federal government promote improvement of the quality of the environment. It is not designed to regulate, but to inform by requiring federal agencies to take environmental factors into consideration during their decision-making processes. The CAA is the basis for regulating emissions of air pollutants and otherwise maintaining or enhancing air quality to protect public health and welfare throughout the United States. NEPA plays an important role in identifying and informing federal decision-makers of potential air quality impacts resulting from their land management decisions. Further, it encompasses a broader scope and provides an independent analysis of CAA requirements for federal actions. NEPA ensures that a broad spectrum of potential environmental effects is examined --- including air quality. In some cases, NEPA analyses involve evaluating trade-offs of beneficial and adverse effects among different environmental media, such as air emissions versus water quality impacts. NEPA air quality analyses sometimes encompass potential concerns that are beyond those required for compliance with the CAA; for instance, acid deposition and acid neutralizing capacity, which are discussed in greater detail in the next section. In some cases, the agencies involved in the review and comment of NEPA documents are the same as those that review and issue any associated air permits for a project.

One example of how the NEPA process can impact the timely progress of a large-scale oil and gas project is the development of the Montana Statewide Oil and Gas Environmental Impact Statement and Amendment of the Powder River and Billings Resource Management Plans. In January 1989, the Montana Board of Oil and Gas Conservation *(MBOGC, This is an arbitrary starting point to demonstrate this issue. Other Resource Management Plans and NEPA/MEPA activities predated the PEIS)* released the draft Programmatic EIS (PEIS) on Oil and Gas Drilling and Production in Montana. The final PEIS was issued in December 1989 and included only 38 public comment letters. In January 2003 the Bureau of Land Management (BLM), the Montana Department of Environmental Quality (MDEQ), and the MBOGC jointly issued the Montana Final Statewide Oil and Gas Environmental Impact Statement and Proposed Amendment of the Powder River and Billings Resource Management Plans (FEIS). The FEIS included an environmental analysis of anticipated coal bed methane and conventional oil and gas development statewide and amended the PEIS to include coal bed methane exploration and production on private and state-owned lands (the FEIS is a NEPA/MEPA combined document, so in this case it applies to non-federal actions covered under the Montana Environmental Policy Act as well as federal actions covered under NEPA). More than 18,000 letters, emails, faxes and cards were received commenting on the draft EIS document. On August 16, 2004, the Environmental Defense Fund and other plaintiffs filed suit against the BLM to include challenges to the Record of Decision on the FEIS (United States 2004; Cause No. CV-04-64-Blgs-RWA). What followed was a ruling directing the BLM to develop a Supplemental EIS (SEIS) to address further alternatives and issues raised in the lawsuit. The SEIS continued to garner a significant level of interest as evidenced by the 30,000 comments received on just one section of the SEIS during public comment. As for air quality issues in this process, the original focus on sulfur emissions in the PEIS has grown into expressed concerns in the SEIS covering all six criteria air pollutants, air toxics issues, visibility degradation, and acid deposition. At least two extensive air dispersion modeling projects were conducted to support the evaluation of these air quality issues. This example points out that the NEPA process plays a significant role in energy development planning where federal lands and mineral estates are concerned.

5.2.4 AIR QUALITY RELATED VALUES

Under Section 169A of the 1977 CAA Amendments, Congress defined mandatory Class I areas as national parks greater than 6,000 acres in size, wilderness areas greater than 5,000 acres in size, and international parks that were in existence on August 7, 1977. There are 156 mandatory Class I areas in the nation. Federal Land Managers (FLM) of each Class I area are charged with the responsibility to protect that area's unique attributes, expressed generically as air quality related values (AQRV's). AQRVs are typically part of a NEPA review and can include such issues as visibility, acid deposition, and acid neutralizing capacity. They are generally expressed in broad terms and may differ depending on the purpose and characteristics of a particular area and on assessments by the area's FLM (FLAG, 2000).

Visibility is a measure of how clearly distant objects can be seen; visibility impairment is commonly called haze. Haze results from the scattering and absorption of light by particles and gases in the air. EPA has identified two general types of visibility impairment in Class I areas:

- *Impairment due to smoke, dust, colored gas plumes, or layered haze emitted from stacks which obscure the sky or horizon and are relatable to a single stationary source or a small group of stationary sources.*
- *Impairment due to widespread, regionally homogeneous haze from a multitude of sources that impairs visibility in every direction over a large area; commonly referred to as regional haze.*

EPA, states, and regional agencies have been monitoring visibility in national parks and wilderness areas since 1988. In 1999, the EPA announced a major effort to improve air quality in national parks and wilderness areas (i.e., Regional Haze Rule). The Regional Haze Rule (RHR) calls for state and federal agencies to work together to improve visibility in Class I areas (EPA, Regional Haze Rule, 1999). The rule requires the states, in coordination with the EPA, the National Park Service (NPS), United States Fish and Wildlife Service (USFWS), the United States Forest Service (USFS), to develop and implement air quality protection plans to reduce the pollution that causes visibility impairment. Because the pollutants that lead to regional haze can originate from sources located across broad geographic areas, EPA recommended that visibility impairment be addressed from a regional perspective. Therefore, particulate matter emissions from exploration and production activities, even though they may be located 200-300 miles from one of the nation's protected areas, can be affected by this rule.

For example: while Nebraska does not have a mandatory Class I area located within the state, computer simulations have demonstrated that ammonia emissions from sources within the state have the potential of being transported into neighboring states and contributing to the formation of haze. Therefore, Nebraska joined representatives from nine central states to form the regional planning organization known as the Central States Regional Air Planning Association (CENRAP). CENRAP coordinates the scientific assessment and planning efforts for these states that are necessary to properly implement the RHR. The assessment and planning efforts include the collection and analysis of air monitoring data, inventorying of air emissions from states and tribes, atmospheric modeling simulations to assess current and future air quality conditions, and the evaluation and planning of possible control scenarios to meet the national visibility goal. CENRAP participation is voluntary and states are not bound to the recommendations that the organization makes. To assist organizations such as CENRAP, a network of more than 100 air quality monitors, known as the IMPROVE Network (Interagency Monitoring of Protected Visual Environments) has been established to gather data from Class I areas throughout the nation (CIRA, 2001).

Acid deposition is the result of gaseous emissions of SO_2 or NO_x that undergo complex reactions in the atmosphere resulting in the formation of the secondary pollutants sulfuric acid and nitric acid, respectively. The deposition process can be either wet or dry. The major contributing source of SO_2 is the combustion of fossil fuels such as coal, fuel oil, and diesel. The predominant sources of NO_x are automobile exhaust and industrial emissions including oil and gas operations. The addition of sulfate and nitrate to the ecosystem of a Class I area can increase the acidity of aquatic and terrestrial systems (i.e. lakes and soils). Acid deposition can occur as a result of precipitation and is often referred to as acid rain. Acid rain has been shown to have adverse impacts on forests, freshwater bodies, and soils, killing off insect and aquatic life forms and causing damage to buildings and having possible impacts on human health. Although exploration and production sources of NO_x and SO_x typically are not large, they have the potential to contribute levels of concern when considering cumulative impacts on sensitive areas such as Class I areas or lakes located near large oil and gas developments.

An issue closely related to acid deposition is acid neutralizing capacity (ANC). ANC is a measure of the ability of lakes and other surface water bodies to resist changes in pH. If an air dispersion model predicts acidic deposition values above the deposition analysis thresholds established by the FLM, additional analysis in terms of ANC are typically conducted at sensitive lakes within the area of concern. The ANC results are then compared against thresholds based on USFS recommended prediction methods (USFS 2000) and another terrestrial deposition loading method (Fox *et al.*, 1989). These comparisons form the basis for possible emissions control decisions by the FLM.

The NEPA process provides guidance to state and federal agencies on a wide variety of environmental issues and typically takes place in the early stages of an energy development opportunity. The air permitting process includes only air issues, continues throughout energy development, and provides the means for regulatory agencies to manage compliance with regulations to include these NAAQS:

- *More than180 HAPs regulated pursuant to the NESHAP sections of CAA.*
- *Any non-attainment area requirements.*
- *The New Source Performance Standards (NSPS) sections of the CAA.*
- *EPA's regional haze rule including its best available retrofit technology (BART) requirements.*
- *Excess and fugitive emissions.*

Additional regulations also might apply in some circumstances. Each of these sets of requirements is discussed in greater detail later in this handbook.

5.2.5 SUMMARY

As a result of the implementation of the CAA, air quality has improved dramatically across the United States during the last few decades and existing regulations should continue to reduce levels of air pollution during the next 20 years or more (EPA, Air Trends, 2007**).** As shown in **Table 5.2** (Percent Change in Air Quality), EPA trend data indicate a reduction in every criteria pollutant over the last 25 years.

Since the CAA was passed into law in the early 70's, there has been a continuous history of amendments leading to new air regulations governing the construction and operation of facilities.

Due to the relatively small level of air pollution typically emitted, many exploration and production industry sources were exempted (or simply not addressed) in the earlier years of implementing most of the air programs. This is no longer the case. States are targeting oil and gas extraction activities with rules specific to those activities and the EPA is developing rules for multiple smaller sources such as tank batteries. Thus, oil and gas production companies are facing a growing number of air regulations originating from both state and federal agencies as they attempt to extract more energy to meet the nation's demands.

Table 5-2: Air Pollution Trends

	1980 vs 2006	**1990 vs 2006**
NO_2	-41%	-30%
O_3 (1-hr) (8-hr)	-29% -21%	-14% -9%
SO_2	-66%	-53%
PM_{10} (24-hr)	---	-30%
$PM_{2.5}$ (annual)	---	-15%
$PM_{2.5}$ (24-hr)	---	-17%
CO	-74%	-62%
Pb	-95%	-54%

Notes:
1. --- Trend data not available
2. $PM_{2.5}$ air quality based on data since 1999
3. Direct PM_{10} emissions (1980-2006) based on data since 1985
4. Negative numbers indicate improvements. in air quality or reductions in emissions.

5.3 AIR POLLUTION CHALLENGES AND BARRIERS TO DOMESTIC ONSHORE OIL AND GAS DEVELOPMENT

5.3.1 REGULATIONS AND PERMITS

Air regulations and permits often are perceived as being overly complex. They may apply to local, regional, or national air pollution; involving criteria from air pollutants to air toxics; and range from simple permits to very rigorous authorizations to operate. Regulations frequently differ from state to state, and federal regulations may even be interpreted differently from one state or region to the next.

A company's permitting responsibility does not end with the issuance of their initial air permit. They must be constantly vigilant that a modification, replacement, or process change does not violate their existing permit and, therefore, require a permit amendment or even a different type of permit. Additionally, most air permits have specific reporting, record keeping, and monitoring requirements that must be addressed throughout the operational year. No matter what level of air permit is required, generally it will include conditions designed to ensure that state and federal standards are met and to prevent any significant degradation in air quality as a result of a proposed activity.

Congress established the New Source Review (NSR) air permitting program as part of the 1977 CAA Amendments. In spite of the name, NSR applies to both new construction as well as modifications to existing facilities. NSR serves two important purposes.

- *First, it ensures that air quality is not significantly degraded from the addition of new and modified facilities. In areas with unhealthy air, NSR assures that new emissions do not slow progress toward cleaner air. In areas with clean air, especially pristine areas like national parks, NSR assures that new emissions do not significantly degrade air quality.*
- *Second, the NSR program assures the public that any new large, or modified existing, industrial source in their neighborhoods will be as clean as possible, and that advances in pollution control occur concurrently with industrial expansion.*

NSR permits are legally binding documents. The permit specifies what construction is allowed, what emission limits must be met, and how the emissions source(s) must be operated. NSR permits may or may not be transferable (either based upon the equipment or to another location) depending on the permitting authority. Depending on the state where the facility is located, a new project could require one or more air permits.

There are generally four types of construction and/or operating air permits:

1. *Prevention of Significant Deterioration (PSD) permits, which are required for new major sources or a major source making a major modification and located in an attainment area.*
2. *Non-attainment permits, which are required for new sources or sources making a modification and located in a non-attainment area.*
3. *Title V operating permits.*
4. *Minor source permits.*

PSD is a permitting program for new and modified stationary sources of air pollution located in an area that attains or is unclassified for the NAAQS. These are typically sources that emit large quantities of air emissions (i.e., greater than 250 tons per year [tpy] of a single criteria pollutant). The PSD program is designed to ensure that air quality does not degrade beyond those air quality standards or beyond specified incremental amounts. The PSD permitting process requires new and modified facilities to be carefully reviewed prior to construction for air quality impacts and to apply the best available control technology (BACT) to minimize emissions of air pollutants. Most states include the federal PSD rules in their air programs. If a state does not have federal delegation over this permitting program, the

EPA retains the authority for the program and any source applying for a PSD permit would do so with the regional EPA office.

A non-attainment area is a geographic area identified by the EPA as not meeting the NAAQS for a given pollutant. It is possible that a major source located in a non-attainment area could propose a modification that would require both a PSD permit and a non-attainment permit. Because this type of permit is dependent on the attainment status of each pollutant that may be emitted from a new or modified source, even small emission sources can be impacted. An example would be gas extraction activities occurring in the Barnett Shale unconventional gas play near the Dallas-Fort Worth metroplex. This location is designated as a moderate ozone non-attainment area. Thus, even relatively small changes to proposed NO_x and VOC emissions (accepted as the main precursors to ozone formation) could subject a facility to non-attainment requirements, which typically are more rigorous than what would be applied to an identical project located just outside the non-attainment area.

The Title V federal operating permit program originated out of the 1990 CAA Amendments. The purpose of the program was to include in a single document all air emissions requirements that apply to a given facility. Title V operating permits, sometimes referred to as Part 70 permits, generally apply to a source that will emit greater than 100 tpy of a single criteria pollutant or a source that will emit greater than 10 tpy of any one HAP or greater than 25 tpy of any combination of HAPs. Depending on the state, a source could be required to obtain both a preconstruction permit and a Title V operating permit (i.e., the preconstruction permit would govern the source during construction or modification and the operating permit would govern the source's continuing operations following construction).

Minor source permits typically apply to smaller emission sources such as those that emit less than 100 tpy of a single criteria pollutant. These permits may be called a permit by rule, general operating permit, synthetic minor permit, true minor source permit, permit exemption, Type 1 permit, etc. It should be noted that, in some cases, the names may overlap into another permitting category such as in the case of a general operating permit also referring to a categorical form of Title V permit.

The terms major and minor can apply to the type of air permit or modification. Since an in-depth definition of these terms is often a challenge (due to differences in pollutants, pollutant amounts, project location, type of industry, etc), a simplified version is that major permits are those that propose potential criteria pollutant emissions greater than either 250 tpy (PSD) or 100 tpy (Title V). Sources that propose to limit emissions to less than these amounts are often referred to as minor sources. Major modifications typically refer to existing major sources that propose a modification that will emit an amount of pollutant greater than its applicable significance level. In addition, if a proposed project includes the emissions of HAPs, a major source is one that will emit 10 tpy of any single HAP or 25 tpy of any combination of HAPs. Sources that will release a HAP in quantities less than these thresholds are referred to as area sources and may still be subject to one or more NESHAP rules.

In spite of the facility or project size or location, all air permits are subject to certain federal requirements. One example of a federal requirement is the NESHAP regulations, discussed earlier. These rules regulate the HAPs emissions (such as benzene) and are authorized by Section 112 of the CAA. NESHAP regulations are published in 40 CFR Parts 61 and 63. New Source Performance Standards (NSPS) are another set of federal rules designed to limit the amount of pollution allowed from new sources or from modified existing sources. The NSPS focus more on a source category rather than a given pollutant and their applicability can range from stationary internal combustion engines to fugitive equipment leaks. These standards are authorized by Section 111 of the CAA and the regulations are published in 40 CFR Part 60.

Air regulations include a provision requiring that new or amended permits be submitted and approved *before* any significant construction or operations are undertaken. This preconstruction requirement does not fit well with most exploration and production operations because often times producers cannot be certain of a new well's production and the chemical properties of any produced oil or gas until some time after the well is drilled. Depending on how the regulatory agency's rules are written and interpreted, the preconstruction requirement could mean that any company considering the option to drill a new well must prepare an application or registration and receive a completeness determination before it would be allowed to drill. Fortunately, most states now include a 30- to 45-day grace period in their rules to allow a production company to determine its permit needs before submitting an application. Such time provisions can mean fewer amended or rescinded applications for companies and less work for the agencies.

5.3.2 REGIONAL DIFFERENCES

Implementation of the CAA by delegated agencies can vary depending on location. Some states, like South Dakota, currently do not single out the exploration and production industry with specific categorical air quality rules. Other agencies, such as the South Coast Air Quality Management District in California, have numerous rules specific to the industry concerning:

- *Oil and gas production wells.*
- *VOC emissions from storage tanks.*
- *Thermally enhanced oil recovery wells.*
- *Emissions of NO_x from stationary gas turbines.*
- *Process heaters.*
- *Stationary liquid or gas fueled engines.*
- *Particulate matter from paved and unpaved roads.*

Wyoming regulations included air quality controls specific to the exploration and production industry in 1997, because the numerous minor emissions sources had cumulatively evolved into an area of concern. A year later, Wyoming set control standards for flash emissions and then added control standards for glycol dehydration units in 2000. In 2004, the state added area-specific control requirements for the booming Jonah and Pinedale Fields. Then in 2007, Wyoming further tightened its regulations on oil and gas facilities. In 2006, Montana followed Wyoming's lead by implementing a new program that required well sites with more than 25 tpy of annual emissions to apply for permits or registrations and the installation of emissions controls on sources greater than 15 tpy of emissions.

Location can greatly affect the number of air regulations that apply. California offers a good example where a source of air emissions must consider federal and regional EPA regulations, as well as rules issued by the California EPA, California Air Resources Board, the applicable Air Quality Management District, and an Air Quality Control District. Any proposed operation also would be subject not only to the federal CAA, but perhaps the California CAA, California Environmental Quality Act, Proposition 65, widespread non-attainment areas for different pollutants, and a host of other air-related rules.

Similarly, location can influence how a given air regulation is interpreted. Consider the example of an oil and gas field spread out across two states. The operator of such a field could be subject not only to different state regulations but also different interpretations of those rules for identical facilities. That could mean that a tank battery in one state might require an air permit; whereas, a similar tank battery across the state line would not. Or one facility might need emissions controls yet an identically equipped facility in the adjoining state might not.

The attainment status of a given location is another concern. Consider either the Barnett Shale play discussed earlier or an oil and gas operation located in most air districts within California. These areas have one or more non-attainment areas that must be considered. Therefore, operations in these locations that propose to emit relatively minor amounts of particulate matter and/or ozone precursors (NO_x and VOC) would be subject to tougher emissions controls than a similar operation located outside the non-attainment area.

Regional issues may also be a factor in location-specific rules. Oil and gas activities located in or near any of the Nation's Class I areas could be subject to issues such as the regional haze rule, ozone transport concerns, or other rules even though they might be located 200-300 miles from the sensitive area.

5.3.3 TRACKING PERMITS AND FACILITIES

Consider the following scenario: A particular exploration and production company has grown due to acquisitions and expanded drilling, but the task of keeping track of all the air quality related requirements such as air permits, record keeping requirements, reporting deadlines, and stack testing and monitoring concerns has become a seemingly insurmountable task. No requirement by itself is an issue; however, the cumulative volume of such issues contained in hundreds of air permits can create significant challenges for environmental managers.

As an example, one major oil producer identified more than 900 sites and 80,000 different permit-related tasks, including 5,000 different environmental permits that required compliance tracking. In such cases moving from notebooks and spreadsheets used for compliance to an integrated electronic system seems reasonable. However, some companies have found that path to be difficult; barriers encountered when switching to an electronic environmental management system might include:

- *Determining who will be allowed access to input data and extract reports.*
- *Addressing who will reprogram the system when rules or report formats change.*
- *Identifying what backup procedures are needed to prepare for potential system crashes.*
- *Funding issues.*

5.3.4 ONSHORE OIL AND GAS INDUSTRY-SPECIFIC ISSUES

In 2007, small independent producers were operating 90 percent of the nation's onshore oil and gas sites. Most of these companies have fewer than 20 employees and limited or no full time environmental staff. Keeping up with air permits, changing regulations, and ensuring compliance can represent a significant challenge. In addition, both large and small producers face such issues as:

- *Equipment that becomes oversized when production drops off.*
- *Tracking the change-out of permitted equipment.*
- *Tightened regulations that require increased emissions controls.*
- *Permit-related delays that lead to operational delays.*
- *Staying prepared for agency inspections.*

Because many of these issues can lead to violations and noncompliance, it is important that companies give early consideration to project life-cycle environmental requirements when making operational decisions.

Unfortunately, air regulations normally do not include exceptions for a company's size, the age of a field, or the type of operation. Thus, small producers must comply with the same set of rules as larger companies. Likewise, owners of stripper wells must track regulatory issues the same as any other operator. Typically, air rules are silent on issues such as conventional vs. unconventional plays, old vs. new fields, well depths, and, in some cases, whether a well produces crude or natural gas. Rules are focused on the potential air pollutants that might be released during the processing and handling of the oil or gas extracted. Therefore, despite the potential complexities from air permits, record keeping, or annual air emissions inventories, a production company is expected to be knowledgeable of and in compliance with its air responsibilities.

5.3.5 NEW AND REVISED REGULATIONS

Like most industries in the United States, the oil and gas producers have had to deal with many new air regulatory changes in recent years, most of which were a result of the 1990 CAA Amendments. These rules pose an ongoing challenge to company resources as operators strive to understand and comply --- or face compliance issues, enforcement violations, fines, unfavorable public exposure, and possibly even project cancellations. These changes may appear in the form of new regulations or as revisions to existing regulations.

A recent example is the reciprocating internal combustion engines (RICE) NESHAP (40 CFR Part 63 Subpart ZZZZ) rule. The original rule was published in the Federal Register June 15, 2004, and applied to existing, new, or reconstructed stationary engines of greater than 500 hp located at major sources of HAPs. The complexity of that rule, which was 33 pages long, was demonstrated by EPA's use of three flow diagrams necessary to assist in applicability determinations *(see www.epa.gov/ttn/atw/rice/appdiag.ppt).* On June 12, 2006, (71 Federal Register 33804-33855), an extensive revision to this rule was proposed that required controls for the emissions of formaldehyde and/or carbon monoxide, as surrogates for other HAPs. The proposed rule also would apply to all RICE engines regardless of horsepower rating and include extensive monitoring, recordkeeping, and reporting requirements. The RICE NESHAP was finalized on January 18, 2007 (73 Federal Register 3567-3614).

EPA sometimes adds further confusion by proposing multiple rules in a single announcement. Such was the case for the RICE NESHAP discussed above along with changes to NSPS Subpart JJJJ for spark-ignition internal combustion engines. Although the source categories are related, this combined rulemaking adds to the complexity of the rule development process as well as applicability determinations. In this case, the rule covered two separate sets of federal regulations: the New Source Performance Standards found in 40 CFR 60 and the National Emissions Standards for Hazardous Air Pollutants found in 40 CFR 63. In addition, the co-mingled proposal meant a potentially affected party had to untangle more than 50 pages of rulemaking in the Federal Register in an attempt to see what, if any, requirements would apply to its facilities.

5.3.6 EXCESS EMISSIONS

Excess emissions occur when a regulated pollutant exceeds permitted levels. These are seen during an unplanned shutdown or equipment malfunction. They also might occur during start-up or when conducting maintenance on equipment. Such events can be routine or unscheduled. Should an excess emission occur an initial report (format prescribed) usually is required within a specified time period. Typically, follow-up reporting that defines the event details and describes any proposed corrective actions to prevent a reoccurrence is required. Furthermore, the EPA has ruled that such excess emission events might constitute violations. Although this issue may appear trivial at first glance, considering that each air permit has multiple conditions, if a company experienced several per year at each permitted facility, these events could present a major concern.

Excess emissions events lead to several questions:

- *How does the agency deal with such permit violations or exceedences?*
- *When must the EPA and states conduct a dispersion modeling analysis of these events to examine if an NAAQS has been exceeded?*
- *How and when does a regulatory agency require that excess emissions be rolled into a permit?*
- *When does an agency say a company has had an unacceptable number of such events?*

In addition, some agencies may include such related terms as malfunctions, deviations, violations, upsets, start-ups, and shut-downs in their rules developed for these situations. Although each agency defines these rules in its own terms, the definitions and interpretations can vary across the country and even between different divisions of the same agency, such as the permitting and compliance divisions.

5.3.7 AGGREGATION OF FACILITIES

One permitting issue that has been debated heavily is when and how to combine multiple emission sources into the permitting process. Certainly aggregating several emissions sources can reduce the number of permits and associated compliance tracking efforts, but this issue is not so simple. The complexity of aggregation may include such factors as land or mineral ownership, distance between sources, facility type, and permitting thresholds. Proper facility aggregation potentially can decrease the number of air permits, enhance compliance tracking by reducing record keeping requirements and other duplicative requirements, lower environmental fees, and reduce staffing. Conversely, aggregating multiple facilities into a single permit can lead to exceeding a major source permit threshold, greater federal and public oversight, and tougher emissions controls. The oil and gas industry has struggled with aggregation for some time and it is likely that each new interpretation will remain a case-by-case decision.

5.3.8 FUGITIVE EMISSIONS

Fugitive emissions are defined as those from facilities or activities that could not reasonably pass through a stack, chimney, vent, or other equivalent opening. Typical examples of fugitive emissions at oil and gas exploration and production facilities are:

- *Production component leaks from valves,* *flanges, connectors, and other in-line devices.*

- *Road dust.*
- *Uncontrolled emissions during truck loading operations.*
- *Leaks from pneumatic devices.*

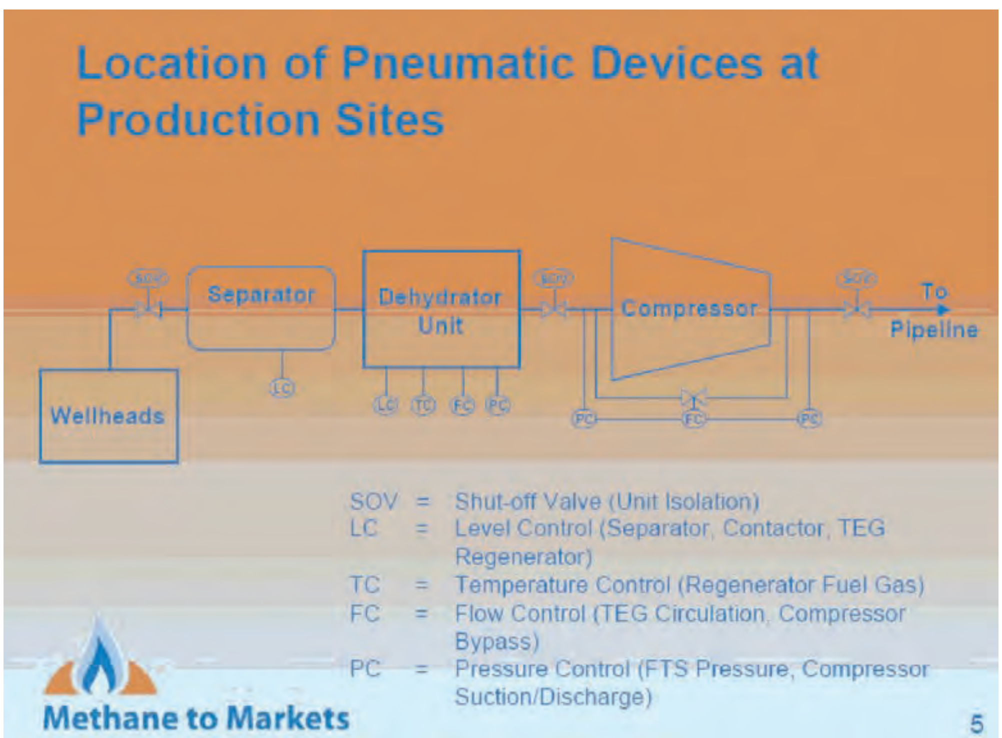
For years the EPA and state agencies focused on regulating individual stationary sources of air pollution, but they have come to recognize that fugitive emissions might not be insignificant; hence, they have broadened the regulations to include these sources.

Oil and gas production equipment component leaks are a potential fugitive emissions source. They are an example of a typically small issue that can become significant due to the sheer number of components. The primary method of identifying and controlling fugitive leaks of this type is a leak detection and repair (LDAR) program. Process components subject to LDAR periodically are monitored by visual, infrared, sound, sensor, or other methods to detect leaks. Once significant leaks are detected, they are required to be repaired within a predefined time period. LDAR --- including inherent component tagging duties, control requirements, and record keeping and reporting requirements --- can constitute a sizeable workload.

In oil and gas field operations, pressurized natural gas is used regularly in pneumatic devices to regulate pressure, control valves, and equilibrate liquid levels. As part of normal operations, pneumatic devices can release natural gas to the atmosphere. It is estimated that there are approximately 800,000 pneumatic devices in the United States production sector accounting for 24 percent of all methane emissions sourced from the oil and gas industry (Methane to Markets, 2005). A typical high-bleed pneumatic device is estimated to have an average bleed rate of 140 Mcf/yr. Given this information, it is apparent that these devices represent a significant contributing source of methane emissions, as well as providing an avenue for lost revenue to producers. Figure 5-1 shows the typical locations of pneumatic regulating devices commonly found at oil and gas production sites.

When considering whether it is economical to control fugitive emissions originating from a single tank battery, a company needs to understand that the combined impacts of fugitive emissions from many small sources, such as venting, flaring, or component leaks across an entire production field, can be significant. For example, research has indicated that gasoline-powered lawn mowers and

5-1: Location of Pneumatic Devices at Production Sites



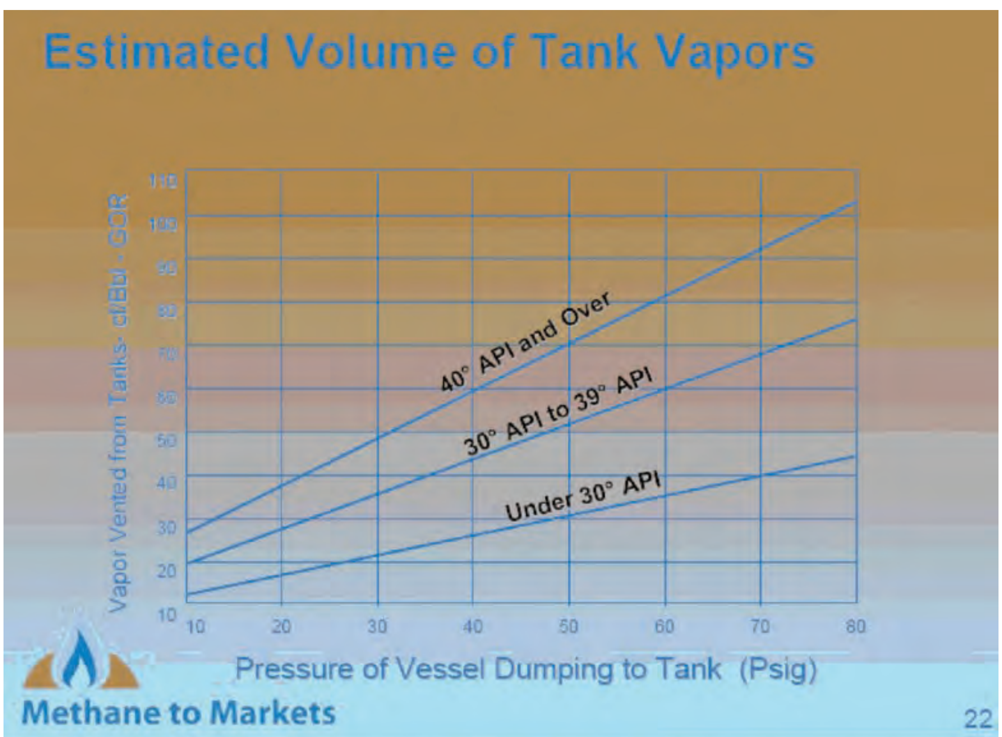
garden equipment can contribute nearly 5 percent of the total man-made hydrocarbons leading to ozone formation (EPA, 1998). The significance of combined emissions from numerous relatively small sources has led the EPA to place restrictions on emissions from these smaller operations. In 2004, EPA Region VIII solicited states within their region for an inventory of VOC emissions from flaring and venting activities of the oil and gas production industry (DENR, 2004). The EPA's continued review and interpretation of the information provided by industry could lead to additional regulations of these and other similar small emissions sources in the production field.

5.3.9 VOC FLASHING LOSSES

Flashing emissions can occur when a hydrocarbon liquid with entrained gases goes from a higher pressure to a lower pressure. These emissions typically are seen as VOC losses at tank batteries when produced liquids are piped from a pressurized vessel, such as a separator or treater, to an unpressurized storage tank. As the pressure on the liquid drops, some of the lighter compounds dissolved in the liquid are released or "flashed", much like carbonation in champagne. Flashing losses increase as the pressure drop increases and as the amount of lighter hydrocarbons in the liquid increases. The temperature of the liquid and the vessel, as well as the API gravity and Reid vapor pressure of the liquid, also influence the amount of flashing losses. Figure 5-2 is a chart depicting vapor potentials from petroleum storage tanks over a variety of operating scenarios and for differing API gravity oils.

In recent years, these flashing losses have gained considerable attention from state and federal regulatory agencies because they can add up to significant quantities of VOC emissions, a precursor to ozone formation. They are also of interest to producers because they can represent a significant potential energy loss that could be captured and sold for a profit. In some states, it is not uncommon that these emissions are the overriding factor when

5-2: Estimated Volume of Tank Vapors



determining the applicability of an air permit for a facility such as a central tank battery.

The most commonly accepted methods of calculating flashing losses include:

- *Vasquez-Beggs Equation (VBE).*
- *Environmental Consultants and Research, Inc. (EC/R) Equation.*
- *An equation of state (EOS) calculation program such as E&P Tank®.*
- *Determination of the gas oil ratio (GOR) and throughput of the hydrocarbon liquids.*
- *Process simulators including HYSYS®, ChemCAD®, WINSIM®, PROSIM®, and others.*
- *Direct measurement of emissions.*

Depending on the emissions method selected, the input data, and the geographic location, the calculated results can differ considerably. Many states have procedures in place or under development that govern the acceptability of the results from these emissions determination techniques.

5.3.10 AIR POLLUTANT DISPERSION MODELING

The EPA and other permitting authorities rely upon air dispersion models to predict the potential air quality impacts from a proposed permit, to analyze regional air impacts, and to compare potential mitigation strategies. Air models are the primary tool used to determine the potential air quality impacts from:

- *Localized projects as small as the installation of a shipping tank.*
- *Regional planning issues such as CBNG development in the Powder River Basin.*
- *National environmental compliance strategies affecting multiple states.*
- *International concerns dealing with global impacts due to increased carbon emissions.*

Modeling difficulties encountered by regulators and industry include uncertainties about the sources and magnitude of various types of air emissions such as fugitive emissions and the growing complexity of the models themselves. Additionally, due to the intricacies and assumptions necessary to run an air model, the predicted results are seldom in perfect agreement with measured levels of ambient air concentrations. What is important to note is that an air dispersion model can provide a conservative estimate of potential impacts prior to those impacts occurring. This allows time to adjust a project to mitigate potential impacts before they occur.

The complexity of today's models has developed in parallel with the computing power necessary to run them. Growth in computer processing capability has led to the ability to run more complex algorithms for air dispersion models in a shorter period of time.

The advancement of computational modeling also has had an unanticipated effect. Due to the rapid evolution of improvements in dispersion modeling, the number of users has dropped. The result is that there is a greater reliance on a shrinking pool of qualified modelers to analyze the impacts from a growing number of air issues.

Although models have become more complex, they still rely on quality input data. Representatives from agencies such as BLM, USFS, EPA, United States Fish and Wildlife Service, National Park Service, Bureau of Indian Affairs, and the Department of Energy often combine as a multi-agency task force to consider NEPA issues or for an environmental analysis of regional issues such as ozone or haze transport. Often the success of their efforts depends heavily upon data availability and data quality to analyze the air quality impacts of proposed actions. Inaccuracies can lead to costly and unnecessary over-regulation of some emissions sources while inappropriately minimizing the impact of other sources.

5.3.11 SUMMARY

As the regulatory requirements stemming from the CAA have increased both in number and complexity, it is not surprising that they raise new barriers to increasing the nation's domestic oil and gas production. The process of obtaining information about air regulations and filing for permits to construct and to operate new facilities can be complex, slow, and costly. Furthermore, obtaining an air permit is not a one-time event. Operators of permitted exploration and production facilities must remain ever vigilant when considering a process change or equipment upgrade to ensure that the proposed modification does not require a new or amended permit to authorize the project. Whether discussing the reporting of excess emissions events, when to aggregate facilities in a permitting consideration, keeping track of permits, or how to interpret a new regulation, the exploration and production industry is facing an unprecedented challenge in dealing with environmental issues such as air quality.

5.4 SOLUTIONS AND PRUDENT MANAGEMENT PRACTICES

The best way to reduce air pollution is to prevent it from occurring. Many exploration and production companies have benefited from implementation of pollution prevention techniques that improve efficiency or increase profits while at the same time minimizing environmental impacts. Pollution prevention can take many forms such as upgrading equipment, improving management or operational practices, reducing waste through byproduct synergies, and installing emissions controls. For example, horizontal drilling technology has led to a reduction in the footprint of well pads, which in turn, has reduced airborne emissions from construction sources in the early stage of oil and gas development. Identifying beneficial uses of byproduct waste streams to limit environmental impacts such as utilizing produced waters of sufficient quality for irrigation or livestock watering has resulted in economic gain through decreased disposal costs while providing a necessary resource for landowners. Advances in software-based Environmental Management Systems (EMS) allow for better compliance tracking leading to greater operational flexibility by providing the ability to assess potential impacts from proposed actions. Lacking a prevention mechanism, a mitigation or minimization technique often can be utilized. Advances made to "end-of-pipe" emissions control solutions, such as Vapor Recovery Units (VRU), have allowed the capture of saleable product while reducing environmental impacts.

Several governmental programs have been established encompassing prevention, minimization, and mitigation strategies applicable to exploration and production activities. The following presents a brief overview of two such programs and how they are applicable to oil and gas resource development.

5.4.1 EPA AND DOE'S STAR PROGRAMS

In 1992, EPA introduced ENERGY STAR as a voluntary program designed to identify and promote energy-efficient products to reduce greenhouse gas emissions. As of 2006 the program had more than 1,400 users in more than 40 industry or product categories. The program is designed to provide the technical information and tools necessary to choose energy-efficient solutions and best management practices (BMP). ENERGY STAR has successfully delivered energy and cost savings across the country. The program saved enough energy in 2006 alone to reduce GHG emissions equivalent to those from 25 million cars. It also saved $14 billion in utility bills (EPA-DOE, 2007).

The Natural Gas STAR program is a voluntary partnership between EPA and the natural gas industry formed in 1995 to find cost-effective ways to reduce methane emissions (EPA's Natural Gas STAR Program, 2007). The primary goals of the program specific to producers are to promote technology transfer and implement BMPs that are cost effective while reducing methane emissions.

One example BMP from this program is the operation of glycol units. Research by Natural Gas STAR indicated operators often maintain a glycol unit circulation rate that is at least two times higher than necessary to achieve the required reduction in natural gas water content. It was determined that if operators calculated the minimum circulation rate, savings can be realized from:

- *Less salable methane lost to the atmosphere.*

- *Less glycol needed.*
- *Improved dehydrator unit efficiency.*
- *Lower fuel pump use.*

In this case, the potential savings for a single dehydrator unit was estimated to range from $260 to $26,280 per year (Natural Gas STAR, 1997 and EPA Sector Notebooks, 2000).

5.4.2 EQUIPMENT UPGRADES

COMPRESSOR ENGINES

As the EPA and state air regulations began focusing more attention on controlling the emissions from exploration and production activities, compressor engines were early targets. Although units used for lift or other exploration and production purposes typically are less than 100 hp, they can emit sufficient amounts of air pollutants to require an air permit when considered individually or in aggregate. In many cases, producers are turning to downsized equipment or electrical units to avoid permitting and/or pollution prevention. In some cases, an acceptable *de minimis* size exclusion for engines less than 50 or 85 hp has been inserted into regulations to avoid permitting or the addition of add-on controls. Nevertheless, the EPA and state agencies have developed several rules specific to compressor engines. In one industry study (Four Corners AQ Task Force, 2007), participants assembled a matrix of engine control options and associated costs. For example, their findings for rich burn, small engines of less than 100 hp included:

- *Install electric compression – Use of an on-site generator would allow a larger lean-burn engine to replace several smaller rich-burn engines and achieve lower overall emissions. The cost of bringing power to the site may be a prohibitive factor.*

- *Adherence to manufacturers' operation and maintenance requirements - Although this option will not convert a high emission engine into a low emission engine, it can prevent the engine from becoming an extremely high emission engine.*
- *Use of non-selective catalytic reduction (NSCR) / 3-way catalysts and air/fuel ratio controllers on stoichiometric engines - Using an air/fuel ratio controller with NSCR is less favorable for smaller engines than it is for larger engines. Cost per unit of power is higher, and there are questions as to whether the correct exhaust temperature for optimum performance can be maintained reliably. NSCR may not be available for many small engines.*
- *Use ignition retard, exhaust-gas recirculation, and/or an air/fuel ratio controller - These technologies can give a modest reduction in emissions, but they may not be readily available. Also, NO_x emissions are sensitive to the air/fuel ratio setting.*

Another possible option related to engine control is a state-funded regional strategy. Such a program was implemented as a regional ozone control program for engine upgrades and/or replacements in east Texas. An added incentive in this example was that the state provided some funding to help offset the cost of adding controls or purchasing replacement engines (TCEQ, SB 2000, 2007).

PNEUMATIC DEVICES

Leaks and releases from pneumatic devices, particularly from inefficient or "high-bleed" devices, are the single largest source of methane emissions by the oil and gas industry (Methane to Markets, 2005). Several strategies exist to reduce such emissions, including the replacement of high-bleed devices with equivalent low-bleed ones and maintenance of existing devices to replace leaking seals and to optimize valves. Field experience shows that up to 80 percent of all high-bleed devices can be replaced or retrofitted with low-bleed equipment, thereby reducing emissions and increasing marketable product. Maintenance is a low-cost way of reducing methane emissions.

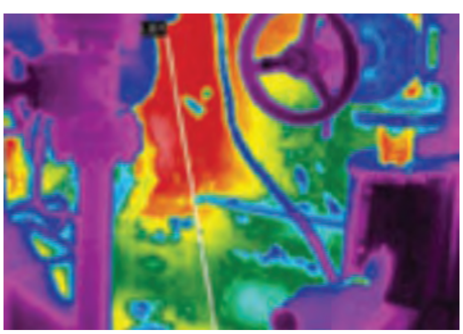
Natural Gas STAR estimates that partners of the program have saved 11.2 billion cubic feet of natural gas to date through improvements to pneumatic devices, saving approximately $22.4 million. Typical pneumatic device replacement costs range from $700 to $3,000 per device. For most of the improvements, the payback period is between six months and a year (Natural Gas STAR, 1997 and Methane to Markets, 2006).

LEAK DETECTION AND REPAIR

Utilization of leak detection and repair (LDAR) programs to identify and reduce fugitive emissions has been in use for several years, particularly in industries that require large numbers of valves, flanges, etc. and is now becoming more common for exploration and production facilities. LDAR practices have grown from periodic sight, smell, and sound practices to incorporating mobile infrared (IR) technology for the detection and location of fugitive hydrocarbon emissions. The exploration and production industry has begun to utilize IR technology through the use of mobile cameras. Environmental agencies as well as oil and gas companies can cover large areas such as entire production fields or target an individual piece of process equipment such as an emergency valve on a storage tank to locate potential gas leaks at remote locations. Such IR cameras may not be capable of identifying the specific components that are leaking or of quantifying the magnitude of the leak. However, they are useful for quickly identifying a relatively small leaking component so that a maintenance team can be mobilized to determine the specific cause of the leak and make necessary repair or adjustments.

VAPOR RECOVERY UNITS

One way to control flashing emissions of VOCs, methane, and natural gas liquids --- and also yield significant economic savings --- is to install vapor



recovery units (VRUs) on oil storage tanks. These units capture approximately 95 percent of the off-gassed hydrocarbon gases, sometimes as rich as 2,000 Btu per scf, which can be diverted to a gas

pipeline for ultimate sale or recirculated for use as onsite fuel. It is estimated that between 8,000 and 10,000 VRUs have been installed in the oil production sector, with an average of four storage tanks connected to each VRU (EPA's Natural Gas STAR Program, 1996). In one case, a VRU installation saved nearly $260,060 a year and offered payback in as little as three months. Since a VRU typically moves relatively low volumes of gases at low pressures, Natural Gas STAR program partners have recommended:

- *Sizing the VRU unit to handle the maximum volume of vapors expected from the storage tanks (a rule-of-thumb is double the average daily volume).*
- *Using a rotary vane compressor or an on-site compressor with excess capacity.*
- *Using a reliable, sensitive control system.*

5.4.3 IMPROVED OPERATIONAL PRACTICES

MICRO TURBINES

Installation of a micro turbine can enable the production of cost effective small-scale electrical power. Micro turbines are small combustion turbines that produce between 25 kW and 500 kW of power. The advantages of micro turbines include relatively low air emissions, low maintenance, and the capability to generate small quantities of electrical power that can be used to power exploration and production equipment.

Micro turbines can run on unprocessed wellhead gas (containing as much as 7 percent acid gases) to generate 3-phase, load-following continuous power. Some micro turbines have been demonstrated to operate on low quality natural gas typically having a heating value of less than 350 btu/scf. At sites where produced gas is flared, a micro turbine will provide an opportunity to limit air pollution and to reduce production power costs. Emissions of NO_x from gaseous fuels have been shown to be less than 9 ppmv at 15 percent oxygen. Emissions of CO and hydrocarbons are typically in the range of 40 ppmv and 9 ppmv, respectively. Post-combustion emissions controls are not required to achieve these numbers, which are comparable to BACT for much larger gas turbines using post-combustion controls such as selective catalytic reduction (Capstone, 2007).

ENHANCED OIL RECOVERY

Enhanced oil recovery (EOR) projects, also known as tertiary recovery, often involve the injection of a gas such as carbon dioxide or high pressure air into the reservoir to improve the recovery of oil from aging fields. In either case, a production company typically will consider methods of capturing the gases recovered during production to both reduce potential air emissions and to enhance the economics of the project. Instead of just destroying the captured gases, there may be advantages to stripping the gases for resale and/or reuse. In the case of capturing carbon dioxide, this gas is normally transported to the field after acquisition from an off-site source; therefore, recycling the CO_2 saves on operational expenses. An added advantage is its potential value in reducing greenhouse gases.

The DOE has estimated that full use of carbon dioxide-EOR in the United States could generate an additional 240 billion barrels of recoverable oil resources. Developing this potential would depend on the availability of commercial CO_2 in large volumes, which could be made possible through carbon capture and transport to producing fields from external CO_2 sources such as power plants, cement kilns, and other large industrial facilities. The DOE estimates that if the EOR potential were to be fully realized for the climate, the CO_2 released from the combustion of 240 billion barrels of oil would be on the order of 100 billion tons of CO_2, equivalent to four times the annual global CO_2 emissions (DOE, 2006).

DIRECTIONAL DRILLING

Directional drilling generally involves drilling non-vertical wells and often drilling multiple wells from the same well pad. Directional wells are drilled for several purposes:

- *Increasing the effective completion length in the reservoir by drilling through the reservoir at an angle.*
- *Drilling into the reservoir where vertical access is difficult such as under a town or lake.*
- *Grouping multiple wellheads together at one surface location can allow fewer rig moves, less surface area disturbance, and reduced permitting requirements.*

CENTRALIZED PRODUCTION FACILITIES

Centralized production facilities are designed with gathering lines from multiple wells leading to a centralized tank battery. This technique is often combined with directional drilling to minimize the development footprint of a production field. Some environmental advantages of centralized well pads include:

- *Reducing the number of areas requiring reclamation by reducing the number of surface disturbances.*
- *Reducing the number of access roads compared to that used for individual tank batteries, which in turn reduces truck traffic and resultant dust emissions.*
- *Reducing the number of facilities requiring permits.*

PERMITTING

Since air permits are often written by the authorizing agency using a template document, the applicant's options are somewhat limited. However, there are some practices that can reduce an applicant's compliance exposure. Regulatory agencies seldom notify the permit holder that a permit or renewal is due, so operators should plan ahead and submit the application to allow ample time for review. Likewise, operators should review the draft permit carefully and respond to any agency query promptly to expedite permit issuance. It is always easier to revise or clarify a permit condition before the permit is issued. Requesting a permit shield in the application can protect the applicant from later enforcement under certain circumstances. It is also important not to include more information or detail in an application than is required to expedite the application review process. Because many air permits are nearly identical, developing an application template might provide significant efficiencies.

Another idea is to derive benefit from project life-cycle strategies. Some air permits can take advantage of strategies that typically occur as production over the life of a long-term exploration and production play unfolds. These permitting strategies include:

- *Emissions caps such as a single limit for one or more pollutants that could be inclusive for an entire field or for several tank batteries.*
- *Using phased development to permit portions of a project to avoid triggering a more rigorous permit for the entire project.*
- *Reducing compression and/or downsizing engines based upon field development and production trends.*
- *Planning that assumes equipment will operate at a maximum capacity of less than 8,760 hours per year (24/365). As an example, emergency generators or flares often are permitted successfully for only 500 hours per year.*

EXCESS EMISSIONS

In recent years, many state regulatory agencies have elevated the priority of defining and regulating excess emissions events. Some states either encourage or require permitting of excess emissions events that occur with regularity, such as planned start-ups and shutdowns or routine blowdowns, and to report on any that are unplanned. Because many agencies are now in the process of determining how to regulate these events, it represents an ideal opportunity for stakeholder participation. Such is the case in Oklahoma where representatives from the state environmental agency, an environmental association, and the air quality advisory council are working closely to draft new rules to address this issue.

AGGREGATION

In an effort to clarify the aggregation issue for the oil and gas industry, the EPA issued a memo providing guidance to permitting authorities in making major stationary source determinations for purposes of the Title V and NSR permitting programs for the industry (EPA, OAR, 2007). Basically, EPA suggested that permitting authorities begin their analysis by evaluating whether each individual surface site qualifies as a stationary source, and then aggregating two or more surface sites only if the sites are under common control and are located in close proximity to each other. The memo defines "surface site" as a single area of development and includes any combination of one or more graded pad sites, gravel pad sites, foundations, platforms, or the immediate physical location upon which equipment is physically affixed.

Congress recognized the unique geographic attributes of the oil and gas exploration and production industry when it provided specific direction under the Air Toxics Program. Specifically, Section 112(n)(4) of the CAA states:

"Emissions from any pipeline compressor or pump station shall not be aggregated with emissions from other similar units, whether or not such units are in a contiguous area or under common control, to determine whether such units or stations are major sources, and in the case of any oil and gas exploration or production well (with its associated equipment), such emissions shall not be aggregated for any purpose under this section."

Although the EPA's memo acknowledges that aggregation determinations for major source purposes remain a case-by-case decision, the agency's guidance suggests that permitting authorities define each single surface site as a separate stationary source. Such sites generally would not need to aggregate activities located on different oil and gas properties (oil and gas lease, mineral fee tract, subsurface unit area, surface fee tract, or surface lease tract) or located on the same lease, when the sites are not located in close proximity to each other.

An important takeaway from the memo is that permitting authorities now have guidance that allows them to make common-sense decisions on aggregating oil and gas facilities. Therefore, oil and gas companies can work with their permitting authority to determine a strategy that is in the best interest of both parties.

TRACKING PERMITS AND FACILITIES

As air and other environmental requirements including permits, plans, reporting, recordkeeping, and monitoring have increased, exploration and production companies have realized that an efficient environmental management system (EMS) is necessary to keep track of these requirements to reduce their compliance risk. Unfortunately, some attempts to select such an EMS have led to more problems than solutions. Therefore, good planning and defining of what the system needs to accomplish is critical in selecting an EMS solution. Up-front planning should include: consolidating all of an operator's environmental applications and systems into a single program, deciding whether to integrate an environmental system into the firm's broader informational technology (IT) framework, and defining what capabilities are absolutely necessary to include in the EMS solution.

A good first step is for the operator to organize all of the existing spreadsheets and databases that are used for collecting and monitoring data and then make an outline to guide how this data is most advantageously consolidated. This task might include assembling hard copy permits for facilities located in various states, checking each agency's web site for rules applicable to registered facilities that are without a hard copy authorization, and reviewing the seller's hard copy permits for acquired sites.

Generally, it is vital to get the IT staff involved in selecting and implementing an EMS and avoid creating or purchasing a stand-alone EMS. Ideally, the EMS is designed to be flexible enough to fit into existing IT systems. By getting IT staff involved in defining the system's requirements and capabilities, the ultimate product will benefit from standardized company IT procedures, assure system support from staff, and hopefully gain buy-in from both upper management and end users.

Finally, an operator must distinguish the capabilities that such a system absolutely must include. Added functionality ("bells and whistles") usually means added complexity and expense. Examples of system functionality considerations include a single data input source or opening access to allow input from multiple staff members, automated reporting, record keeping, and monitoring requirement deadline prompts. How system updates will be integrated, and if the system will be designed strictly for air issues, or comprehensive environmental, or health and safety issues as well, also must be considered. Time spent on this step will be useful when considering candidate systems or serving as a technical advisor for internal development and implementation of the system.

EPA'S COMPLIANCE ASSISTANCE CENTERS

The Internet is a valuable resource for information and possible solutions to air issues. One such site developed by the EPA in partnership with industry, academic institutions, and other groups is the Compliance Assistance Center for the Oil and Gas Extraction Industry (EPA, Sector Notebooks, 2000). This sector-specific, on-line resource is designed to assist users in understanding their environmental obligations, improving compliance, and finding cost-effective ways to comply. The web site contains a notebook that includes:

- *A comprehensive environmental profile.*
- *Industrial process information.*
- *Pollution prevention techniques.*
- *Pollutant release data.*

- *Regulatory requirements.*
- *Compliance and enforcement history.*
- *Government and industry partnerships.*
- *Innovative programs.*
- *Contact names.*
- *Bibliographic references.*
- *Description of research methodology.*

STAKEHOLDER PARTICIPATION

Perhaps one of the most underutilized methods for effectively impacting proposed regulations or policy is to participate as a stakeholder during rule development. Prior to widespread use of the Internet, many stakeholders had to rely on word of mouth or regular attendance at association events to stay current on regulatory updates. Today, operators can monitor multiple state agency and professional association web sites. This can provide early notice on state or federal rule proposals and in some cases the option to submit comments. Early stakeholder input is more effective than a complaint filed after rule promulgation.

One example of a constructive stakeholder interaction was seen in Montana. The state was developing new rules specific to oil and gas production activities and was working closely with the state's petroleum association and other stakeholders in this process. This resulted in new air permitting rules and a registration program that were tailored to the industry yet still protective of the environment. A side benefit is that the state's permitting staff became better informed on exploration and production activities while the industry participants developed a good working relationship with the state regulatory staff.

Another example was a coal bed natural gas (CBNG) resource development project located in New Mexico. The site was a premier hunting and fishing destination and working bison ranch, with a diverse range of ecological environments. CBNG development was being conducted under a partnership between the surface estate owner and mineral estate owner. In this case, these parties voluntarily entered into an agreement that would govern how development operations would take place. That agreement provided the guidelines, checks and balances, and requirements for CBNG development. By agreeing to use global positioning technologies, satellite imagery, and wildlife/forestry management tools, the development phase of the project was completed in such a manner as to minimize both short- and long-term adverse effects to the surface estate owner, while allowing for the efficient development and production of CBNG.

5.4.4 SUMMARY

The concepts and reasonable and prudent management practices discussed in this section are not a complete list of solutions to the issues affecting the onshore production of oil and gas in the United States; however, these practices may both inform and assist with that task. The next section outlines air concerns that could present challenges to domestic energy development in the future and discusses recommended areas for additional research based upon their potential benefits to the industry.

5.5 FUTURE DEVELOPMENTS IN AIR QUALITY ISSUES RELATED TO DOMESTIC OIL AND GAS DEVELOPMENT

5.5.1 GLOBAL CLIMATE CHANGE

The oil and gas industry will play a large role in two highly important issues over the coming decades – global climate change and the need for increased energy development. The industry role in global climate change is linked to the emissions of greenhouse gases (GHG). Some greenhouse gases such as carbon dioxide occur naturally and are emitted to the atmosphere through natural processes and human activities. Other GHG, such as fluorinated gases, are created and emitted solely through human activities. The principal GHGs potentially resulting from exploration and production activities are:

- *Carbon Dioxide: CO_2 enters the atmosphere through the burning of fossil fuels and as a result of chemical reactions during the manufacture of cement, biofuels, etc.*

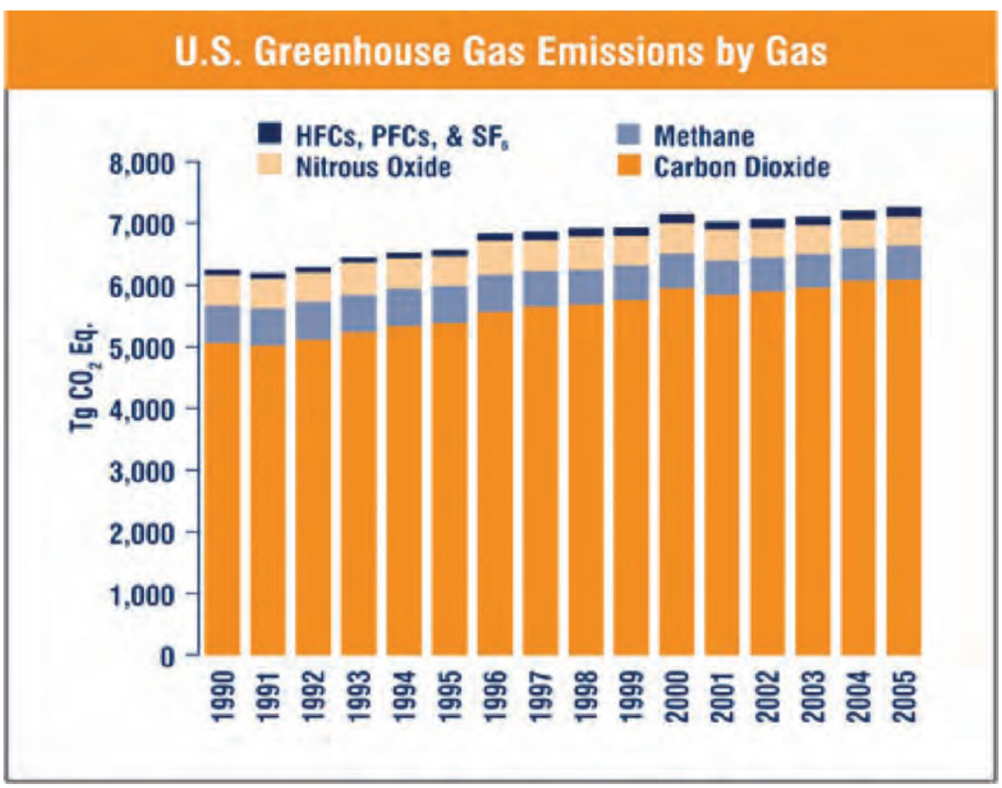
- *Methane: CH_4 potentially is emitted during the production of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.*
- *Nitrous Oxide: N_2O is emitted during the combustion of fossil fuels and solid waste, as well as from agricultural and industrial activities.*

Carbon dioxide and methane are the GHGs most commonly found in conjunction with oil and gas exploration and production operations. Figure 5-3 illustrates the relative contribution of each GHG for the period 1990-2005 (EPA, Climate Change, 2007). By far, the primary GHG emitted in the United States was CO_2, representing approximately 84 percent of total greenhouse gas emissions. However, the global warming potential of each GHG can vary considerably. For example, an EPA inventory states that a ton of methane has the global warming potential of 21 tons of carbon dioxide (EPA, Climate Change, 2007). This is because methane has a much greater potential to trap heat in the atmosphere, which potentially results in increased global warming. Methane emissions from United States natural gas field production in 2000 were at 26.2 teragrams (Tg, or million metric tons), expressed as carbon dioxide equivalents, and methane emissions from crude field production for that year at 21.2 Tg CO_2 equivalent. These numbers do not include the greenhouse gas impact from fuels burned to support field production operations.

Another point found in the EPA's GHG emissions inventory is a comparison of field production losses with processing and distribution losses. Total methane emissions from the entire natural gas supply chain, including field production, processing, transmission, storage, and distribution, were 5.54 Tg. The corresponding total from the crude supply

Figure 5-3: United States Greenhouse Gas Emissions by Gas

EPA Climate Change. 2007



chain, including refining, was 1.04 Tg. Thus, while field production of the two fuels accounts for roughly the same quantity of methane emissions, by the time the fuel is ready for distribution to the end user, a disparity emerges. Field production is approximately 23 percent of the total methane loss for natural gas, but accounts for nearly the entire methane loss for crude. The potency of methane as a GHG should be considered when the relative environmental merits of crude and natural gas are being compared.

5.5.2 FUTURE GHG IMPACTS ON THE OIL AND GAS INDUSTRY

In 2007, California published a preliminary draft for comment of a proposed regulation for the mandatory reporting of GHG emissions. California is not alone in moving to mandate such reporting. Georgia, Illinois, Maine, Maryland, New Hampshire, New Jersey, New Mexico, New York, Oregon, Vermont, Washington, and Wisconsin also have rallied around this issue. These programs vary widely from mandated efforts to cooperative efforts, from reporting carbon dioxide only to reporting all GHGs, from state efforts to regional efforts, and from a reporting program only to a program with a cap and trade marketing system. Although the EPA has yet to develop a federal program mandating GHG emissions reporting, the DOE has issued guidelines for the voluntary reporting of GHG emissions. It seems only a matter of time before all GHG emissions will be a routine part of the oil and gas industry's annual reporting requirements across the country.

The 1992 Energy Policy Act established a GHG reduction registry. The registry was intended to allow for the quantification and submittal of GHG reduction actions into a central database for future use in response to new regulatory requirements. Although established and functional, the registry is not without problems. Since it is designed to cover only specific project reductions, a registrant can receive credit for reductions in one sector of its business while possibly producing increased levels of GHGs overall. Reliability is also a concern because the data is self-reported with no standardization or third-party certification. Since participation in the registry is voluntary, some of the biggest emitters might not be participating.

The United States can expect the controversy over the causes of global warming to continue, but it should be evident that every industry, including domestic energy development, will continue to see a great deal of future attention on GHG-related issues such as:

- *GHG synergies.*
- *Renewable energy credits.*
- *Energy conservation.*
- *Methane collection and combustion.*
- *Emissions quantification.*
- *Sequestration credits.*
- *Capping and trading of credits.*

5.5.3 METHANE REDUCTION PROGRAMS

Because mandatory methane emissions reduction programs are still developing, the oil and gas industry, along with state and local governments, can collaborate with EPA to promote profitable opportunities for reducing emissions of methane. One such program is the Methane to Markets Partnership (EPA, Methane to Markets, 2007). The Partnership is an international initiative that advances cost-effective, near-term methane recovery for use as a clean energy source. The goal of the program is to reduce global methane emissions to enhance economic growth, strengthen energy security, improve air quality, improve industrial safety, and reduce emissions of greenhouse gases.

The Partnership focuses on four sources of methane emissions:

- *Agriculture (animal waste management).*
- *Coal mines.*
- *Landfills.*
- *Oil and gas systems.*

The collective results of this voluntary program have been substantial. Total United States methane emissions in 2005 were more than 11 percent lower than emissions in 1990, despite economic growth over that same time period (EPA, Methane to Markets, 2007). EPA expects that these emissions will continue to fall in the future due to expanded industry participation and the ongoing commitment of the participating companies to identify and implement cost-effective technologies and practices.

The production, processing, transmission, and distribution of oil and natural gas is the second largest anthropogenic (human-influenced) methane source worldwide, releasing as much as 88 billion cubic meters (BCM) or 343 million metric tons of carbon equivalent (MMTCE) of methane to the atmosphere annually. Although natural gas is a clean source of energy, methane losses from natural gas systems account for 15 percent of total worldwide methane emissions. Emissions primarily result from normal operations, routine maintenance, and system disruptions. Emissions vary greatly from facility to facility and are largely a function of operation and maintenance procedures and equipment conditions. **Figure 5-4** presents methane emissions from the oil and gas sector in selected countries (EPA, Methane to Markets, 2007).

Methane leaks and other fugitive emissions along the natural gas industry's supply chain represent product losses that can be avoided using cost-effective practices discussed in the preceding section of this report. In addition to financial benefits, pursuing natural gas emission reductions makes good environmental sense and effectively contributes to both natural resource protection and good environmental stewardship.

5.5.4 CARBON DIOXIDE SEQUESTRATION

Atmospheric levels of CO_2 have risen from pre-industrial levels of 280 parts per million (ppm) to present levels of 377 ppm (IPCC, 2001). Some evidence suggests this observed rise in atmospheric CO_2 levels is due primarily to expanding use of fossil fuels for energy. Predictions of global energy use in the next century suggest a continued increase in carbon emissions and rising concentrations of CO_2 in the atmosphere unless major changes are made in the way energy is produced and used. One way to accomplish this is to use energy more efficiently allowing a reduction in fossil fuel dependence. Another is to increase the use of nuclear power and renewable sources such as solar energy,

Figure 5-4: International Methane Emissions from Natural Gas and Oil Infrastructure

Country	Methane Emissions (MMTCE)		
	1990	2000	2010 (projected)
Russia	91.6	69.1	74.7
United States	40.3	37.8	39.6
Ukraine	19.6	16.4	10.8
Venezuela	11.0	14.3	18.6
Uzbekistan	7.4	9.2	11.7
India	3.5	6.7	15.0
Canada	4.7	6.4	6.5
Mexico	3.0	4.2	6.0
Argentina	2.2	3.7	8.3
Thailand	0.8	2.3	4.3
China	0.2	0.4	1.3

wind power, and biomass fuels. A third method to manage carbon is through sequestration.

Carbon sequestration refers to the provision of long-term storage of carbon in the terrestrial biosphere, underground, or in the oceans so that carbon dioxide concentrations in the atmosphere will be reduced. Planting trees is one example of a natural mechanism that acts as a carbon sink. This is an effective way to capture significant levels of atmospheric carbon dioxide; however, more novel techniques are also being considered. DOE's Office of Science is focusing its carbon sequestration efforts on (DOE- Sequestration, 2007):

- *Sequestering carbon in underground geologic repositories.*
- *Enhancing the natural terrestrial cycle through CO_2 removal from the atmosphere by vegetation and storage in biomass and soils.*
- *Sequestering carbon in the oceans by fertilization of phytoplankton with nutrients, and injecting CO_2 to ocean depths greater than 1000 meters.*
- *Using microbial processes to produce fuels such as methane and hydrogen from fossil fuels or other carbonaceous sources, including biomass or even waste products.*

A significant amount of research with regard to carbon sequestration methodologies has been conducted. One such paper, entitled "Applying a Synergistic Approach to Sustainable Energy Development" (ALL, 2007), outlines a variety of sustainable approaches that explore beneficial use alternatives for produced water, carbon capture and sequestration, and the manufacture of biofuels.

5.5.5 ENHANCED OIL RECOVERY

One unconventional method of producing more energy is through EOR utilizing carbon dioxide injection. Developing this potential depends on the availability of CO_2 in large volumes, typically from geologic or industrial sources. Where old oil fields are not located in close proximity to one of these sources, the CO_2 would require transportation infrastructure (*e.g.*: pipelines) to move it from the source to the oil field. In the United States, the DOE has estimated that undeveloped domestic oil resources total 1,124 billion barrels, of which some 430 billion barrels are estimated to be technically recoverable (DOE-EOR, 2007). These potentially recoverable oils include: yet to be discovered reservoirs, CO_2-EOR recoverable oil, unconventional oil from deep heavy oil reservoirs and tar sands, and residual oil in reservoir transition zones. Although these estimates are debatable, the amount of potentially recovered oil by processes such as CO_2-EOR is vast. CO_2 injection has been used successfully throughout the Permian Basin of West Texas and eastern New Mexico, and is now being pursued to a limited extent in Alaska, Colorado, Kansas, Mississippi, Montana, North Dakota, Oklahoma, Pennsylvania, Utah, and Wyoming.

One topic that is being debated and researched is the trade-off between EOR and global warming (The Oil Drum, 2005). As discussed above, most CO_2-EOR methods do sequester a GHG as a part of the process. However, to claim some marketable credit in a trading program, the CO_2 must remain in the underground reservoir formation. Some studies have suggested that the subsequent burning of the recovered oil creates as much if not more carbon than was sequestered. Thus, the debate over the amount of CO_2 injected vs. the amount of CO_2 released from the recovered oil. There is also the argument that CO_2-EOR that captures CO_2 from industrial sources such as coal-fired power plants or ethanol plants provides a more GHG-friendly method of oil recovery by reusing CO_2 that would otherwise be vented into the atmosphere. With growing energy demand and widespread applicability of carbon sequestration potential in EOR methods, these issues will continue to be the subject of future research and discussion.

5.5.6 NEW REGULATIONS

In 2007, the United States Supreme Court ordered the EPA to reconsider its earlier decision not to regulate GHG emissions. The court said that the agency considered improper factors in 2003 when it decided not to order cuts in carbon emissions and that the agency has the authority to regulate GHGs. Although the EPA has been slow to regulate GHG emissions, there is increasing pressure for them to do so from state agencies, international organizations, and the public. It's likely that major GHGs will become subject to federal regulation in the near future.

Ozone (O_3) is a gas created by a photochemical reaction between oxides of nitrogen and VOCs in the presence of sunlight. To protect public health and welfare, the EPA issues NAAQS for ground-level ozone. The agency first issued standards in 1971 (1-hour standard of 0.08 ppm); then revised the standard in 1979 (1-hour standard of 0.12 ppm); and again in 1997 (8-hour standard of 0.08 ppm). In 2007, the agency again proposed to strengthen the ozone NAAQS with the new standard to take effect in 2010 (EPA, Ozone, 2007). When the new ozone NAAQS becomes final, some areas previously in attainment will be re-designated as non-attainment areas while others that were already in non-attainment status could be reclassified ("bumped up") to a new category: *e.g.*: changing from moderate to serious. Since agencies regulate ozone through restrictions on VOC and NO_x emissions, the exploration and production industry would be impacted by additional controls for those regulated pollutants.

A potential example of such a classification change is Tulsa County in Oklahoma. The Tulsa area has experienced monitored readings of ground level ozone close to the current non-attainment levels. The new designation could force EPA to re-designate this area and thus lead to more restrictive levels of VOC and NO_x emissions for sources emitting in or near Tulsa County.

5.5.7 RESIDUAL RISK RULES

In March 1999, EPA released a final report entitled "Residual Risk Report to Congress." This report described the strategy the agency would use to assess health and environmental risks from air toxics remaining after implementation of technology or performance-based air toxics regulations (MACT) required under the CAA. This remaining risk is referred to as "residual risk." The CAA [section 112(f) and (d)] requires EPA to assess residual risks, and if necessary, promulgate additional regulations to provide an ample margin of safety (NPRA, 2007).

EPA employs a two-tier risk approach to determine the extent of the residual risk. The first tier is a screening level assessment, followed, if necessary, by a second tier consisting of a more detailed assessment. The refined assessment provides the basis for setting standards. EPA is continuing to gather industry-specific data and to analyze what, if any, residual risk exists based upon that data. Since the air toxics associated with the exploration and production industry are well known and most regulations already have been developed based upon those risks, additional residual risk-based standards are not expected in the near future.

5.5.8 ENERGY LOSS FROM FLARING

Flares have been an integral part of the oil and gas exploration and production industry since its inception and that will likely continue; however, their role may be changing. Traditionally, flares have proven to be a suitable means of destroying VOCs and a cost-effective emergency backup emissions control strategy, but they are not without their concerns. Perhaps the most important issue occurs when flares are relied upon to destroy produced natural gas in areas without pipeline access. Such loss of valuable energy is almost certainly to come under heavy scrutiny from both regulatory agencies and producers. It seems logical that this interest will lead to new research to find uses for this gas such as on-site fuel, methods to gather sufficient quantities to create new sales markets, and of course new pipelines to get it to market.

While flares are effective in destroying VOCs and methane, they also release carbon dioxide, which leads to some trade-offs on the GHG issue. Flares have found common use in burning sulfur bearing gas either directly or downstream of an amine unit. However, this process typically represents a trade-off between the destruction of hydrogen sulfide and creation of sulfur dioxide, which is itself a criteria pollutant and thus heavily regulated. In light of the nation's growing demand for energy and increased awareness of global warming, it seems likely that flare applications will be the subject of future research.

5.5.9 ENERGY LOSS FROM DRILL RIG ENGINES

Although air emissions from drill rigs generally do not require a permit (they are often considered portable emission units that are exempted due to their short duration of emissions), they are included in NEPA and other regional studies. Typically, rising oil and gas prices signal an associated increase in drilling activity. Therefore, emissions reduction strategies for drill rig engines can be expected to come under greater scrutiny as the U.S. seeks to solve its growing energy needs.

Some of the same emissions controls (SCR, AFRC, replacement by electric units, etc.) for compressor engines discussed in this handbook can be equally useful to lower emissions from drill rig engines. Other options useful for this purpose can include: injection-timing strategies, solar-powered engines, use of ultra-low sulfur diesel fuel, and exhaust gas recirculation. This source of air emissions, although a temporary one at most locations, can be expected to be subject to added regulatory scrutiny and thus a likely target for emissions reductions in the future.

5.5.10 SUMMARY

Concerns over the nation's role in global climate change and the growing energy deficit continue to gain international attention. As debate over these issues continues, it is reasonable to expect that funding will be made available for continued research into solutions to address these important issues. The oil and gas industry will be challenged to develop new energy sources to meet a growing demand while doing its share to reduce the GHG emissions that may play a role in global climate change.

5.6 CONCLUSIONS AND RECOMMENDATIONS

5.6.1 CONCLUSIONS

Air quality has been improving steadily across the United States since the implementation of the CAA. Current regulations should further reduce air pollution levels. Even the relatively small air emissions sources typical of oil and gas extraction activities are becoming the subject of specific rule-making. At the same time, the oil and gas industry faces the task of continuing to develop the nation's energy resources in an environmentally responsible manner. This will require the industry to do its share in addressing future air issues such as reducing GHG emissions that might play a role in global climate change. Perhaps it is not surprising then that as the regulatory requirements stemming from the CAA have increased both in number and complexity, an associated outcome is the creation of new barriers to domestic oil and gas development.

To meet these challenges, operators must keep abreast of evolving air regulatory requirements. In some circumstances they could be required either to seek new authorizations or to amend existing permit(s) to construct, modify, or operate their facilities. As a result, many production companies are adopting some of the new management practices presented herein to avoid, minimize, and/or mitigate air impacts.

5.6.2 RECOMMENDATIONS

Today, the oil and gas producer faces an unprecedented challenge in new environmental regulations and a growing number of air issues. Since it is reasonable to expect such challenges to continue to impact domestic oil and gas development, companies may be able to ease their burden through one or more of the following recommendations:

- *Today's operator must stay abreast of new regulatory requirements and comply with those already in place. As ever greater numbers of production companies become more environmentally proactive, they are recognizing the positive impacts that can arise from a compliant program.*
- *Operators are urged to organize their environmental documents either by simple self-generated spreadsheets or formal integrated environmental management information systems. There is significant benefit to organizing air permits, reports, and other environmental records that could otherwise quickly become a record-keeping nightmare if not well managed.*
- *Operators should turn environmental barriers into benefits. By staying atop new regulations, a progressive company can look for opportunities such as: emissions trading, emissions capture for sale, beneficial uses from emissions reductions, state or federal environmental funding, and positive public relations.*
- *The industry is also urged to embrace active stakeholder involvement in the development of new regulations.*

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