ENERGY DEVELOPMENT GUIDELINES FOR MULE DEER

A Product of the
Mule Deer Working Group

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PREFACE

The geographic scope, intensity, and pace of domestic energy development have potential to impact fish and wildlife habitats on a large scale. The capability of habitat to sustain wildlife into the future will depend on effective project planning and mitigation developed through constructive collaboration among federal land management agencies, state, provincial, and tribal wildlife management agencies, private landowners, industry, and other conservation partners.

This document establishes guidelines that will enable energy development to proceed in a manner reasonably compatible with habitat requirements of mule and black-tailed deer. These *Energy Development Guidelines for Mule Deer* will help resource managers focus on pre-project risk assessments, appropriate project designs, effective mitigation and reclamation, and adequate monitoring to better conserve mule deer habitats through adaptive management. Historically, the federal process of energy leasing and development has been too inflexible to apply best technology and information currently available. These guidelines represent the state of our knowledge at the time of publication, but it is the intent of the Mule Deer Working Group that they be promptly updated with all subsequent and pertinent research that becomes available to decision makers.

Photo courtesy of George Andrejko/AZGFD

INTRODUCTION

Black-tailed and mule deer (collectively mule deer, *Odocoileus hemionus*) are icons of the North American West. Perhaps no animal better symbolizes the region in the minds of the American public. Because of their popularity and broad distribution, mule deer are one of the most economically and socially important animals in western North America. In a 2006 survey of wildlife-related recreation, the U. S. Fish and Wildlife Service (USFWS) reported nearly 3 million people hunted in the 19 western states (USFWS 2007). In 2006 alone, hunters were afield almost 50 million days and spent more than $7 billion on lodging, gas, and hunting-related equipment. Although the survey encompassed all forms of hunting, mule deer have traditionally been one of the most important game animals in the West. According to the same survey, 25.6 million residents in 19 western states spent more than $15.5 billion "watching wildlife" in 2006. The value of abundant wildlife populations cannot be overemphasized. Because mule deer are inextricably tied to the history, development, and future of the West, the species is one of the true barometers of ecological conditions in western North America.

Mule deer are distributed throughout western North America from the coastal islands of Alaska, to southern Baja Mexico and from the northern border of the Mexican state of Zacatecas to the Canadian provinces of Saskatchewan, Alberta, British Columbia, and the southern Yukon Territory. Within these broad latitudinal and geographic gradients, mule deer have developed incredibly diverse behavioral and ecological adaptations enabling the species to occupy a diversity of climatic regimes and vegetation associations.

Federal land management agencies regulate surface disturbing activities, including energy development, throughout much of the mule deer range in the West. In the eastern portions of mule deer range, private landowners control how habitat is managed. Mule deer habitats are increasingly vulnerable to unprecedented threats from a range of anthropogenic developments. If mule deer habitats are to be conserved, it is imperative that government agencies and private conservation organizations elevate their awareness of the species' key habitat requirements, engage in habitat restoration initiatives, and fully integrate effective habitat protection and mitigation practices into all land use decisions.

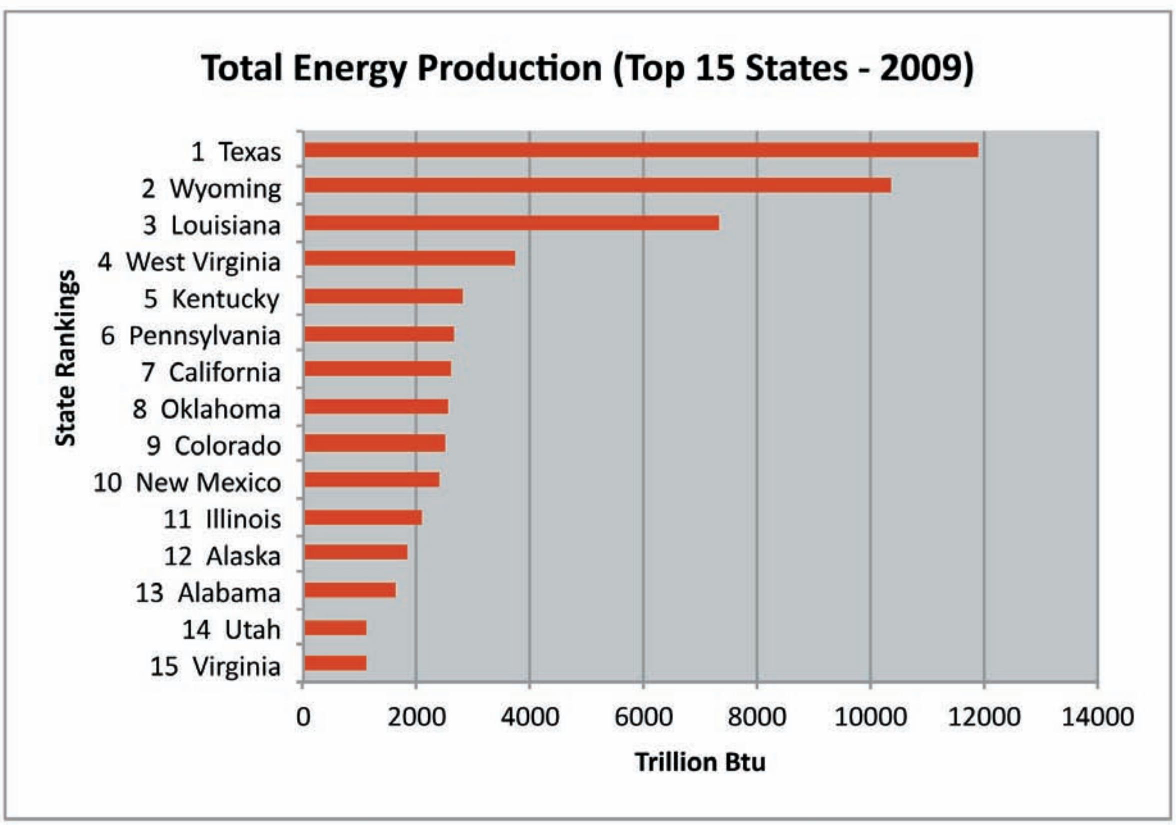
State wildlife agencies manage and regulate wildlife populations that are dependent on those habitats managed by the Federal land management agencies and private landowners. The Western Governors' Association (WGA) recognized the need to coordinate efforts to protect and maintain wildlife migration corridors and crucial habitats (WGA 2008). They approved Policy Resolution 07-01 to work "in partnership with important stakeholders, to identify key wildlife corridors and crucial wildlife habitats in the West and make recommendations on needed policy options and tools for preserving those landscapes." The WGA's *Wildlife Corridors Initiative*, is a multi-state and collaborative effort to improve knowledge and management of wildlife corridors and crucial habitat. The primary objective was to develop a tool for policy makers to integrate wildlife corridor and crucial habitat values into planning decisions, and promote best management practices for development to reduce harmful impacts on wildlife.

Energy consumption and production continue to be the focus of the nation's energy policy. According to the National Energy Policy (2001), "…if energy production increases at the same rate as during the last decade our projected energy needs will far outstrip expected levels of production. This imbalance, if allowed to continue, will inevitably undermine our economy, our standard of living, and our national security." As pressure mounts to locate and develop additional sources of domestic energy in the western states, careful attention must be given to how industry can maintain effective habitat conditions for mule deer. To best do that, rigorous research to determine population level effects of energy development on mule deer needs to continue as many questions remain unanswered. Hebblewhite (2011) observed many population level surveys have identified important changes, but the mechanisms of change remain speculative. He concludes research needs to occur to better achieve an evidence-based framework for mitigating development.

Sawyer et al. (2002) suggested habitat loss and fragmentation caused by extensive energy development could pose a serious threat to mule deer and pronghorn (*Antilocapra americana*) populations in western Wyoming. The national focus on energy independence should, at the same time, recognize the importance of maintaining intact wildlife habitats supporting diverse economic, recreational, social, and aesthetic values.

Areas of known or potential energy resources overlap much of what is considered important mule deer habitat. Development of those resources brings about habitat disturbance or loss due to construction of well pads, roads, pipelines, mine facilities, wind and solar farms, and other features. In addition, disturbances from vehicle traffic, noise, and human activities often displace mule deer to areas farther away from well pads (Sawyer et al. 2006). Presumably this displacement is to areas of less suitable habitat. This disturbance and displacement diverts time and energy away from foraging, resting, and other activities that improve physiological condition (Gill et al. 1996, Frid and Dill 2002). Therefore, there is the potential to decrease mule deer survival and recruitment rates and ultimately lead to population-level effects. Activities associated with energy exploration and development often preclude or inhibit use of winter ranges that are critically important to mule deer (Lutz et al. 2003, Sawyer et al. 2006). Roads and traffic also limit mule deer use of important habitats (Sawyer et al. 2009c). The impact of roads has been increasingly recognized in the past decade (Forman et al. 2003). In fact, highway-associated impacts are one of the most prevalent and widespread stressors affecting natural ecosystems in the U.S. (Noss and Cooperrider 1994, Trombulak and Frissell 2000, Farrell et al. 2002). These impacts are especially severe in the western states where oil and gas, and more recently wind and solar energy, are being developed rapidly at a time when mule deer populations are depressed (Heffelfinger and Messmer 2003, Lutz et al. 2003, Hebblewhite 2008).

While other energy sources such as nuclear and woody or cellulosic biomass conversion could present some issues or concerns, their impact on mule deer or mule deer habitat is not considered significant and therefore not addressed here. For purposes of this document we focus guidelines on the forms of energy development having significant effect on mule deer and their habitat.



Nine of the top 15 energy producing states are in the West and provide habitats for black-tailed or mule deer (U.S. Energy Information Administration, http://www.eia.doe.gov/state/state_energy_rankings.cfm?keyid=89&orderid=1)

OIL AND GAS ENERGY DEVELOPMENT

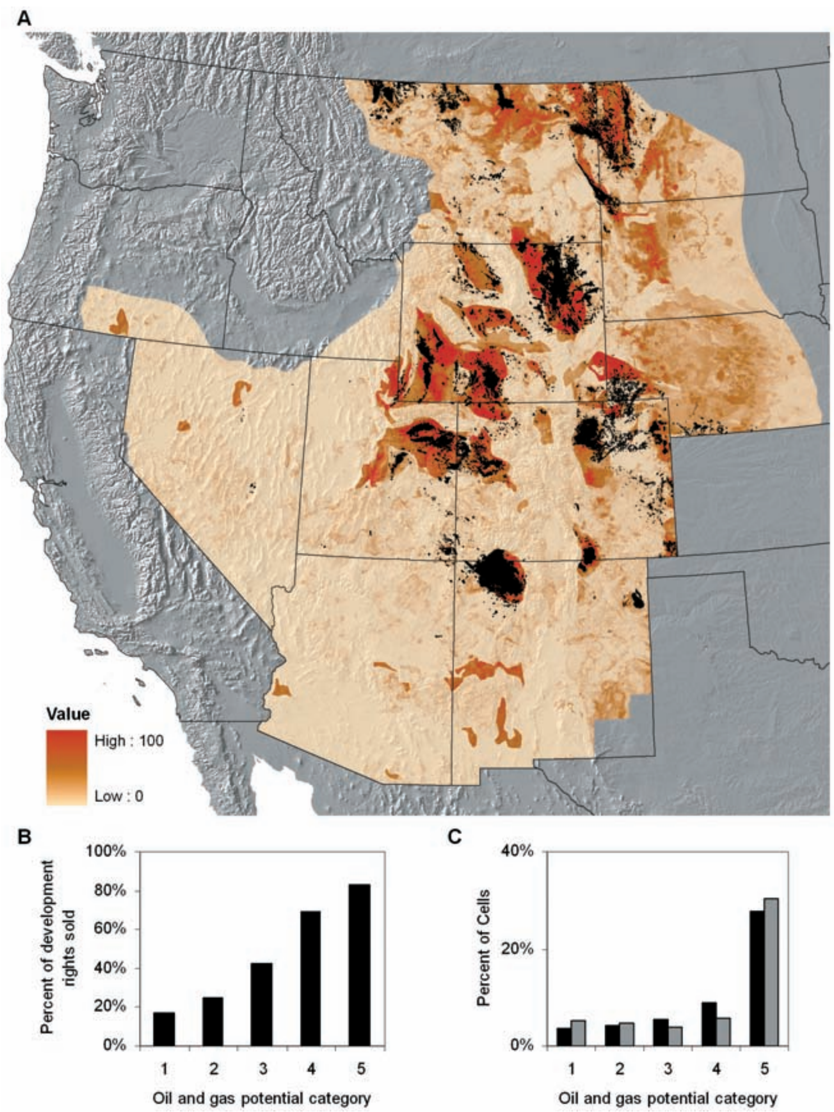
Background

Exploration and extraction of oil and gas resources continue to have a range of effects on mule deer habitats. Some types of disturbance can be positive if they improve vegetative structure or nutritional content. However, activities associated with extraction of energy resources often have adverse effects on mule deer. The severity of impact depends upon the amount and intensity of the disturbance, specific locations and arrangements of disturbance, and ecological significance of habitats affected. In Colorado, it has been demonstrated most mule deer populations are ultimately limited by habitat (Bartmann et al. 1992, White and Bartmann 1998, Bergmann et al. 2007, Bishop 2007, Watkins et al. 2007). Thus, small isolated disturbances within non-limiting habitats are of minor consequence within most ecosystems. However, larger-scale developments within habitats limiting the abundance and productivity of a mule deer population are a significant concern. Both direct and indirect impacts associated with energy and mineral development have the potential to affect ungulate population dynamics, especially when impacts are concentrated on winter ranges (Sawyer et al. 2002).

In order to meet their nutritional and energy needs, mule deer throughout most of North America depend on distinct seasonal ranges for summer (high elevation forests) and winter (low elevation shrub and grasslands). Migratory mule deer rely on networks of migration routes to transition between these critical areas (Sawyer et al. 2005). Oil and gas development not only removes habitats from these ranges, but may also displace deer from other preferred habitats (Sawyer et al. 2006) and create barriers that hinder migration and use of remaining habitats (Sawyer et al. 2009a). In some cases, construction activities might remove decadent vegetation and provide the opportunity to reclaim the area with improved forage.

Throughout the West, reservoirs of oil and gas commonly overlie important mule deer habitats, including winter ranges (Sawyer et al. 2006). Freddy et al. (1986) demonstrated that mule deer exhibit an alert-flight response at distances up to 0.08 and 0.12 mile from sources of noise and activity from snowmobiles and people afoot, respectively. Sawyer et al. (2006, 2009a, b) showed that high-use deer areas on winter range consistently occurred 1.2 to 1.8 miles away from well pads. Additionally, Sawyer et al. (2009a) found mule deer avoided all types of well pads, but selected areas farther from well pads with greater levels of human disturbance (i.e., traffic). They also concluded liquid gathering systems and directional drilling are effective practices to reduce human activity and surface disturbance during development. They suggested indirect habitat loss to mule deer may be reduced approximately 38-63% when liquids are collected in pipelines rather than stored at well pads and hauled away with tanker trucks. In western Wyoming, surface disturbance was reduced by 70-80% using directional drilling (Sawyer et al. 2009b).

A relatively new area of significant interest has been development of natural gas from coal beds. Depending on depth of the coal seam, coal bed natural gas (CBNG) production and coal mining activities can occur in the same general area, thus raising concerns about possible cumulative effects on mule deer and other wildlife. Development and extraction activities associated with CBNG,



Oil and gas resource potential in the Intermountain West (Copeland et al. 2009)

coal, and deep-well natural gas have potential for profound and long-term impacts on the environment. For the purpose of this discussion, oil and gas development includes those activities used to extract all hydro-carbon compounds such as natural gas, crude oil, coal bed methane, and oil shale.

Drilling operations during winter months (15 Nov – 30 Apr) causes measurably greater impact on mule deer compared to production and maintenance activities. Sawyer et al. (2009a) cautioned wintering mule deer are sensitive to drilling disturbance and that indirect habitat loss may increase by a factor of >3 when seasonal wildlife protection restrictions are waived. Wildlife managers should expect considerable short-term displacement of wintering mule deer if wide-spread, year-round drilling is permitted in crucial winter range and long-term displacement depending on the level of disturbance during well field operation.

Impact Thresholds
Impact thresholds are levels of development and disturbance that impair key habitat functions by directly eliminating habitat; disrupting wildlife access to, or use of habitat; or causing avoidance and stress (WGFD 2010a). Impact thresholds, appropriate management, and mitigation will vary depending on habitats affected. Our most pressing need is to address the species and habitat functions affected by impending, large-scale developments primarily in sagebrush-steppe ecosystems.

Impact thresholds are based on 2 quantitative measures: density of well pad locations and cumulative area of disturbances/mile^2. The cumulative area of disturbance represents direct loss of habitat. While evaluating impacts to sage-grouse, Naugle et al. (2006) concluded density of well pads is highly correlated with other features of development and therefore comprises a suitable index representing the extent of development. Although the density of well pads and cumulative acreage serve as a general index to well-field development and activities, thresholds based upon these alone may under-represent the actual level of disturbance (WGFD 2010a). Relative degrees of impact are described as follow:

Low Impact— One well pad location with total disturbance not exceeding 20 acres/mile^2. Habitat effectiveness is reduced within a zone surrounding each well, facility, and road corridor through human presence, vehicle traffic, and equipment activity.

Moderate Impact— Two to 4 well pad locations with total disturbance not exceeding 60 acres/mile^2. At this range of development, impact zones surrounding each well pad, facility and road corridor begin to overlap, thereby reducing habitat effectiveness over much larger, contiguous areas. Human, equipment and vehicular activity, noise, and dust are also more frequent and intensive and will impair the ability of animals to use critical areas (winter range, parturition grounds, etc.) and impacts will be much more difficult to mitigate. It may not be possible to fully mitigate impacts caused by higher well densities, particularly by developing habitat treatments on site. Habitat treatments will then generally be located in areas near, rather than within well fields to maintain the function and effectiveness of critical areas.

High Impact— Greater than 4 well pad locations or 60 acres of disturbance/mile^2. At this level of development, the function and effectiveness of habitat becomes compromised. Long-term consequences would likely include continued fragmentation and disintegration of habitat leading to decreased survival, productivity, and ultimately, loss of carrying capacity for the herd. This will result in a loss of ecological functions, recreation opportunity, and income to the economy. An additional consequence may include permanent loss of migration memory from large segments of unique, migratory mule deer herds.

Issues and Concerns

For purposes of these guidelines, impacts to mule deer from oil and gas development can be divided into the following general categories: 1) direct and indirect loss of habitat; 2) physiological stress, 3) disturbance and displacement; 4) habitat fragmentation and isolation; and 5) other secondary (offsite) effects.

The presence of well pads, roads, pipelines, compressor stations, and out buildings directly removes habitat from use (Photo courtesy of New Mexico Department of Game and Fish [NMDGF]).

Direct and Indirect Loss of Habitat

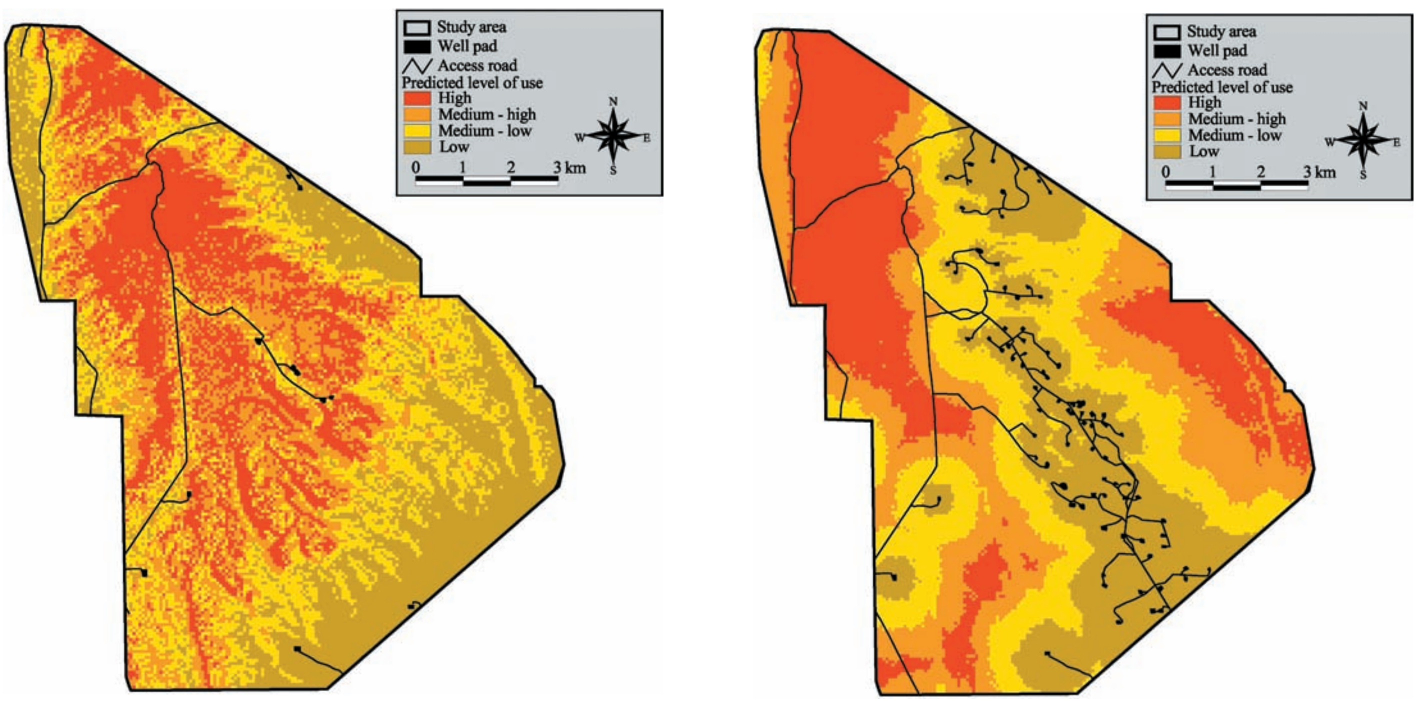
Direct loss of habitat results primarily from construction and production phases of development. The construction and subsequent presence of well pads, roads, pipelines, compressor stations, and out buildings directly removes habitat from use. Production activities require extensive infrastructure and depending upon scale, density, and arrangement of the developed area, indirect loss of habitat can be extensive (USDI 1999). As an example, within the Big Piney-LaBarge oil and gas field in Wyoming, the actual physical area of structures, roads, pipelines, pads, etc. covers approximately 7 miles^2. However, because of the arrangement of these structures, the entire 166 mile^2 landscape is within 0.5 mile of a road, and 160 miles^2 (97% of the landscape) is within 0.25 mile of a road or other structure (Stalling 2003).

Generally, it is possible to reclaim 50% of a disturbed area to minimal cover standards within 3-5 years after construction. However, re-establishing suitable habitat conditions (appropriate native species composition, diversity, structure, and age) may take 30–40 years (Young and Evans 1981, Bunting et al. 1987, Winward 1991), or may take well over 100 years (Baker 2006, Cooper et al. 2007). The remaining 50% of the disturbed area consists of the working surfaces of roads, well pads, and other facilities, and represents a much longer term loss of habitat (USDI 1999). Successful reclamation of sagebrush communities is difficult at best, as success is highly dependent upon amount and timing of precipitation. Sagebrush seed remains viable in salvaged topsoil for a comparatively brief period and reseeding is usually required if reclamation is conducted >1 year post-disturbance. Restoration of shrub habitats important to wintering deer is critical, but reclamation of these vegetation types in dry regions may not occur quickly (Baker 2006) and therefore any disturbance will likely represent a longer-term habitat loss.

Physiological Stress

Animals become physiologically stressed when energy expenditures increase due to alarm or behavioral avoidance. These responses are generally attributed to interactions with humans or activities associated with human presence such as traffic, noise, pets, and etc. Physiological stress diverts time and energy away from critical activities such as foraging and resting important to maintain or improve fitness (Gill et al. 1996, Frid and Dill 2002). This seems especially critical to wintering deer whose nutritional condition is closely associated with survival (Sawyer et al. 2009a).

During winter months, additional stress can be particularly harmful because a deer's energy balance is already operating at a deficit (Wallmo et al. 1977). In addition, the diversion of energy reserves can be detrimental to other vital functions during the life cycle such as gestation and lactation. An environmental assessment of oil and gas development in the Glenwood Springs (CO) Resource Area expressed concern these impacts could ultimately have population effects through reduced production, survival, and recruitment (USDI 1999).



Predicted levels of mule deer use before and after natural gas development in western Wyoming. Avoidance of well pads can create indirect habitat losses that are considerably larger than direct habitat loss (from Sawyer et al. 2006)

Disturbance and Displacement

Increased human presence and activity, equipment operation, vehicle traffic, and noise related to wells and compressor stations, etc. are primary factors leading to avoidance of a developed area by wildlife (Barber et al. 2010). The avoidance response by mule deer (indirect habitat loss) extends the influence of each well pad, road, and facility to surrounding habitats. In winter ranges of western Wyoming, mule deer were shown to prefer habitats 1.2 to 1.8 miles away from well pads (Sawyer et al. 2006, 2009b).

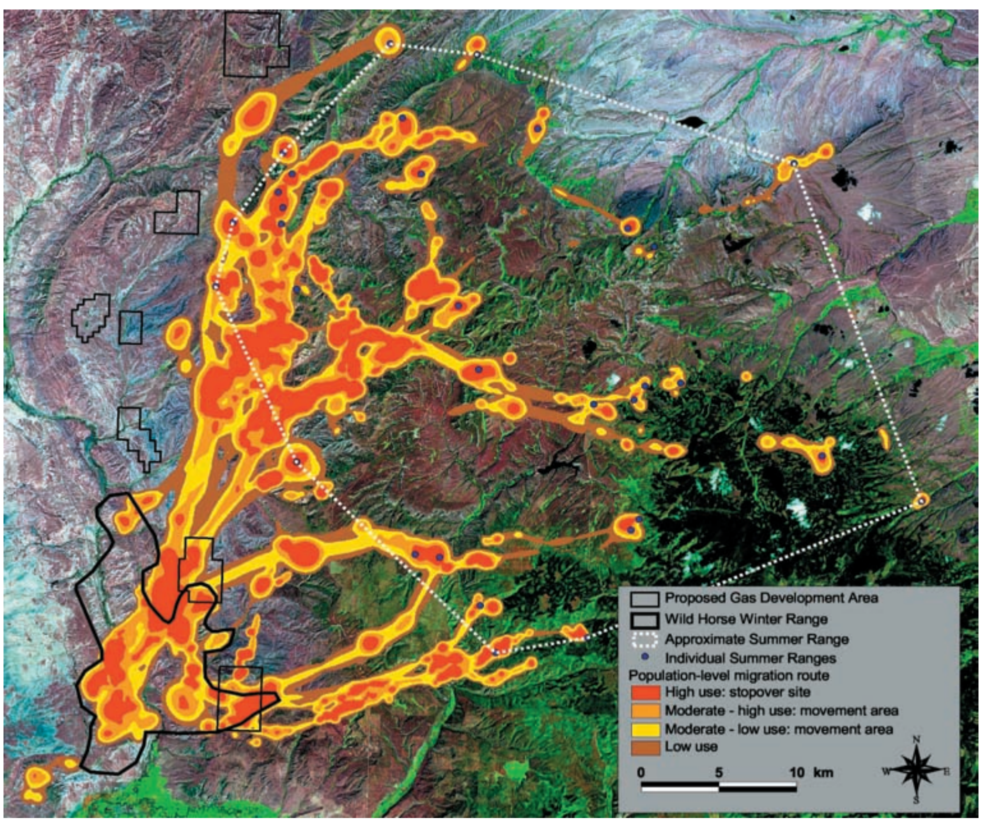
During all phases of well field development and operation, roads tend to be the most significant concern because they often remain open to unregulated use. This contributes to noise and increased human presence within the development area. Rost and Bailey (1979) documented an inverse relationship between habitat use by deer and elk and distance to roads. Sawyer et al. (2009a) found mule deer selected areas farther from well pads associated with higher levels of traffic, primarily heavy truck traffic used to remove condensate from producing wells. This 'displacement' effect can result in the under use of otherwise suitable habitats near infrastructure and disturbances and over use of habitats in more distant locations. Displacement also adds to the potential for depredation problems within nearby agricultural properties. Some other consequences of increased human presence include, but are not limited to, mortality and injury due to vehicle collisions, illegal hunting, and harassment from a variety of increasing recreational activities such as OHV use.

Habitat Fragmentation and Isolation

Human caused habitat fragmentation creates landscapes fundamentally different from those shaped by natural processes to which species have adapted (Noss and Cooperrider 1994). Human caused changes often manifest as altered plant composition, often dominated by weedy and invasive species. This, in turn, changes the type and quality of the food base as well as the structure of the habitat. When the ability to move between important daily or seasonal habitats (e.g., parturition areas, winter range, etc.) is severely disrupted, abandonment of habitat ultimately could result.

When planning developments, it is critical to consider these corridors and how to avoid or mitigate impacts in order to sustain deer migration corridors (Merrill et al. 1994). Sawyer et al (2009c) recently developed a framework to identify and prioritize mule deer migration routes for landscape-level planning. Such a framework may improve

The Rosa gas field in northwestern New Mexico shows an example of extreme impact. (Photo courtesy of NMDGF)

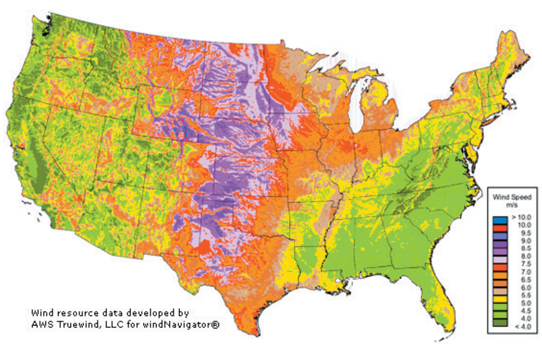


Estimated migration routes for mule deer relative to proposed gas development in southwest Wyoming. High-use areas represent stopover sites presumably used as foraging and resting habitat, whereas moderate-use areas represent movement corridors (from Sawyer et al 2009c).

both management and planning and ensure potential impacts to mule deer migration routes are minimized. In much of the Southwest, mule deer do not engage in predictable migrations, but may make long-distance "nomadic" movements based on seasonal variation in water and food availability. Flexibility in movement across ranges can be ultimately reflected in the survival and productivity of the deer population and likely enhances their ability to recover from population declines.

Secondary Effects
The severity of activities associated with support or service industries linked to development often equals or exceeds that of the direct effects described above. These impacts are similar to those that occur during construction and operations. Additional human presence from increased support industries and community expansion will contribute to human-wildlife interactions and declines in mule deer habitat availability and quality.

Roads, pipelines, and transmission corridors not only remove habitat, but also have the potential to contaminate ground and surface water supplies. Noxious weeds introduced by equipment can infiltrate roadside impact zones and cause additional negative impacts such as non-native bacteria, viruses, insect pests, or chemical defense compounds with toxic or allergenic properties (NMDGF 2007). In addition, these invasive species can spread to adjoining native plant communities.



Wind energy resource potential in the U. S. (U.S. Department of Energy, Natural Renewable Energy Laboratory)

Construction of wind turbines can create habitat disturbances similar to other forms of energy development. (Photo by J. Heffelfinger/AGFD

Impervious roads and disturbed pipeline corridors increase surface water runoff which can reduce infiltration, lower the water table, and result in lower rangeland productivity. This problem will increase if the nation's energy infrastructure is expanded as recommended in the Energy Policy Act of 2005.

Activities occurring at the well site (drilling, pumping, etc.) or associated with product transportation to other destinations via pipeline or vehicle may lead to the release of a variety of toxic hydro-carbon based compounds. These compounds are common by-products and can pose serious health risks to not only employees, but also the environment and mule deer in the surrounding area. All these events can decrease the amount of area available to mule deer and other wildlife. Finally, potential exists for rendering an area useless to wildlife for an indeterminable amount of time unless careful consideration is given to planning and implementing quality mitigation and reclamation programs.

WIND ENERGY DEVELOPMENT

Background
Wind-energy development is a component of the nationwide effort to reduce dependence on foreign oil and minimize carbon emissions associated with energy derived from oil, gas, and coal. At the end of 2007 the U. S. had the second highest cumulative wind capacity globally. In 2009, the U.S. wind industry installed 10,010 megawatts (MW) of generating capacity, breaking U.S. installation records for the third year in a row. Wind power represented 39% of all U.S. electric generation capacity additions for the year (USDOE 2010). This rate of development is expected to continue, and perhaps to accelerate, as U.S. energy policy emphasizes independence from foreign oil and reduction of carbon emissions. The USFWS and members of the Wind Turbine Guidelines Advisory Committee (USFWS 2010) recognize wind-generated electrical energy is renewable, and is considered to be generally environmentally friendly. The U.S. Department of Energy (DOE) estimates that a single 1.5 megawatt (MW) wind turbine displaces 2,700 metric tons of CO_2/year compared with the current U.S. average utility fuel mix. Wind energy development is proceeding without basic fact-finding research on the environmental consequences and impacts to mule deer.

Although fossil fuel consumption and carbon emissions are largely confined to the manufacture, construction, and maintenance aspects of wind power generation, wind farms themselves are an intensive, industrial-scale use of the land and have the potential to impact mule deer habitats throughout the West. With current technology, individual turbines typically generate in the range of 1.5-2.0 megawatts each. Towers range from 212 to >260 feet tall with blade sweeps of 328 to >400 feet above ground level. For maximum generating efficiency, tower strings are separated by approximately 10 rotor diameters, and individual towers within strings are separated by 3 rotor diameters. Wind farms incorporate a road network to facilitate access for turbine maintenance. In addition, power lines provide connection to transfer stations that connect to nearby transmission lines. Based on other wildlife energy research (Sawyer et al. 2006, 2009a), associated infrastructure has potential to affect mule deer.

The open areas mule deer occupy usually have high potential for wind energy development. (Photo by S. Gray, TPWD)

Issues and Concerns

Little is known about the effect of wind power development on mule deer. Although research on avian species and bats has received much attention in recent years, very little research has been done to evaluate impacts on larger mammals. The USFWS (2011) states siting of a wind energy project is the most important element in avoiding effects to wildlife and their habitats. The direct impact from surface disturbance may be relatively small in scope as turbines and roads typically constitute a small total acreage within a development area (WGFD 2010b). However, indirect impacts affecting habitat use by ungulates may be much larger. Due to the acreages that large-scale wind projects encompass (10,000- to 100,000-acre project areas), the potential exists to displace mule deer from important seasonal habitats. If displacement does occur, it may affect migration routes, parturition areas and important summer ranges, all of which provide essential seasonal habitat components to maintain mule deer populations. Other indirect effects identified by the USFWS (2011) include introduction of invasive vegetation that result in alteration of fire cycles; increase in predators or predation pressure; decreased survival or reproduction; and decreased use of the habitat as a result of habitat fragmentation.

The transmission corridors that transfer energy production to electrical grids may represent a greater impact than the actual siting of wind turbines. Transmission corridors and any associated roads can cause direct mortality and remove habitat, but they also have the potential to fragment important habitat components. These corridors can also facilitate the spread of invasive species not native to that area (Gainer 1995, NMDGF 2007). The impact of associated corridors must be considered along with the area chosen for turbine placement when evaluating impacts (Kuvlesky et al. 2007).

Mule deer crucial habitats, especially winter ranges, are often characterized by open landscapes comprised of sagebrush-steppe or sagebrush-grassland habitat types. These areas often provide accessible lands with high potential for wind-energy development. Potential impacts to mule deer include direct and indirect habitat loss, displacement, and cumulative impacts associated with other nearby energy developments.

Mule deer have been observed to maintain populations in conjunction with coal mine development where the pace of development is slow and dependent upon bond release after successful reclamation (Medcraft and Clark 1986, Gamo and Anderson 2002). However, Sawyer and Nielson 2010) found mule deer numbers declined by 40-60% following intensive gas development of the winter range. Over a 9-year period, they found no evidence of similar mule deer declines in winter ranges adjacent to the gas field (Sawyer and Nielson 2010).

Wind energy development, like other forms of development, does include a certain amount of construction and resulting infrastructure (WGFD 2010b). Temporary and permanent roads are constructed, maintenance activities occur, and the landscape becomes fragmented. It is expected that mule deer will be displaced from habitats during construction. The impacts of long-term facility operation are unclear.

SOLAR ENERGY DEVELOPMENT

Background

Solar energy development is also a component in the nationwide effort to secure a free fuel source and reduce carbon emissions associated with energy derived from oil, gas, and coal. Solar energy development in the U. S. is viewed as a source of "green" energy. Where solar energy is being developed, habitat loss for mule deer approaches 100% within the footprint of the project. Currently, identified solar projects in Arizona alone range in size from 2,000 to >25,000 acres and, in totality, encompass an estimated potential 800,000 acres resulting in significant habitat loss for wildlife (AGFD 2010).

Photovoltaic

Photovoltaic (PV) solar systems are a series of small cells made of crystalline silicon or a thin film layer that are assembled into a panel of cells, and in turn several panels can be clustered into an array. These PV cells convert sunlight directly into electricity when the sun's photons agitate electrons in the PV cell, and electrons are then channeled directly as DC electrical current. The DC output may be converted to AC output. Photovoltaic systems have mainly been used to power small and medium-sized applications, such as supplementing energy for individual homes or facilities not connected to a main power grid. Recently, multi-megawatt PV plants are becoming more common. A proposed 550 MW power station in southern California encompassing 4,245 acres is characteristic of the trend toward larger PV stations throughout the country and world. Photovoltaic solar-energy development sites are an intensive, industrial-scale use of the land and have the potential to significantly impact mule deer and their habitats throughout the West. The advantage of PV systems from a wildlife perspective is that they use much less water than other solar technologies. No water is used to collect, transfer, or store energy; water is only needed to wash the PV panels. Although efficiency is increasing, the disadvantage is their lower productivity and greater land area required to produce the same amount of energy as more efficient systems.

Nellis Air Force Base in Nevada is home to a PV system with 72,000 solar panels that produce 14 MW of electricity. (U.S. Air Force photo by Airman 1st Class N. Y. Barclay)

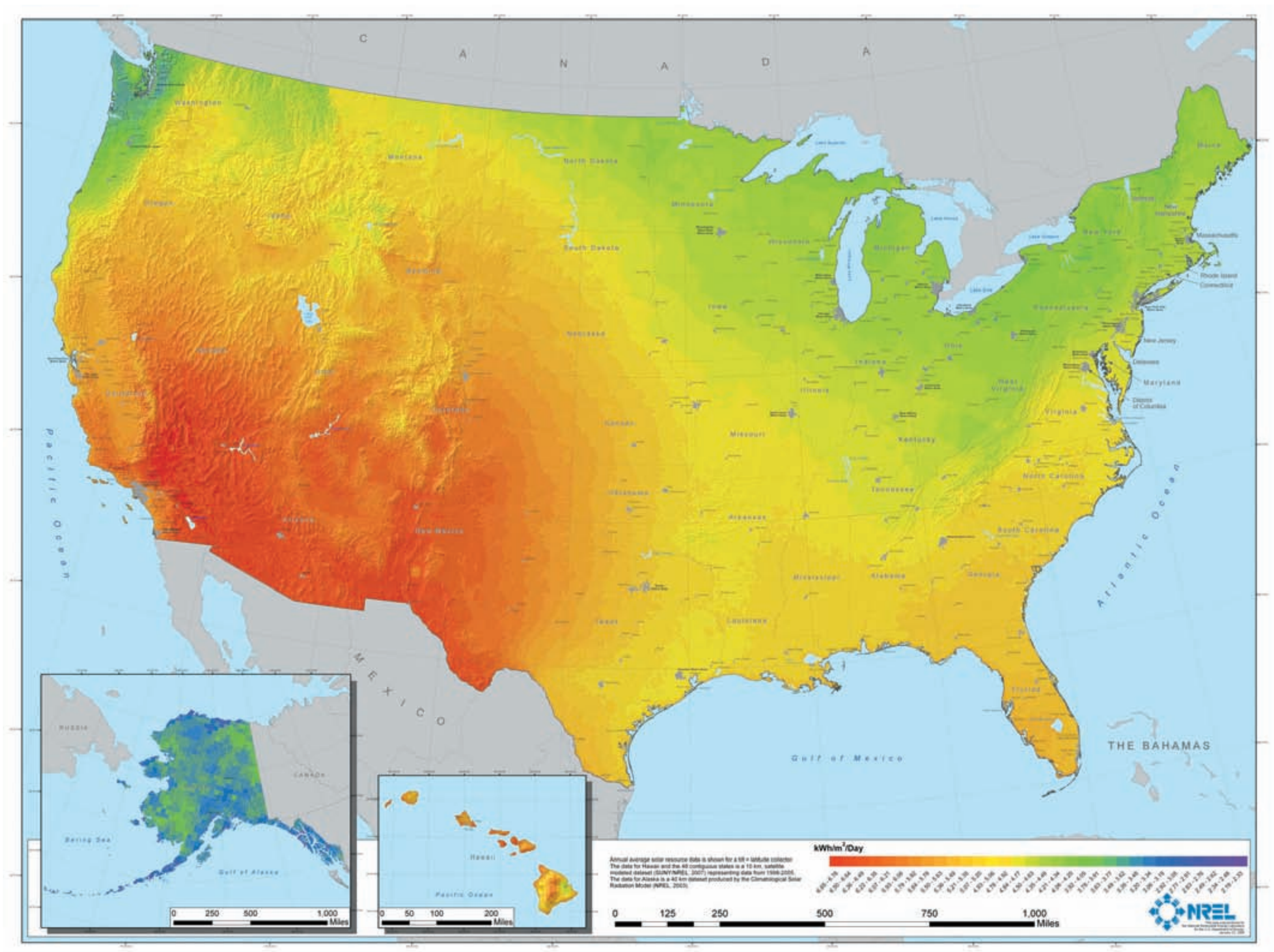
Each of these Dish/Engine units produces 10 kW of power. (Photo courtesy of Sandia National Laboratory)

Concentrating Solar Power

Concentrating Solar Power (CSP) differs from PV in that it uses a reflective surface to concentrate solar energy to heat a liquid medium to generate steam that drives a turbine to generate electricity. If thermal energy storage is included in the system, electricity generated with CSP can be supplied to an electrical grid or stored for peak usage times, nighttime, or cloudy days. This is unlike PV which does not store energy. The Southwest holds potential to generate significant amounts of electricity with this technology. However, CSP technology requires more water for energy production and washing of mirrors.

Dish/Engine Systems

Dish/Engine systems consist of a solar collector (usually a mirrored dish) that concentrates solar energy into a central power conversion unit (Stirling engine) in front of the dish. The concentrated sunlight heats a thermal receiver in the engine made of tubes filled with liquid such as helium or hydrogen. This heated gas (1,400° F) then moves pistons in the engine to directly generate electricity (DOE 2007). The dishes are designed to track movements of the sun throughout the day to assure maximum exposure. These units are well-suited for more dispersed applications because they generate relatively small amounts of energy (1-25 kW, DOE 2007). Of all the CSP technologies, Dish/Engine systems require the least amount of water, therefore minimizing impact to local hydrologic resources. However, these units can be installed on uneven ground and that could result in more solar development in important mule deer habitat.



Solar PV energy potential in the United States. (National Renewable Energy Laboratory, http://www.nrel.gov/gis/solar.html)

Parabolic Trough Systems

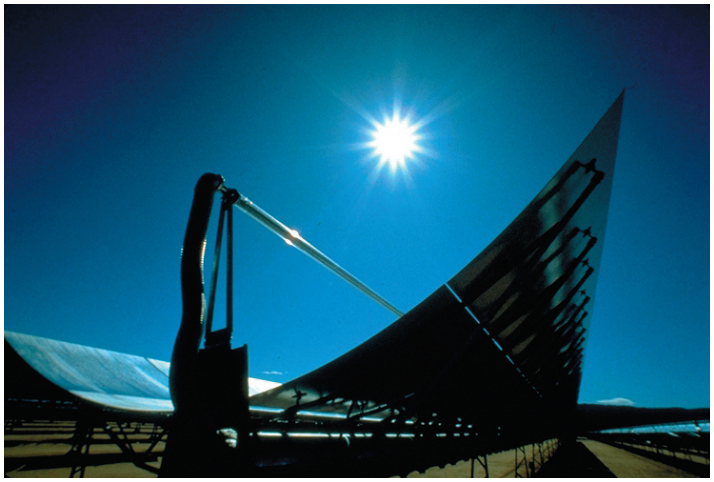
These CSP systems use parallel rows of long trough mirrors to reflect sunlight onto a linear receiver containing a liquid (usually an organic oil). That liquid is then superheated (about 750°F) and used to create steam which turns turbines to generate electricity. Most Parabolic Trough Systems use long parabolic troughs to simply reflect light onto the oil filled tube, but a variation called the Fresnel Reflector system uses linear mirrors to reflect sunlight onto a linear receiver suspended above the mirrors. These linear structures are oriented north-south and tilt to track the sun across the sky throughout the day. Concentrating Solar Power technology can also be combined with natural gas, resulting in hybrid systems that can provide power at any time. Currently, the largest solar trough facility in the world is being constructed near Gila Bend, Arizona and has the potential to generate 250 MW of electricity.

Power Tower Systems

Power Tower systems consist of a tall tower supporting a thermal receiver surrounded by a large field of flat "heliostat" mirrors that track the sun's movement and keep solar energy focused on the receiver. The heat concentrated (1,050° F) in the receiver is used to generate steam, which turns turbines to generate electricity. The heat can be collected and transported by water, but newer designs are incorporating molten salt because of its superior thermal energy storage properties. Individual commercial plants can produce up to 200 MW of electricity. Both parabolic trough and power tower systems can be engineered with molten salt thermal storage so that the heat can be stored and then used later to generate electricity. Molten salt integrated in a tower system allows for significantly higher power plant operating temperatures and therefore higher generation efficiencies (i.e., lower cost of electrical generation) compared with direct steam towers or trough systems.

Issues and concerns

Primary impacts to mule deer from solar energy development can be summarized into the following general categories: 1) direct loss of habitat; 2) habitat fragmentation; and 3) hydrologic changes. Each of these,



A Parabolic Trough System uses a reflective trough to heat a tube filled with oil to produce steam to drive a turbine to generate electricity. (Photo courtesy of Sandia National Laboratory)

Compact Linear Fresnel reflectors and linear receiver. (Photo courtesy of Areva Media Department)

Abengoa's PS10 and PS20 power towers near Seville, Spain use reflectors that track the sun to concentrate the sun's energy to a focal point in the tower where liquid is heated to >1,000° F and used to generate electricity.

alone or in conjunction with others, has the potential to significantly influence whether deer can maintain robust or depressed populations in the developed area or abandon it altogether.

Direct Loss of Habitat

Wildlife habitat loss may result from construction of large-scale solar facilities. The largest contiguous loss of habitat would occur within the perimeter of the facility's security fence. Additional habitat loss may take place through the construction of new or expansion of existing substations, new transmission lines, and associated access roads (AGFD 2010). In addition, drainages are re-routed around large facilities eliminating critical desert dry wash woodlands used as refuge and spring foraging habitats. Finally, conversion of irrigated agriculture areas to solar facilities is eliminating important water sources in some areas, although water consumption for power generation is generally comparatively lower than for agricultural use.

Habitat Fragmentation

Solar development will potentially disturb and fragment mule deer habitat during and after construction of a facility. The development of utility-scale solar fields and associated infrastructure including substations, transmission lines, and access roads will likely affect mule deer movement and habitat use (AGFD 2010). In California, several utility-scale facilities may be built adjacent to one another and are completely fenced which may impede mule deer movement over large areas. It is imperative wildlife movement corridors to and from crucial habitats are identified during pre-construction planning. These data could be used to establish the location of sensitive resources and recommend the most appropriate locations of roads, fences, and other infrastructure to minimize habitat fragmentation and disturbance.

Hydrology

Much of the Southwest, where solar energy development potential is highest, also lacks abundant water resources. In this region, water is a very crucial component that can limit mule deer populations. Any changes to hydrologic resources, ground or surface water, have the potential to affect mule deer distribution and abundance. Solar energy development can impact hydrologic resources through development of the project footprint (e.g., land disturbance, erosion, changes in runoff patterns, and hydrological alterations), project emissions (e.g., sediment runoff, chemical spills, herbicide use, and water releases), and resource use (e.g., water extraction, diversion, or change in use; AGFD 2010). Though evaporation ponds are typically located within the fenced solar facility, mule deer are attracted to any form of open water and therefore are susceptible to inadvertent poisoning due to concentrated salts and other minerals.

Because of their thermal processes, Parabolic Trough and Power Tower systems may require large amounts of water to collect and transfer heat, cool and condense steam, and also to clean mirrored surfaces. A typical wet-cooled coal or nuclear power plant consumes 500 gallons of water per megawatt hour (gal/MWh), which is similar to the amount used by a Power Tower system (DOE 2007). A water-cooled parabolic trough plant consumes approximately 800 gal/MWh, and of this, 2% is used for mirror washing (DOE 2007). Recent advances in cooling technology have shown water usage in these plants can be reduced by up to 90% with a resultant increase in energy costs of 2-10% by using dry cooling or a hybrid of wet and dry cooling technologies (DOE 2007).

GEOTHERMAL ENERGY DEVELOPMENT

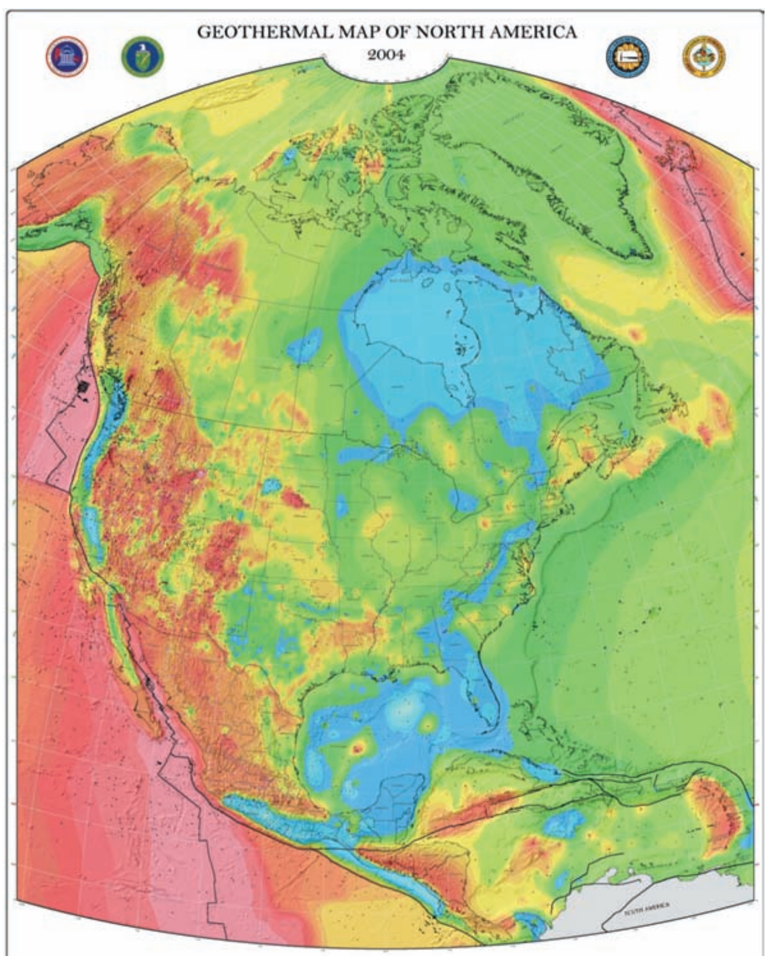
Background

Geothermal energy development has increased 20% worldwide in the last five years (Holm et al. 2010). The 2010 figures reflect 10,715 MW on line, generating 67,246 gigawatt hours (GWh) of power with a projected growth to 18,500 MW by 2015. Seventy countries currently have geothermal power projects proposed or under development. Geothermal capacity increased by 530 MW in the U.S. over the past 5 years, the largest growth logged by any single country. From a continental perspective, the largest growth occurred in Europe and Africa. Although the growth is encouraging, overall the resource as a whole is under-utilized. Some countries are developing only a small amount of the geothermal resources available and a number of countries with resources are not developing them to any significant degree. World-wide, most of the new development is for use in direct heating or other direct use application.

In North America, development is concentrated in the western third of the continent from Alaska to southern Mexico. Some lesser resource potential occurs in the southeastern U. S.. In the U. S., the increase in geothermal development is primarily to supply off-site electrical grids. The increase in activity in the U.S. is tied to increased financial support and other incentives for development, such as the Renewable Energy Tax Credit. It is unknown how long this support will be sustained. Mexico continues to be a significant developer of geothermal power production and is currently ranked fourth in the world for installed capacity. Although Canada has not developed geothermal resources for power production, a number of projects are under consideration.

The DOE maintains a website listing incentives available in the U. S. (http://www.dsireusa.org/). A growing number of states are developing requirements (Renewable Portfolio Standards) for energy providers to include renewable energy as a percent of the power provided to their customers. This mix could include geothermal-sourced energy. A list of state standards is maintained by the DOE (http://apps1.eere.energy.gov/states /maps/renewable_portfolio_states.cfm).

In Section 225 of the Federal Energy Policy Act of 2005, the Secretaries of Interior and Agriculture were charged with developing a program to reduce (by 90 percent) the backlog of geothermal lease applications. In 2008, the Bureau of Land Management and U.S. Forest Service drafted a Programmatic Environmental Impact Statement (USDI and USDA 2008) addressing this issue. The EIS addresses alternatives that identify opportunities for development and areas with sensitive resources that should be avoided. Site-specific documentation is still required, but the programmatic EIS allows for the streamlining of the leasing process. Two primary



Geothermal resources are concentrated primarily in western North America (Blackwell and Richards 2004). Energy potential ranges from very little (blue) to high (red).

A flow test in progress at the Blue Mountain Geothermal site. The initial drilling of the wells may occupy only 2-3 acres, but this is the phase where most disturbance occurs. Photo courtesy of Bureau of Land Management, Nevada State Office.

After drilling, a fenced well casing and control equipment is left in place like this structure at the Salt Wells Geothermal well site near Fallon, Nevada (operated by ENEL North America, Inc.). Photo courtesy of Bureau of Land Management, Nevada State Office.

considerations determine whether a geothermal resource is suitable for development; the temperature of the resource and its extent or size. The temperature will determine how the resource could be used and the size will determine the longevity. A large amount of capital is needed to develop a resource, so developers must fully evaluate the overall value and potential before proceeding.

Depending upon its quality, a geothermal resource may produce steam (most desirable), hot water, or warm water (least desired). Current protocols are to reinject used geothermal fluids to replenish the resource, enabling it to last longer. This also allows for safe disposal of brine or high concentrations of dissolved and suspended solids, which had been a site management issue before reinjection became the standard procedure.

Geothermal resources have a range of uses, including power generation, domestic or industrial heating, recreation, fish farming and other types of aquaculture, greenhouse operation, commercial food processing, and others. Some geothermal resources have incorporated a clean surface water component which provides habitat for shorebirds and waterfowl and a source of drinkable water for larger game species and livestock.

Five components of geothermal development should be considered when assessing impacts: exploration, well drilling, power production or on-site use, transmission lines, and facility operation. Exploration usually involves site visits, drilling by a truck-mounted auger, some minimal site disturbance and noise. The effects at this early phase are short-term and temporary in nature. Well drilling results in moderate site disturbance and may include the construction of a flat well pad that could occupy 2-3 acres or more. A well casing and some apparatuses to control the well are left in place, usually within a fenced facility. Site disturbance should be temporary if the area is not needed for the development of facilities. The well site is usually connected to a primary use area by above-ground insulated piping. Existing access roads may be utilized or new roads constructed if no other access exists.

The construction of the power production or resource use facility (on-site heating, vegetable drying, electricity production, etc.) may permanently occupy ≥10 acres depending on the geothermal resource use and size of the facility. This area will represent a permanent loss of habitat (unless constructed in an area of low value initially, as recommended). Construction activity is relatively short-term, but has the potential to disturb wildlife through noise, human and vehicle presence, and habitat loss. These temporary use areas are generally reclaimed if not needed for operational activities.

The Ormat Steamboat power station at the southern edge of Reno, NV with a large brown heat exchanger, above-ground piping, and access road visible. Photo courtesy of Bureau of Land Management, Nevada State Office.

Associated linear project components such as power lines, pipelines, and roads create additional permanent impacts to mule deer habitat if existing linear disturbances are not followed. Depending upon where the facilities are sited and how they are constructed, they can result in temporary disturbance during construction as well as permanent habitat loss and fragmentation.

Site activity is greatly diminished during facility operation. The operation phase entails periodic human presence including intermittent noise and vehicle use. Depending upon the technology employed, if resources are captured and re-injected there may be a decrease in the amount of surface water available. Also, a portion of the facility may be fenced which may impede deer movements across the site.

Issues and Concerns

In general, geothermal resource development has minimal impact on mule deer. Sites are usually compact in contrast with other forms of energy development such as wind, solar, or fossil fuels. All temporary disturbance is reclaimed and long-term disturbance at the site (human presence, vehicles, or noise) should be minimal. There can be a few potential impacts to mule deer such as above ground pipelines and elevated noise levels (USDI and USDA 2008).

Habitat Loss, Disturbance, and Fragmentation

Impacts of geothermal energy exploration, development and extraction in mule deer habitat can be similar to those caused by oil and gas development, albeit at a smaller scale. Although pertinent to this section, there is no need to reiterate similar issues and concerns related to the direct loss of habitat, physiological stress on deer, disturbance and displacement from important habitat, fragmentation and isolation of important habitat components, and secondary effects.

It is important to consider the total impact of the project, not only at the well site and power production area, but also from the transmission corridors and access roads used in construction and operation of facilities. These linear components are more likely to fragment habitat and could present a greater concern than the core facilities. These effects will not likely be as severe or extensive as experienced from oil and gas development, but should still be evaluated by resource managers on a case by case basis.

Related Concerns

The Programmatic EIS for geothermal leasing (USDI and USDA 2008) identified several related concerns that may be an issue in some phases of geothermal energy development. Although direct habitat loss, disturbance, and fragmentation are the most obvious impacts of geothermal projects, invasive vegetation, fire, direct mortality, noise, and chemical contaminants warrant additional vigilance of managers.

Spread of invasive vegetation could result from construction activity, especially ground disturbance, vehicle traffic, or creation of new access routes. Once established, some invasive species have proven difficult or impossible to control. As demonstrated by several cases in the West, invasive plant species can alter entire vegetative communities, resulting poorer quality mule deer habitat on a landscape scale.

Fires accidentally ignited during construction or maintenance activities can alter the natural fire regime

and produce undesirable changes in plant communities. An increase in fire frequency provides opportunities for invasive plants to become established and may result in loss of desirable vegetation for many years. Once invasive species such as cheatgrass become established, the fire cycle and natural plant community may be permanently altered, especially in native shrub-dominated communities.

Additional issues include: 1) direct mortality of mule deer from vehicle collisions, open trenches or ditches, fencing and above-ground piping, 2) intermittent noise associated with construction activity and some operational activities (e.g., steam venting), and 3) infrequent exposure to contaminants such as vehicle fuels, herbicides, or accidental spills (USDI and USDA 2008).

Photo courtesy of Tom Newman

CONSOLIDATED GUIDELINES

General guidelines and additional mitigation recommendations (Habitat Mitigation Options) are provided to minimize impacts of energy development on mule deer and their habitat. Recommendations are also categorized according to impact thresholds. When energy development is proposed on public lands, federal permitting agencies have the dual responsibility of authorizing the development while conserving surface resources, including wildlife and other environmental values.

A. GENERAL GUIDELINES

1. Consult the appropriate wildlife and land management agencies at least 2 years prior to submitting project permit applications to allow time for appropriate studies and inventories to be conducted and site-specific recommendations developed (TWS 2008a).
2. Identify minimum quality and quantity of information necessary for analysis before a lease or annual permit for construction can be issued (WAFWA 2010).
3. Develop a map of important habitats and potential conflict areas. Developers should use the map as one of the first steps in pre-development planning to identify important, sensitive, or unique habitats and wildlife in the area (TWS 2008b).
4. Utilize the Decision Support System developed by the Western Governor's Association to coordinate planning.
5. Use the most current wildlife data and applicable plans to identify important wildlife habitat resources that should be conserved (WAFWA 2010).
6. Design configurations of energy development to avoid or reduce unnecessary disturbances, wildlife conflicts, and habitat impacts. Where possible, coordinate planning among companies operating in the same area to minimize the footprint of development (e.g., negotiate unitized field development plans, co-locate power lines and pipe lines in existing corridors).
7. Implement timing stipulations that minimize or prohibit activities during critical portions of the year.
8. At a minimum, construction activities should be suspended from November 15-April 30 on areas designated as crucial winter range. If project features will be sited within identified parturition areas, activities should be suspended from 1 May – 30 June (Pojar and Bowden 2004). Minimize disturbances and activities within producing well fields during the same timeframe. Include provisions in subcontractor agreements requiring adherence to the same seasonal use restrictions observed in company operations.
9. Avoid placing facilities in locations that bisect major migration corridors and other important habitats. Also, avoid unstable slopes and local factors that can cause soil instability (groundwater conditions, precipitation, seismic activity, slope angles, and geologic structure).
10. Plan the pattern and rate of development to avoid the most important habitats and generally reduce extent and severity of impacts (TWS 2008a). Implement phased development in smaller increments with concurrent reclamation of abandoned wells.
11. Disturb the minimum area (footprint) necessary to efficiently develop and operate the facility.
12. Design and implement habitat treatments sufficient to maintain habitat functions on-site. In cases where offsite mitigation would provide greater benefits than onsite mitigation, the offsite mitigation should be located within the same landscape unit indentified in consultation with the state or provincial wildlife agency. Habitat treatments should include appropriate options from Habitat Mitigation Options, selected through consultation with the state or provincial wildlife agency.
13. Mitigation should be planned to offset the loss of habitat effectiveness throughout the areas directly and indirectly affected by energy project development. Management practices identified in Habitat Mitigation Options may reduce the extent of habitat treatments needed to offset or mitigate the effect.
14. When it is not possible to avoid, minimize, or effectively mitigate impacts through other means create a Mitigation Trust Account. The operator would contribute funding to a mitigation trust account based on the estimated cost of habitat treatments or other mitigation needed to restore the functions and effectiveness of impacted habitats.
15. For mitigation planning purposes the acreage basis for mitigation will be the amount of surface that is directly disturbed plus the additional area on which habitat functions are impacted by noise, activities, and other disturbance effects. Mitigation recommendations may be refined and possibly standardized as habitat treatments are implemented and their effectiveness monitored.

Oil, Gas, & Geothermal General

16. When geological substrate and hydro-carbon resource types lend themselves to directional technologies, drill multiple wells from the same pad.
17. Utilize mats to support drill rigs in order to eliminate top-soil removal.
18. Locate drill pads, roads, and facilities in the least sensitive areas or cluster these features in locations already impacted.
19. Locate drill pads, pipelines, roads, and facilities below ridgelines or behind topographic features, where possible, to minimize visual and auditory effects, but away from streams, drainages, and riparian areas as well as important sources of forage, cover, and habitats important to different life cycle events (reproduction, winter, parturition, and rearing).

Additional Guidelines for Moderate Impact Developments (2-4 well pad locations/mile^2 with no more than 60 acres of total disturbance).

20. Apply all general guidelines prescribed above to retain as much effective habitat as possible.
21. Develop multiple wells from single pads by employing directional or horizontal drilling technologies and unitized development. The highest management priority within crucial winter range is to recover oil and gas resources with the least possible infrastructure and associated disturbance. Where several companies hold smaller, intermingled leases, the cumulative impact could be reduced substantially if the companies enter a cooperative agreement (called unitization) to directional drill from common well pads.
22. Use clustered development configurations. Locate well pads, facilities and roads in clustered configurations within the least sensitive habitats. Clustered configurations are a geographical and not necessarily a temporal (i.e., "phased development") consideration.
23. Install a liquid gathering system to convey liquids from producing wells to a centralized collection point. If fluids cannot be piped off site, enlarge storage tank capacity to minimize truck trips to ≤1/month and to eliminate trips during sensitive times of year. If the potential for production of liquids is unknown, but exceeds 1 truck trip/month after production begins, consider retrofit the field with pipelines or larger storage.
24. Install telemetry to remotely monitor instrumentation and reduce or eliminate travel required to manually inspect and read instruments.
25. Develop a travel plan that minimizes frequency of trips on well-field roads. Include provisions in subcontractor agreements requiring adherence to the same travel plan provisions observed in company operations.
26. As appropriate, gate and close newly constructed roads to public travel during sensitive times of year.
27. Implement a robust wildlife monitoring program such as the Before-After Control-Impact (BACI) research design to detect and evaluate ongoing effects such as mortalities, avoidance responses, distribution shifts, habituation, evidence of movement or migration barriers, and depressed productivity (e.g., low fawn:doe ratios), and to assess the effectiveness of mitigation. Monitor vegetation utilization within and outside the well field.
28. If it is not possible to maintain habitat effectiveness within or immediately adjacent to the well field, off-site and off-lease mitigation should be considered on a case-by-case basis. The primary emphasis of off-site or off-lease mitigation is to maintain habitat functions for the affected population or herd as close to the impacted site as possible and within the same landscape unit. Off-site and off-lease mitigation should only be considered when feasible mitigation options are not available within or immediately adjacent to the impacted area, or when the off-site or off-lease location would provide more effective mitigation than can be achieved on-site.

Additional Guidelines for High Impact Developments (>4 well pad locations/mile^2 or disturbance exceeding 60 acres).

29. Adhere to all general guidelines and those applicable to "Moderate Impact Developments."
30. Develop the well field in smaller incremental phases (phased development) to reduce the overall impact of a high-density field. Although complex geological, technical, and regulatory issues may constrain the use of this strategy, it should be considered where feasible.
31. Opportunities may exist to partially offset the loss of crucial winter range by completing habitat rehabilitation and enhancement projects in appropriate locations outside the well field (off-site mitigation). This type of mitigation is difficult and should never be looked upon as a prescriptive solution to authorize high-density well fields in crucial winter range. The most effective solution is to avoid high-density developments. If avoidance is not feasible, plan effective habitat treatments in locations selected to minimize the loss of habitat function for the affected herd or population, within the same landscape unit.

Wind and Solar

32. Site wind and solar energy developments within areas already affected by other forms of development (e.g., urban areas, agricultural land, oil and gas fields, and existing or reclaimed mines). Avoid further fragmentation of intact native habitats.
33. Avoid locating wind and solar energy facilities within crucial mule deer winter ranges.

B. ROADS

1. Use existing roads, no matter how primitive, where they exist in areas that do not impact wildlife habitat and are not within environmentally sensitive areas.
2. If new roads are needed, close unnecessary roads that impact important mule deer habitat.
3. Roads should not bisect or run immediately adjacent to any water feature, or prevent mule deer from reaching adjacent habitat.
4. Construct the minimum number and length of roads necessary.
5. Coordinate road construction and use among companies operating in the same area.
6. Design and construct roads to a minimum standard to accommodate their intended purpose.
7. Design roads with adequate structures or features to discourage off-road travel.

C. TRANSMISSION CORRIDORS

1. Use existing utilities, power lines, roads, and pipeline corridors to the extent feasible.
2. Site new corridors in areas of already disturbed or poor quality mule deer habitat or adjacent to other linear disturbances.
3. Bury power lines whenever possible. All trenching should occur with concurrent back filling. All buried power lines should be placed in or adjacent to roads or other existing utility rights-of-way.
4. If fence construction is necessary, consult with the state or provincial wildlife agency to determine appropriate locations and designs based on wildlife resources of the site.
5. Construct above ground pipelines conveying geothermal fluids with sufficient ground clearance to allow adequate mule deer passage.
6. Conduct concurrent backfilling with trenching operations to minimize the amount of trench left open.

D. NOISE AND LIGHTING

1. Minimize noise to the extent possible. All compressors, vehicles, and other sources of noise should be equipped with effective mufflers or noise suppression systems (e.g., "hospital mufflers").
2. Wind turbines and other non-motorized structures should be designed to minimize noise.
3. Whenever possible, use electric motors instead of diesel engines to power compression equipment.
4. Use topography to conceal facilities and reduce noise disturbance in areas of known importance.
5. Manage on-site lighting to minimize disturbance to mule deer.

E. TRAFFIC AND HUMAN DISTURBANCE

1. Develop a travel plan that minimizes the amount of vehicular traffic required to monitor and maintain wells and other facilities (USDI 2005).
2. Limit traffic to the extent possible during high wildlife use hours (within 3 hours of sunrise and sunset).
3. Use pipelines (liquid gathering systems) to transport condensates off site.
4. Transmit instrumentation readings from remote monitoring stations to reduce maintenance traffic.
5. Post speed limits on all access and maintenance roads to reduce wildlife collisions and limit dust (30-40 mph is adequate in most cases).
6. Employees should be instructed to avoid walking away from vehicles or facilities into view of wildlife, especially during winter months.
7. Prohibit employees from carrying firearms in development fields or sites.
8. Institute a corporate-funded reward program for information leading to conviction of poachers, especially on winter range.

F. HYDROLOGIC RESOURCES (AGFD 2010)

1. Prepare a water management plan in those regions and for those operations that discharge surplus water of questionable quality (e.g., Coal Bed Methane).
2. Develop a contingency plan to prevent potential groundwater and surface water contamination.
3. Develop a storm water management plan to ensure compliance with state, provincial, and federal regulations and prevent off-site migration of contaminated storm water or increased soil erosion.
4. Spread excess excavated soil to match surrounding topography or dispose of in a manner to minimize erosion and leaching of hazardous materials.
5. Incorporate best management practices for addressing hydro-modification impacts (e.g., retention basins for treatment of water from runoff and infiltration and recharge of the groundwater basin).
6. Refuel in a designated fueling area that includes a temporary berm to contain the spread of any potential spill.
7. Use drip pans during refueling and under fuel pump and valve mechanisms of any bulk fueling vehicles parked at the project site to contain accidental releases.
8. Identify sustainable yields of groundwater and nearby surface water bodies.
9. Limit the withdrawal of water at the facility so it does not exceed the sustainable yield in order to preserve natural discharge sites (springs), ponds, and wells that may provide sources of water and enhanced forage for mule deer.
10. Avoid streams, wetlands, and drainages where possible. Locate access roads to minimize stream crossings and cause the least impact where crossings cannot be avoided. Where access roads would cross a dry drainage, the road gradient should be 0% to avoid diverting surface waters from the channel. Cross water bodies at right angles to the channel and in locations producing minimum impact.
11. Develop a Stormwater Pollution Plan. The Environmental Protection Agency (EPA) website contains templates for such a plan: http://cfpub.epa.gov/npdes/stormwater/swppp.cfm.
12. Locate contaminated ponds in places wildlife tend to avoid, such as areas of high human use or highly disturbed areas.
13. Waste water contaminant ponds should be fenced to prevent mule deer access.
14. Monitor ponds to detect wildlife mortalities. Develop a contingency plan to handle wildlife mortality incidents (e.g., if a waterfowl die-off is observed contact state, provincial, or federal agencies as soon as possible and have a contingency plan to handle the situation).
15. Maintain existing surface waters that mule deer use as a water source. Consider constructing freshwater ponds or wetlands nearby to attract wildlife away from

potentially toxic evaporation ponds. Water sources should not be placed in areas where increased wildlife-vehicle collisions could occur.

16. Monitor toxicity of the ponds and prepare a mitigation plan to address any rise in toxicity levels. The plan should include short- and long-term measures to deter wildlife from the area.
17. Rely on "dry cooling" technology to reduce water consumption at solar facilities. If this is not feasible, the hybrid parallel wet-dry cooling method should be used.

G. POLLUTANTS, TOXIC SUBSTANCES, DUST, EROSION, AND SEDIMENTATION

1. Avoid spilling or dumping oil or fuel (synthetic or hydrocarbon) or molten salts. Oil spills should be contained and all contaminated soil removed. Oil pits should not be used, but if absolutely necessary, they should be enclosed in netting and small-mesh fence. All netting and fence must be maintained and kept in serviceable condition.
2. Produced water from oil, gas, and geothermal facilities should not be pumped onto the surface except when beneficial for wildlife, provided water quality standards for wildlife and livestock are met. Produced water of suitable quality may also be used for supplemental irrigation to improve reclamation success.
3. Re-injection of water into Coal Bed Methane or geo-thermal sites should be considered when water quality is of concern.
4. Hydrogen sulfide should not be released into the environment.
5. If inorganic salts are spilled in solar operations, the molten material should be immediately cooled to a solid, contained within concrete dikes and curbing, and removed or recycled back into the system (AGFD 2010).
6. To contain hazardous materials such as arsenic, cadmium, or silicon, create a protocol for responsible disposal of decommissioned PV solar panels. Prior to facility construction, determine whether PV panel manufacturers provide an Extended Producer Responsibility (EPR) service which requires the manufacturer to take back their product, thus ensuring panels are recycled safely and responsibly, or recycle PV panels at existing responsible electronic waste recycling facilities or at facilities that recycle batteries containing lead and cadmium.

H. MONITORING AND ENVIRONMENTAL RESPONSE

1. Monitor conditions or events that may indicate environmental problems (e.g., water quality in nearby rivers, streams, wells, etc.). Such conditions or events can include any significant chemical spill or leak, detection of multiple wildlife mortalities, sections of roads with frequent and recurrent wildlife collisions, poaching and harassment incidents, severe erosion into tributary drainages, migration impediments, wildlife entrapment, sick or injured wildlife, or other unusual observations.
2. Immediately report observations of potential wildlife problems to the state or provincial wildlife agency and, when applicable, federal agencies such as USFWS or EPA.
3. Apply GIS technologies to monitor the extent of disturbance annually and document the progression and footprint of disturbances. Use this spatial data to evaluate the cumulative effects of existing and proposed impacts. Release compilations and analyses of this information to resource management agencies at least annually.

I. PUBLIC RECREATION AND ACCESS

1. Prior to finalizing development and travel management plans, state or provincial wildlife agencies should be consulted to ensure adverse impacts to hunting opportunity are prevented, minimized, or mitigated.
2. As projects are constructed, there is a possibility projects located over established roads may impede or restrict access to public lands. To guard against the creation of illegal roads and maintain access to public lands, coordinate with the appropriate landowners to create alternate travel routes. These alternate routes must be created in close proximity to the project and should be similar in function to the original routes. Signs should be installed to indicate public travel routes while project construction takes place and remain in place after project completion (AGFD 2010).
3. Hunting access should continue within developments on public lands and on private land with landowner permission.

J. RESEARCH AND SPECIAL STUDIES

1. Where there are questions or uncertainties regarding cumulative impacts, the degree of impact to specific resources, or effectiveness of mitigation, industries and companies should fund special studies to collect data for evaluation and documentation.
2. Conduct research to better understand wind-energy development impacts. Research should primarily investigate deer distribution pre- and post-development, abundance, and demography. Research on habitat should document vegetation species composition, utilization rates, location of migration corridors, location of important seasonal habitats, and changes in habitat use and distribution of deer.
3. Use the Before-After Control-Impact (BACI) research design. Data should be collected ≥2 years prior to development and 3 years post-development to provide a quantitative basis for estimating development impacts.
4. Evaluate alteration of vegetation and micro-climate adjacent to energy development.
5. Evaluate movement and behavior patterns of mule deer pre- and post-construction, especially the impact on movement corridors.
6. More research is needed on population-level effects of energy development on mule deer.

K. NOXIOUS WEEDS

1. Control noxious and invasive plants that appear along roads and at development sites and ancillary facilities (USDI 2005).
2. Designate specific areas to clean and sanitize all equipment brought in from other regions. Seeds and propagules of noxious plants are commonly imported by equipment and mud clinging to equipment.
3. Request employees to clean mud from footwear before traveling to the work site, to prevent importation of noxious weeds.

L. INTERIM RECLAMATION

1. Establish effective, interim reclamation on all surfaces disturbed throughout the operational phase of the development.
2. Reclaim abandoned or decommissioned development sites concurrently with development of new sites.
3. Salvage topsoil from all construction and re-apply during interim reclamation.
4. Approved weed-free mulch application should be used in sensitive areas (dry, sandy, steep slopes).
5. A variety of native grasses, shrubs, and forbs endemic to the site should be used for revegetation. Non-native vegetation is discouraged and should not be used unless native forbs and grasses are not available or are ineffective in quickly recovering the site.
6. Continue to monitor and treat reclaimed surfaces until satisfactory plant cover is established.
7. Solar facilities need not be fenced. Native and preferred non-native forbs and grasses should be established to sustain use by wildlife during energy production.

M. FINAL RECLAMATION

1. Develop a comprehensive reclamation plan addressing vegetation and hydrology considerations, which includes specifically measurable objectives for wildlife and habitat so success can be achieved during the production phase of development (WAFWA 2010).
2. Salvage topsoil during decommissioning operations and reapply to reclaimed surfaces.
3. All buildings, well heads, turbines, solar arrays, and ancillary facilities should be removed.
4. Replant a mixture of forbs, grasses, and shrubs that are native to the area and suitable for the specific ecological site.
5. Restore vegetation cover, composition, and diversity to achieve numeric standards commensurate with the ecological site.
6. Do not allow grazing on re-vegetated sites until the plants are established and can withstand herbivory as noted through monitoring.
7. Reevaluate the existing system of bonding. Bonds should be set at a level adequate to cover the company's liability for reclamation of the entire development project.

HABITAT MITIGATION OPTIONS

The habitat enhancements suggested in this section are largely based on a similar document used successfully in Wyoming (WGFD 2010a). These represent options for companies and resource agencies to consider in designing an integrated mitigation plan to sustain mule deer habitat functions potentially affected by energy developments. The list is not exhaustive; many additional options and practices could also provide effective mitigation. Regional biologists, company personnel, and others may have alternative suggestions to address specific circumstances.

Corporate-owned Lands under Conservation Management – Management of corporate-owned or -controlled lands may be one of the best alternatives to achieve effective, long-term mitigation of energy development impacts. Availability of corporate-owned lands can provide managers with increased options and flexibility to mitigate impacts and potentially provide increased recreational access.

Conservation Easements – This concept includes numerous options and practices for mitigating impacts to the most crucial habitats. These options and practices include maintaining open space, excluding subdivisions, keeping an agricultural base of operations compatible with wildlife, excluding fencing or other developments that are restrictive to wildlife migration and movement, grazing management systems, etc. Where appropriate, conservation easements could be established through the formation of a land trust, or by earmarked contributions to an existing land trust. Depending upon the amount of property rights acquired, costs range from 35% to 95% of fee title acquisition. The mitigation would be in effect as long as the easement is held and monitored by the assignee. The intent is to maintain the easements at least throughout the time habitat functions are disrupted, including the time required for reclamation to mature.

Grazing or AUM Management Program – This practice could include many options, with the owner's or permittee's concurrence, to improve habitat quality for wildlife. Some options might include: 1) paying for private grazing AUMs to provide rest or treatments on public lands; 2) paying for a portion of the AUMs within an allotment; 3) providing for rest or treatments and once completed, turning the land back to grazing use; 4) purchase of AUMs to reduce grazing use on important habitats; or 5) establishing forage reserves (grass banks) to provide management flexibility for habitat treatments and livestock grazing. Other grazing management options include electric fencing to provide pasture systems, herding, water developments, etc. These could all be utilized to better manage grazing animals to improve range and habitat conditions.

Habitat Improvements – Several states and NGOs are currently implementing programs to acquire, protect, and improve to recover mule deer populations. The same habitat management practices could be applied as off-site mitigation where important habitats could potentially be improved to restore habitat functions impacted in other areas. Before habitat treatments are applied, qualified personnel should evaluate the prospective site to determine its condition, improvement potential, and ecologically appropriate treatments. Practitioners are encouraged to consult the Mule Deer Habitat Guidelines in their respective ecoregion for recommended practices (www.muledeerworkinggroup.com). Early consultation with the state or provincial wildlife management agency and land management agencies can greatly assist with the planning of effective habitat work and selection of appropriate treatments.

LITERATURE CITED

Arizona Game and Fish Department (AGFD). 2010. Guidelines for solar development in Arizona. Arizona Game and Fish Department, Phoenix, USA.

Baker, W. L. 2006. Fire and restoration of sagebrush ecoystems. Wildlife Society Bulletin 34:177-185.

Barber, J. R., K. R. Crooks, and K. M. Fristup. 2010. The costs of chronic noise exposure for terrestrial organisms. Trends in Ecology and Evolution 25:180-189.

Bartmann, R. M., G. C. White, and L. H. Carpenter. 1992. Compensatory mortality in a Colorado mule deer population. Wildlife Monographs 121:1-39

Bergman, E. J., C. J. Bishop, D. J. Freddy, and G. C. White. 2007. Evaluation of winter range habitat treatments on over-winter survival and body condition of mule deer. Wildlife Research Report, Colorado Division of Wildlife, Fort Collins, USA.

Bishop, C. J. 2007. Effect of enhanced nutrition during winter on the Uncompahgre Plateau mule deer population. Dissertation, Colorado State University, Fort Collins, USA

Blackwell, D. D., and M. Richards. 2004. Subset of geothermal map of North America. American Association of Petroleum Geologists, Tulsa, Oklahoma, USA. <http://www.smu.edu/geothermal> Accessed 1 September 2010.

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the northern Great Basin. U.S. Forest Service General Technical Report INT-231, Ogden, Utah, USA.

Cooper, S. V., P. Lesica, and G. M. Kudray. 2007. Post-fire recovery of Wyoming big sagebrush shrub-steppe in central and southeast Montana. Report to the U.S. Department of the Interior, Bureau of Land Management, State Office. Montana Natural Heritage Program, Helena, USA.

Copeland, H. E., K. E. Doherty, D. E. Naugle, A. Pocewicz, and J. M. Kiesecker. 2009. Mapping oil and gas development potential in the U.S. Intermountain West and estimating impacts to species. PLoS ONE 4(10): e7400. doi:10.1371/journal.pone.0007400

Energy Policy Act of 2005. 2005. Energy policy act of 2005. <www.epa.gov/oust/fedlaws/publ_109-058.pdf> Accessed 17 Dec 2010.

Farrell, J. E., L. R. Irby, and P. T. McGowen. 2002. Strategies for ungulate-vehicle collision mitigation. Intermountain Journal of Sciences 8:1-18.

Freddy, D. J., W. M. Bronaugh, and M. C. Fowler. 1986. Responses of mule deer to disturbance by persons afoot and snowmobiles. Wildlife Society Bulletin 14:63-68.

Frid, A., and L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology 6:11.

Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. Road ecology: science and solutions. Island Press, Washington, D.C., USA.

Gainer, R. S. 1995. Range extension of white-tailed deer. Alberta Naturalist 25:34-36.

Gamo, R. S., and S. H. Anderson. 2002. Use of reclaimed minelands by pronghorn and mule deer. Intermountain Journal of Sciences 8:213-222.

Gill, J. A., W. J. Sutherland, and A. R. Watkins. 1996. A method to quantify the effects of human disturbance for animal populations. Journal of Applied Ecology 33:786-792.

Hebblewhite, M. 2008. A literature review of the effects of energy development on ungulates: implications for central and eastern Montana. Report prepared for Montana Fish, Wildlife and Parks, Miles City, USA.

Hebblewhite, M. 2011. Effects of energy development on ungulates. Pages 71–94 in D. E. Naugle, editor. Energy development and wildlife conservation in western North America. Island Press, Washington D.C., USA

Heffelfinger, J. R., and T. A. Messmer. Introduction. Pages 1-11 in J. C. deVos, Jr., M. R. Conover, and N. E. Headrick, editors. Mule deer conservation: issues and management strategies. Jack H. Berryman Institute Press, Utah State University, Logan, USA.

Holm, A., L. Blodgett, D. Jennejohn, and K. Gawell. 2010. Geothermal energy: international market update. Geothermal Energy Association, Washington, D.C., USA.

Kuvlesky, W. P., Jr., L. A. Brennan, M. L. Morrison, K. K. Boydston, B. M. Ballard, and F. C. Bryant. 2007. Wind energy development and wildlife conservation: challenges and opportunities. Journal of Wildlife Management 71:2487-2498.

Lutz, D. W., M. Cox, B. F. Wakeling, D. McWhirter, L. H. Carpenter, S. Rosenstock, D. Stroud, L. C. Bender, and A. F. Reeve. 2003. Impacts to changes to mule deer habitat. Pages 13-61 in J. C. deVos, Jr., M. R. Conover, and N. E. Headrick, editors. Mule deer conservation: issues and management strategies. Jack H. Berryman Institute Press, Utah State University, Logan, USA.

Medcraft, J. R., and W. R. Clark. 1986. Big game habitat use and diets on a surface mine in northeastern Wyoming. Journal of Wildlife Management 50:135-142.

Merrill, E. H., T. P. Hemker, K. P. Woodruff, and L. Kuck. 1994. Impacts of mining facilities on fall migration of mule deer. Wildlife Society Bulletin 22:68-73.

National Energy Policy. 2001. Reliable, affordable, and environmentally sound energy for America's future. Report of the National Energy Policy Development Group. U.S. Government Printing Office, Washington, D.C.

Naugle, D. E., B. L. Walker, and K. E. Doherty. 2006. Sage-grouse population response to coal-bed natural gas development in the Powder River Basin: interim progress report on region-wide lek-count analysis. Unpublished report, University of Montana, Missoula, USA.

New Mexico Department of Game and Fish (NMDGF). 2007. Oil and gas development guidelines: conserving New Mexico's wildlife habitats and wildlife. <http://www.wildlife.state.nm.us/documents/oilandgasguidelines.pdf> Accessed 8 July 2010.

Noss, R. F., and A. Y. Cooperrider. 1994. Saving nature's legacy. Island Press, Washington, D.C., USA.

Pojar, T. M., and D. C. Bowden. 2004. Neonatal mule deer survival in westcentral Colorado. Journal of Wildlife Management 68:550–560.

Rost, G. R., and J. A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43:634-641.

Sawyer, H., M. J. Kauffman, and R. M. Nielson. 2009a. Influence of well pad activity on winter habitat selection patterns of mule deer. Journal of Wildlife Management 73:1052-1061.

Sawyer, H., M. J. Kauffman, R. M. Nielson, and J. S. Horne. 2009c. Identifying and prioritizing ungulate migration routes for landscape-level conservation. Ecological Applications 19:2016-2025.

Sawyer, H., F. Lindzey, D. McWhirter, and K. Andrews. 2002. Potential effects of oil and gas development on mule deer and pronghorn populations in western Wyoming. Transactions of the 67th North American Wildlife and Natural Resources Conference 67:350-365.

Sawyer, H., F. Lindzey, and D. McWhirter. 2005. Mule deer and pronghorn migration in western Wyoming. Wildlife Society Bulletin 33:1266-1273.

Sawyer, H., and R. Nielson. 2010. Mule deer monitoring in the Pinedale Anticline project area: 2010 annual report. Western Ecosystems Technology, Inc. Cheyenne, Wyoming, USA.

Sawyer, H., R. M. Nielson, F. Lindzey, and L. L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. Journal of Wildlife Management 70:396-403.

Sawyer, H., R. Nielson, and D. Strickland. 2009b. Sublette mule deer study (phase II): final report 2007 - long-term monitoring plan to assess potential impacts of energy development on mule deer in the Pinedale Anticline project area. Western Ecosystems Technology, Inc. Cheyenne, Wyoming, USA.

Stalling, D. 2003. Gas and oil development on western public lands; impacts on fish, wildlife, hunting, and angling. A report produced by Trout Unlimited's Public Lands Initiative.

The Wildlife Society. 2008a. Impacts of wind energy development on wildlife and wildlife habitat, final position statement. The Wildlife Society, Bethesda, Maryland, USA.

The Wildlife Society. 2008b. Oil and gas development in the Rocky Mountain West, final position statement. The Wildlife Society, Bethesda, Maryland, USA.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

U.S. Department of Energy (DOE). 2007. Concentrating Solar Power commercial application study: reducing water consumption of Concentrating Solar Power electricity generation. Report to Congress. U.S. Department of Energy, Washington, DC, USA.

U.S. Department of Energy (DOE). 2010. Wind and water power program: wind power today 2010. USDOE, DOE/GO-102010-3011 May 2010. http://www1.eere.energy.gov/windandhydro/wind_pubs.html. Accessed 17 May 2011.

U.S. Department of the Interior, Bureau of Land Management (USDI). 1999. Glenwood Springs Resource Area; oil and gas leasing and development: final supplemental environmental impact statement, Bureau of Land Management. Glenwood Springs Field Office, Colorado, USA.

U.S. Department of the Interior, Bureau of Land Management (USDI). 2005. Record of decision: implementation of a wind energy development program and associated land use plan amendments. Washington, D.C., USA.

U.S. Department of the Interior, Bureau of Land Management (USDI) and U.S. Department of Agriculture, U.S. Forest Service (USDA). 2008. Programmatic Environmental Impact Statement for geothermal leasing in the Western United States. FES 08-44, U.S. Government Printing Office. Washington, D.C., USA.

U.S. Fish and Wildlife Service (USFWS). 2007. 2006 national survey of fishing, hunting, and wildlife-associated recreation. <http://library.fws.gov/Pubs/nat_survey2006_final.pdf>. Accessed 7 Dec 2009.

U.S. Fish and Wildlife Service (USFWS). 2010. Wind Turbine Guidelines Advisory Committee recommendations. <http://www.fws.gov/habitatconservation/windpower/wind_turbine advisory_committee.html>. Accessed 29 Oct. 2010.

U.S. Fish and Wildlife Service (USFWS). 2011. U.S. Fish and Wildlife Service draft land-based wind energy guidelines: recommendations on measures to avoid, minimize, and compensate for effects to fish, wildlife, and their habitats. <http://www.fws.gov/habitatconservation/wind.html>. Accessed 17 May 2011.

Wallmo, O. C., L. H. Carpenter, W. L. Regelin, R. B. Gill, and D. L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. Journal of Range Management 30:122 – 127.

Watkins, B. E., C. J. Bishop, E. J. Bergman, B. Hale, B. F. Wakeling, A. Bronson, L. H. Carpenter, and D.W. Lutz. 2007. Habitat guidelines for mule deer: Colorado Plateau shrubland and forest ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies, USA.

Western Association of Fish and Wildlife Agencies (WAFWA). 2010. Resolution on energy development, Western Association of Fish and Wildlife Agencies, USA.

Western Governor's Association. 2008. Wildlife corridors initiative. <http://www.westgov.org>. Accessed 17 Dec 2010.

White, G. C., and R. M. Bartmann. 1998. Effect of density reduction on overwinter survival of free-ranging mule deer fawns. Journal of Wildlife Management 62:214-225.

Winward, A. H. 1991. A renewed commitment to management of sagebrush grasslands. Pages 2-7 in Management in the sagebrush steppe. Oregon Agricultural Experiment Station Special Report 880. <oregonstate.edu/dept/eoarc/sites/default/files/researchhome/documents/360a.pdf>. Accessed 17 May 2011.

Wyoming Game and Fish Department (WGFD). 2010a. Recommendations for development of oil and gas resources within important wildlife habitats. Wyoming Game and Fish Department, Cheyenne, USA.

Wyoming Game and Fish Department (WGFD). 2010b. Wildlife protection recommendations for wind energy development in Wyoming. Wyoming Game and Fish Department, Cheyenne, USA.

Young, J. A., and R. A. Evans. 1981. Demography and fire history of a western juniper stand. Journal of Range Management 34:501-506.

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