# U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative—2008 Annual Report

Open-File Report 2009-1201

U.S. Department of the Interior
U.S. Geological Survey

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By Zachary H. Bowen, Cameron L. Aldridge, Patrick J. Anderson, Timothy J. Assal, Lori Anne Baer, Sky Bristol, Natasha B. Carr, Geneva W. Chong, Jay E. Diffendorfer, Bradley C. Fedy, Steven L. Garman, Stephen Germaine, Richard I. Grauch, Collin Homer, Daniel Manier, Matthew J. Kauffman, Natalie Latysh, Cynthia P. Melcher, Kirk A. Miller, Jessica Montag, Constance J. Nutt, Christopher Potter, Hall Sawyer, David B. Smith, Michael J. Sweat, Anna B. Wilson

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**U.S. Department of the Interior**
**U.S. Geological Survey**

**U.S. Department of the Interior**
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**U.S. Geological Survey**
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# Conversion Factors

## SI to Inch/Pound

| Multiply | By | To obtain |
|---|---|---|
| Length | | |
| centimeter (cm) | 0.3937 | inch (in.) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |
| meter (m) | 1.094 | yard (yd) |
| Area | | |
| square meter ($m^2$) | 0.0002471 | acre |
| hectare (ha) | 2.471 | acre |
| square kilometer ($km^2$) | 247.1 | acre |
| square meter ($m^2$) | 10.76 | square foot ($ft^2$) |
| hectare (ha) | 0.003861 | square mile ($mi^2$) |
| square kilometer ($km^2$) | 0.3861 | square mile ($mi^2$) |

## Inch/Pound to SI

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| inch (in.) | 2.54 | centimeter (cm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| yard (yd) | 0.9144 | meter (m) |
| | Area | |
| acre | 4,047 | square meter ($m^2$) |
| acre | 0.4047 | hectare (ha) |
| acre | 0.004047 | square kilometer ($km^2$) |
| square foot ($ft^2$) | 0.09290 | square meter ($m^2$) |
| square mile ($mi^2$) | 259.0 | hectare (ha) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F=(1.8×°C)+32. Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows: °C=(°F-32)/1.8.

Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, “North American Vertical Datum of 1988 (NAVD 88).”

Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here for instance, “North American Datum of 1983 (NAD 83).”

Altitude, as used in this report, refers to distance above the vertical datum.

## Acronyms Used in this Report

| | |
|---|---|
| **AOGCM** | Atmosphere-ocean general circulation model |
| **AWiFS** | Advanced Wide Field Sensor (a multispectral camera) |
| **AWVED** | Assessment of Wildlife Vulnerability to Energy Development |
| **BLM** | U.S. Bureau of Land Management |
| **BMP** | Best management practice |
| **BOR** | U.S. Bureau of Reclamation |
| **CSC** | Comprehensive Science Catalog |
| **CT** | Coordination Team (for the WLCI) |
| **CWCS** | Comprehensive Wildlife Conservation Strategy (of Wyoming) |
| **DIMT** | Data and Information Management Team |
| **DOI** | U.S. Department of the Interior |
| **EC** | Executive Committee (for WLCI) |
| **FWS** | U.S. Fish and Wildlife Service |
| **GIO** | Geographic information office (of the USGS) |
| **GIS** | Geographic information system |
| **GRTS** | Generalized Random Tessellation Stratified (design) |
| **HUC** | Hydrological unit code |
| **I&M** | Inventory and monitoring |
| **JIO** | Jonah Interagency Office |
| **LPDT** | Local Project Development Team |
| **MT** | Monitoring Team |
| **NDVI** | Normalized difference vegetation index |
| **NewMRDS** | New Mineral Resources Data System |
| **NWreGAP** | Northwest Regional Gap Analysis Project |
| **NPS** | National Park Service |
| **NWISWeb** | National Water Information System Web site |
| **QB** | QuickBird |
| **RMGSC** | Rocky Mountain Geographic Science Center |
| **SCIM** | Simple Content Item Manager (application) |

| | |
|---|---|
| **SGCN** | Species of Greatest Conservation Need |
| **STAC** | Science and Technical Advisory Committee (of the WLCI) |
| **USFS** | U.S. Forest Service |
| **USGS** | U.S. Geological Survey |
| **WBEA** | Wyoming Basins Ecoregional Assessment |
| **WGFD** | Wyoming Game and Fish Department |
| **WLCI** | Wyoming Landscape Conservation Initiative |
| **WDA** | Wyoming Department of Agriculture |
| **WRD** | Water Resources Discipline (of the USGS) |
| **WYNDD** | Wyoming Natural Diversity Database |

## Acknowledgments

We thank the Wyoming Landscape Conservation Initiative's Science and Technical Advisory Committee and the Coordination Team for their ideas and advice regarding this report. We also thank Dan Blake (Wyoming Ecological Services of the U.S. Fish and Wildlife Service), Tim Kern (Arctic Slope Regional Corporation Management Services contracted to U.S. Geological Survey), and Catherine Jarnevich (Invasive Species Branch, Fort Collins Science Center, U.S. Geological Survey) for their reviews.

# U.S. Geological Survey Science for the Wyoming Landscape Conservation Initiative: 2008 Annual Report

By Zachary H. Bowen,[1] Cameron L. Aldridge,[1,2] Patrick J. Anderson,[1] Lori Anne Baer,[3] Sky Bristol,[4] Natasha B. Carr,[1] Anna Chalfoun,[5] Geneva W. Chong,[2,6] Jay E. Diffendorfer,[3] Steven L. Garman,[3] Stephen Germaine,[1] Richard I. Grauch,[7] Collin Homer,[8] Natalie Latysh,[4] Daniel Manier,[9] Matthew J. Kauffman,[5] John J. Kosovich,[4] Kirk A. Miller,[10] Jessica Montag,[1] Constance J. Nutt,[7] Christopher Potter,[11] Hall Sawyer,[5] David B. Smith,[7] Michael J. Sweat,[10] Anna B. Wilson[7]

## Abstract

The Wyoming Landscape Conservation Initiative (WLCI) was launched in 2007 in response to concerns about threats to the State's world class wildlife resources, especially the threat posed by rapidly increasing energy development in southwest Wyoming. The overriding purpose of the WLCI is to assess and enhance aquatic and terrestrial habitats at a landscape scale, while facilitating responsible energy and other types of development. The WLCI includes partners from Federal, State, and local agencies, with participation from public and private entities, industry, and landowners. As a principal WLCI partner, the U.S. Geological Survey (USGS) provides multidisciplinary scientific and technical support to inform decisionmaking in the WLCI. To address WLCI management needs, USGS has designed and implemented a five integrated work activities: (1) Baseline Synthesis, (2) Targeted Monitoring and Research, (3) Integration and Coordination, (4) Data and Information Management, and (5) Decisionmaking and Evaluation. Ongoing information management of data and products acquired or generated through the integrated work activities will ensure that crucial scientific information is available to partners and stakeholders in a readily accessible and useable format for decisionmaking and evaluation. Significant progress towards WLCI goals has been achieved in many Science and Technical Assistance tasks of the work activities. Available data were identified, acquired, compiled, and

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integrated into a comprehensive database for use by WLCI partners and to support USGS science activities. A Web-based platform for sharing these data and products has been developed and is already in use. Numerous map products have been completed and made available to WLCI partners, and other products are in progress. Initial conceptual, habitat, and climate change models have been developed or refined. Monitoring designs for terrestrial and aquatic indicators have been completed, pilot data have been collected for terrestrial indicators, and evaluations of alternative monitoring designs are underway. Initial models and map products have been developed for assessing vegetation, surface disturbance, oil and gas resources, mineral resources, surficial geology, invasive species, aspen treatments, ungulate migration corridors, greater sage-grouse (*Centrocercus urophasianus*), pygmy rabbits (*Brachylagus idahoensis*), and songbirds, and data were collected or compiled to validate and refine the models. Coordination and collaboration among partners has led to the production of several documents addressing WLCI objectives, strategies, and guiding principles, and has facilitated implementation of on-the-ground habitat treatments.

## Introduction

Southwest Wyoming contains abundant wildlife, habitat, and energy resources. To date, settlement of this region has been limited and the area is characterized by open spaces, sparse human population, and local economies tied to agriculture, resource extraction, and recreation. An important component of development in southwest Wyoming is energy extraction, including coal, oil, natural gas, and uranium. The region is part of the Greater Green River Basin, which has been explored and developed for fossil fuels since the late 19th century. Since 2000, the pace of energy development in the region has increased significantly, especially development associated with natural gas and, more recently, wind energy. Energy development, combined with increased residential and industrial development, has resulted in land use and socioeconomic change in the region. Concern about the potential effects of increased development on wildlife and wildlife habitat led the U.S. Bureau of Land Management (BLM) and the Wyoming Game and Fish Department (WGFD) to conceptualize a landscape-level initiative to address their concerns.

Driven by local and regional leaders, the Wyoming Landscape Conservation Initiative (WLCI) was officially launched in 2007 with support from the U.S. Department of the Interior (DOI). The mission of the WLCI is to implement a long-term, science-based effort to assess, conserve, and enhance fish and wildlife habitats while facilitating responsible development through local collaboration and partnerships. Partners in the WLCI include the BLM, U.S. Geological Survey (USGS), U.S.

Kevin Hughes (Biological Science Technician, USGS) weighing a Thirteen-lined Ground Squirrel in the Wyoming Landscape Conservation Initiative region. (Photo by Steve Germaine, USGS)

Fish and Wildlife Service (FWS), Wyoming Game and Fish Commission (the policy-making board for the WGFD), Wyoming Department of Agriculture (WDA), U.S. Forest Service (USFS), six Wyoming County Commissions, and eight of Wyoming's Conservation Districts. Additional collaborators providing support to the WLCI effort include many public agencies, including the National Park Service (NPS), U.S. Natural Resources Conservation Service, U.S. Bureau of Reclamation (BOR), Wyoming Department of Environmental Quality, Wyoming State Land Board, Jonah Interagency Mitigation and Reclamation Office (JIO), as well as non-profit entities, industry, and landowners.

The role of USGS as a partner in the WLCI is to provide multidisciplinary scientific and technical support to WLCI partners and to advance the overall scientific understanding of southwest Wyoming's ecosystems. Fulfilling these roles entails

- evaluating the effectiveness of habitat treatments implemented by WLCI partners and collaborators,
- assessing the cumulative effects of energy development and other land-use changes on wildlife and habitat in the WLCI area, and
- coordinating work activities and demonstrating how to integrate research findings into on-the-ground management actions.

Information gained from research conducted by the USGS is being used to guide and improve future habitat treatments, best management practices (BMPs), and other conservation activities. Background information, goals, and strategies for WLCI science and technical assistance are detailed in the USGS WLCI Science Strategy (Bowen and others, 2009).

To support the mission and achieve the goals of the WLCI, many people have accomplished a great deal in a short time period. In less than one year, an organizational structure was defined; committees and teams were organized and staffed; charter documents and plans—including a WLCI Strategic Plan (Anderson and others, 2008), WLCI Operation Plan, WLCI Science and Management Integration Plan, and USGS WLCI Science Strategy (Bowen and others, 2009)—were written; a Web site and project database were developed; and, most importantly, habitat projects were developed and implemented. In 2008, 29 habitat projects were supported by BLM and FWS, along with in-kind support of $1.5 million from other groups. Habitat projects included fencing, prescribed burns, weed treatments, wetland creation, riparian enhancements, and river restoration. These projects are designed to benefit multiple species, including greater sage-grouse (*Centrocercus urophasianus*), trumpeter swan (*Cygnus buccinator*), migratory birds, cutthroat trout (*Oncorhynchus clarki* ssp.), various warm water fish, and big game species.

This report, the first annual summary of work and results, explains integrated scientific and technical assistance tasks conducted by USGS during 2008 as part of the WLCI. The Introduction section presents the management needs of the overall WLCI and the USGS research approach developed to address these needs. It also provides context and an organizational structure for USGS work reported in subsequent sections. The main section of the report, Science and Technical Assistance Summaries, describes individual science and technical assistance tasks conducted in 2008; these task summaries include scope and methods, objectives, study area and map, and work and products completed. The last section is an appendix that provides additional or more detailed information about individual tasks.

## Management Needs and WLCI Research Approach

As part of the overall WLCI effort, USGS scientists developed a USGS WLCI Science Strategy (Bowen and others, 2009), which builds on the management needs (listed below) identified by WLCI partners and integrates them with USGS capabilities and priorities. Addressing management needs (D'Erchia, 2008), which is critical for the successful implementation of effective management and conservation actions, includes

- evaluating the cumulative effects of development activities in southwest Wyoming (all other management needs support evaluation of cumulative effects);
- identifying the key drivers of change;
- identifying the condition and distribution of key wildlife species, habitat, and species' habitat requirements;
- evaluating wildlife and livestock responses to development;
- identifying the most effective and needed restoration, reclamation, and mitigation activities, as well as locations for such activities that will maximize conservation benefits;
- developing an integrated inventory and monitoring (I&M) strategy; and
- developing a data clearinghouse and information management framework.

Each management need listed above is described in the USGS WLCI Science Strategy (Bowen and others, 2009) along with overall research objectives for each management need, and both short-term and long-term activities designed to fulfill the research objectives. The Science Strategy document also describes an iterative set of activities for structuring and integrating WLCI science and technical assistance activities (fig. 1). This approach allows for rapid program implementation to identify information gaps and assess status and trends, while gradually

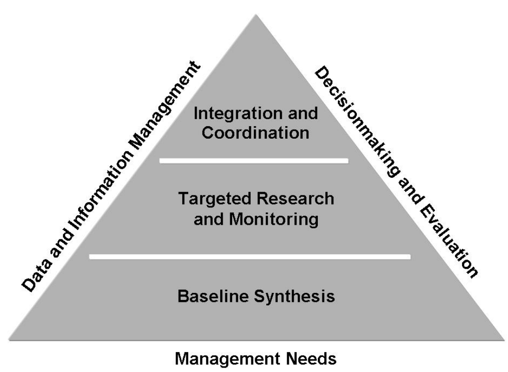
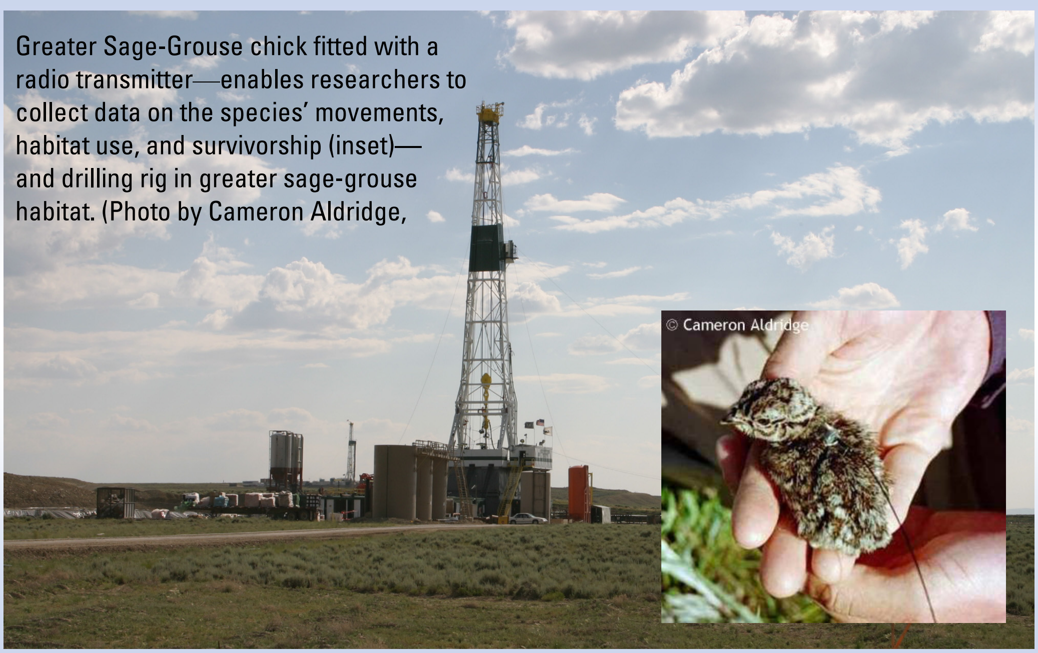



**Figure 1.** This diagram illustrates the U.S. Geological Survey's approach to researching and monitoring ecosystem components. The Management Needs identified by the WLCI partners form the foundation of the five major WLCI work activities: (1) Baseline Synthesis, (2) Targeted Monitoring and Research, (3) Integration and Coordination, (4) Data and Information Management, and (5) Decisionmaking and Evaluation. They represent successive stages that build on information gained from earlier stages, and at any stage Data and Information Management ensures access for use in Decisionmaking and Evaluation. The approach may be used iteratively and allows for stages to overlap.

expanding the program through feedback from an adaptive monitoring framework linked to WLCI goals and objectives (as described in the WLCI Strategic Plan; Anderson and others, 2008). Collectively, the activities are designed to ensure that quality information is available and useful. The approach also provides a framework for coordinating work among many agencies.

## Implementation of the USGS WLCI Science Strategy

In 2008, USGS conducted work on four of the five major work activities illustrated in figure 1: Baseline Synthesis, Targeted Monitoring and Research, Integration and Coordination, and Data and Information Management. Work focused on addressing immediate needs identified by WLCI members—supporting the identification, implementation, and tracking of habitat projects in priority areas—while simultaneously launching longer-term, priority technical assistance, research, and monitoring activities as part of the overall research approach for the WLCI. Work activities were initiated to address questions and issues at a range of spatial scales, from individual habitat treatment sites to the entire WLCI landscape. This approach provides information to support policy and planning decisions while meeting specific technical assistance needs. Combined, these activities also represent a pilot effort to conduct integrated resource assessments—a goal identified in the USGS Strategic Plan (U.S. Geological Survey, 2007)—that will help form a basis for evaluating cumulative effects of energy development on wildlife and habitats. As the initiative continues, the long-term vision is to continue providing technical assistance and research for management needs while structuring scientific observation and experimentation to improve understanding of the region's ecosystems and how they are driven by and respond to change. This understanding will strengthen the basis for management decisions and advance the mission of the initiative.




Greater Sage-Grouse chick fitted with a radio transmitter—enables researchers to collect data on the species' movements, habitat use, and survivorship (inset)—and drilling rig in greater sage-grouse habitat. (Photo by Cameron Aldridge,

# Science and Technical Assistance Summaries

## Baseline Synthesis

### Overview

The first goals of Comprehensive Assessment activities were to identify and acquire selected resource data and to develop decision support tools. A Comprehensive Assessment Workshop, held in March 2008, provided initial input on preferred map products and priority information needs. More than 175 relevant datasets have been obtained and compiled, and numerous map products were developed to support WLCI tasks. Data and products derived from the Comprehensive Assessment are being used to identify common areas of interest among all WLCI partners, to improve the quantification of habitat and human disturbance, provide information for management decisions, and to support WLCI science tasks.

Additional Comprehensive Assessment activities began to address land disturbance, energy futures, mineral resources, and socioeconomic issues. Methods to quantify land disturbance using satellite imagery were developed and initial land disturbance maps were completed for two priority areas. To document and disseminate available information on the temporal development of oil and gas production, as well as subsurface geology, a Web service was developed (in Biewick and others, 2009; *http://pubs.usgs.gov/ds/437/html/download.html*). It synthesizes information on past exploration and production, as well as undiscovered oil and gas resources, in southwest Wyoming. To provide an overview of base- and precious-metal mineralized areas, records of mines and prospects were updated in USGS's New MRDS (Mineral Resources Data System) database. Compilation of information about socioeconomic costs and benefits of energy development is underway and an assessment of social and economic issues surrounding oil and gas development in the western United States has been completed.

Another component of the Baseline Synthesis was to develop and revise models to help establish priorities and guide conservation and management activities. A preliminary set of hierarchical conceptual models was developed. These models captured and documented current knowledge about key drivers and stressors of target terrestrial systems in southwest Wyoming (sagebrush [*Artemisia* spp.] steppe, aspen foothill woodlands, riparian, and mixed mountain shrublands). As part of an additional task—Assessing Wildlife Vulnerability to Energy Development (AWVED)—a set of improved range maps for Wyoming's Species of Greatest Conservation Need (SGCN) was developed, and an analysis of environmental data necessary for developing habitat distribution models was completed. The WLCI partners identified climate change as a key driver/stressor in the conceptual models. To address this issue, temperature and precipitation data are being down-scaled to the regional level; these data will form the basis for future climate predictions and will be used to simulate vegetation dynamics in the WLCI area. Collectively, these products will help to identify additional indicators of change, conservation and management priorities, and potential impacts in the future.

Details of the work accomplished in Baseline Synthesis tasks are provided below in (1) Application of Comprehensive Assessment Data to Support WLCI Decisionmaking and Conservation Actions, (2) Land Use/Cover Change, (3) Energy Futures, (4) Mineral Resources, (5) Social and Economic Evaluation Supporting Adaptive Management for the Wyoming Landscape Conservation Initiative, (6) Assessing Wildlife Vulnerability to Energy Development, (7) Climate Change and Potential Future Vegetation Simulations, and (8) Conceptual Models and Indicators of

Change: Effects of Energy Development and Climate Change on Ecosystems of the Wyoming Basin.

## Application of Comprehensive Assessment Data to Support WLCI Decisionmaking and Conservation Actions

### *Scope and Methods*

The comprehensive assessment is a collaborative effort to compile and analyze resource data from many sources to support diverse needs and efforts within the WLCI. This assessment is being conducted to identify common areas of interest for all WLCI partners, to improve the quantification of habitat and human disturbance, and to provide the best available information for management decisions by the WLCI Coordination Team (CT) and other teams and committees of the WLCI. This information will help the WLCI CT support conservation planning and development of conservation strategies, identify priority areas for future conservation projects, and support the evaluation and ranking of conservation projects. In general, this assessment will include data and information that will help characterize important ecological systems (for example, important species, priority habitats, and migration routes), known infrastructure and developed areas, and locations of past and current conservation projects. Data and information sources include low- and high-resolution imagery, regional-level resources (for example, maps of soils, land cover, and roads), local resources and managers associated with WLCI partners (BLM, USFS, FWS, WGFD, WDA) and industry, and results from modeling efforts for sage-grouse and other species. Additional information on potential wind energy development and energy transmission corridors will be collected in 2009 to aid in building data layers for these activities in southwest Wyoming.

### *Objectives*

- Inventory and acquire important ecosystem, conservation, land management, and energy-related information and data across the WLCI area.
- Develop strategies and approaches to evaluate relationships between data derived from modeling and data acquired from WLCI partners, which will inform decision makers such as the CT and other WLCI committees about risks, threats, and priorities for future conservation actions.
- Using the comprehensive assessments, provide an understanding of the relationships between stressors and drivers, and their influence on important species and habitats.
- Develop a coarse screen to identify potential threats and support retrospective analyses for identifying important areas for future conservation projects and assist the livestock industry with spatially representing priority areas, such as calving or lambing areas, and areas for potential forage reserves and grass banks.
- Compile, rectify, manage, and provide data to USGS Geographic Information Office (GIO) in support of the USGS/WLCI Comprehensive Science Catalog and Data Clearinghouse.
- Provide a data and analytical foundation for all WLCI science and technical assistance tasks.

### *Study Area and Map*

Activities associated with the comprehensive assessment apply to the entire WLCI region (fig. 2).

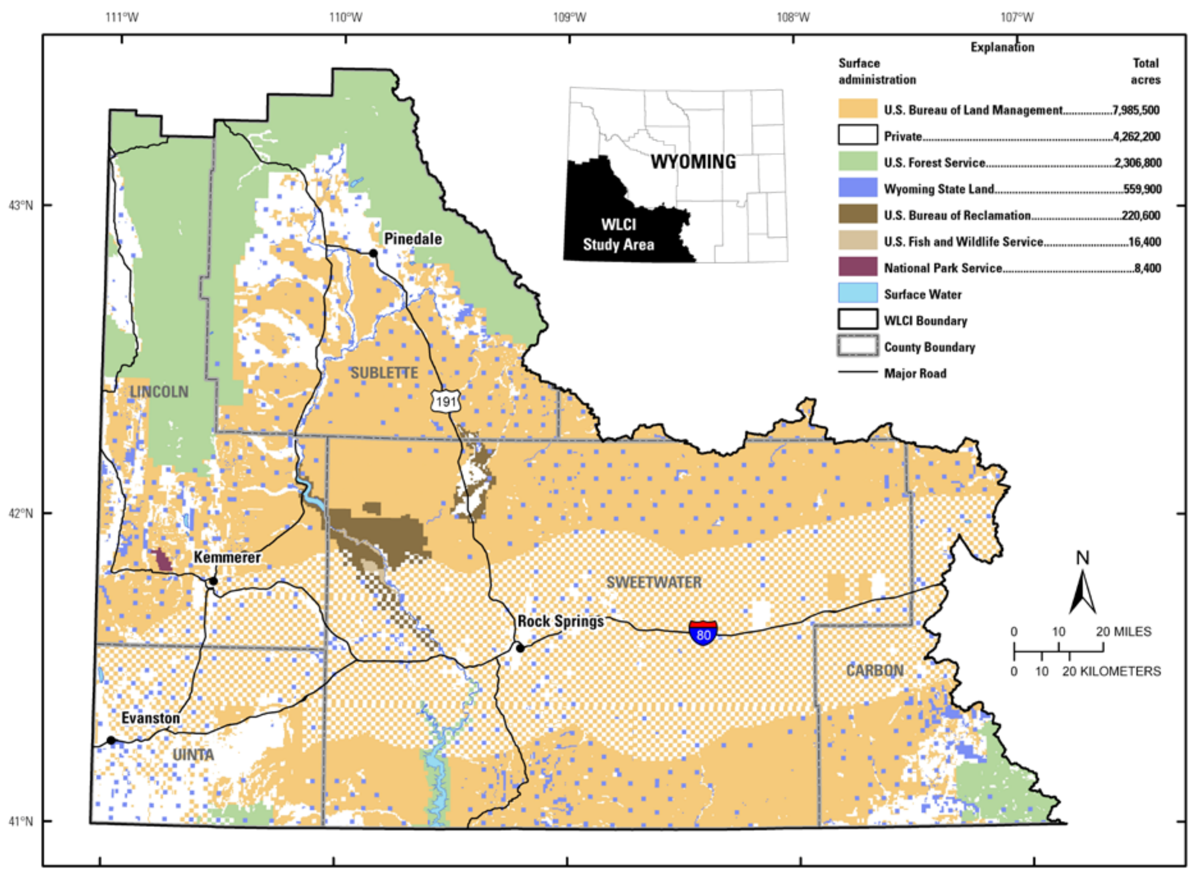



**Figure 2.** The Wyoming Landscape Conservation Initiative (WLCI) region, by jurisdictional boundaries. (Note: The WLCI boundary changed after 2008 work was initiated; thus, future maps and reports will show the new boundaries.) (Areal data provided by the U.S. Bureau of Land Management.)

### *Work and Products Completed*

- Obtained over 175 datasets relevant to WLCI, which may be viewed by authorized users at *https://my.usgs.gov/csc/wlci*.
- Created and populated an MS Access database, an enterprise geodatabase, and an ARC GIS map service (accessible at *https://www.wlci.gov*) that identify the status of compiled data in terms of quality and appropriate metadata.
- Developed numerous map products, as well as evaluation criteria for habitat projects and for ranking and prioritizing conservation actions, to support the CT and inform decisions.

- Comprehensive Assessment Workshop: Organized and led a WLCI workshop on ecological indicators and their application to the USGS Comprehensive Assessment. This workshop was held in March 2008 and included presentations and discussions by USGS scientists and invited partners. Approximately 45 people participated in the workshop and represented BLM, WGFD, WDA, Trout Unlimited, The Nature Conservancy, Wyoming Natural Diversity Database (WYNDD), Wyoming Conservation Districts, Wyoming County Commissioners, NPS, USFS, FWS, and USGS. Map products and discussions at the workshop were used to achieve several outcomes, including
    - identifying partner data gaps and other data contributed by WLCI partners;
    - understanding WLCI partner priorities and focus areas;
    - identifying numerous ecological indicators to support the development of future project evaluation criteria and the selection of indicators for effectiveness monitoring for past and current treatments;
    - supporting the development of WLCI conservation goals, objectives, and strategies;
    - developing the basic framework for developing future conservation projects; and
    - developing evaluation criteria for 2009 proposed conservation activities.

## Land Use/Cover Change

### *Scope and Methods*

Maps of human-induced land disturbances, made using remotely sensed data for the WLCI study area, provide important information for assessing impacts at the landscape scale. In 2008, surface disturbance was mapped by developing and evaluating methods of extracting land disturbances from satellite imagery though use of feature-recognition procedures with SPOT imagery (10-m resolution). USGS scientists selected SPOT imagery due to its relatively low cost, its reasonable spatial resolution relative to the spatial grain of human disturbances, and the feasibility of using it to census human disturbances across the entire WLCI study area. Two priority areas were identified by WLCI scientists for total disturbance mapping, both of which included the large Jonah and Pinedale gas fields. Disturbance mapping for both priority areas has been completed. Four tasks related to comprehensive assessment were identified for work in 2009:

- analysis of patterns shown by existing disturbance maps, with an emphasis on generating metrics to describe the implications of energy development;
- examination of different methods for extracting infrastructure within the WLCI study area from imagery;
- continuation of land disturbance mapping; and
- new work to evaluate the response of biophysical and ecosystem services to potential land-use scenarios.

### *Objectives*

- Develop methods to extract land-disturbance areas from satellite imagery in the WLCI study area.
- Employ developed methods to extract total land disturbance from satellite imagery.

### *Study Area and Map*

Activities associated with this subtask apply to the entire WLCI region (fig. 2).

### *Work and Products Completed*

- Developed total land-disturbance maps for two 2007 SPOT images (scene image nos. 3264, 3265; see Land Use/Cover Change section in appendix 1).

## Energy Futures

### *Scope and Methods*

Future effects of energy development in southwest Wyoming ecosystems are highly dependent on which particular energy resources are exploited and which geologic conditions (including oil and gas play concepts[1]) lead to development. For this reason, it is critically important to apply a geologic understanding of emerging patterns in energy extraction to identify the regions most likely to be developed in the future. Planning is underway to develop strategies for identifying possible scenarios of future development, based on geologic knowledge of emerging play concepts and other factors. A GIS-based (geographic information system) product (Biewick, 2009) was completed in 2008, illustrating the progression of oil and gas exploration and production in the Greater Green River Basin over the last century.

Additional work will concentrate on improving the understanding of other energy resources in southwest Wyoming. A refined understanding of the geologic facies in the Green River Formation, and of the geochemical properties of the oil shale, will lead to enhanced estimates of recoverable volumes of oil shale and the hydrocarbons within the oil shale. These studies will improve predictions of the areal extent of possible future shale oil extraction. Work on the properties of coal, coalbed gas, and produced waters[2] in the Powder and Green River Basins is producing an extensive coalbed methane database. It also contributes to the development of new concepts and understandings relative to the geologic and biologic controls on coalbed methane accumulations in the Basins. As the production of coalbed methane begins to have greater impacts in the Atlantic Rim (located in the eastern part of the Southwestern Wyoming Province), USGS coalbed methane studies will have increased significance for the WLCI. Importantly, this work will

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[1] A “play concept” is a hypothesis for the existence of oil and gas accumulations that is based on a specific set of geologic assumptions used in a given exploration effort. This entails using seismic reflection and well data to learn about the coincidence of certain key geologic conditions (in the subsurface) that petroleum geologists deem to be favorable for a particular style of oil or gas accumulation. Then they will drill it to test the hypothesis.

[2] Produced waters are waters co-produced with the extraction of natural gas. Within the coalbed at depth (under pressure), the natural gas (mostly methane) occurs in solution within the formation (rock strata) waters. As the water is pumped to the surface in a coalbed methane well, the natural gas separates from the water (at lower pressures near the earth's surface). The gas is then routed toward a natural gas pipeline, and the water is produced at the surface. Depending on the operation, the water might be re-injected into the ground or, commonly in Wyoming, discharged at the surface.

help inform resource conservation by incorporating potential development patterns into planning and monitoring efforts.

### *Objectives*

- Document progression of energy resource production in the Southwestern Wyoming Province, in the context of oil and gas assessment units defined in the USGS 2002 assessment of undiscovered oil and gas resources in southwestern Wyoming (Kirschbaum and others, 2002).
- Enhance our understanding of the subsurface geology in the Southwestern Wyoming Province for updating our perspective on the potential impact of future energy development on critical ecosystems.

### *Study Area and Map*

Activities associated with this subtask apply to the Southwestern Wyoming Province (fig. 3).

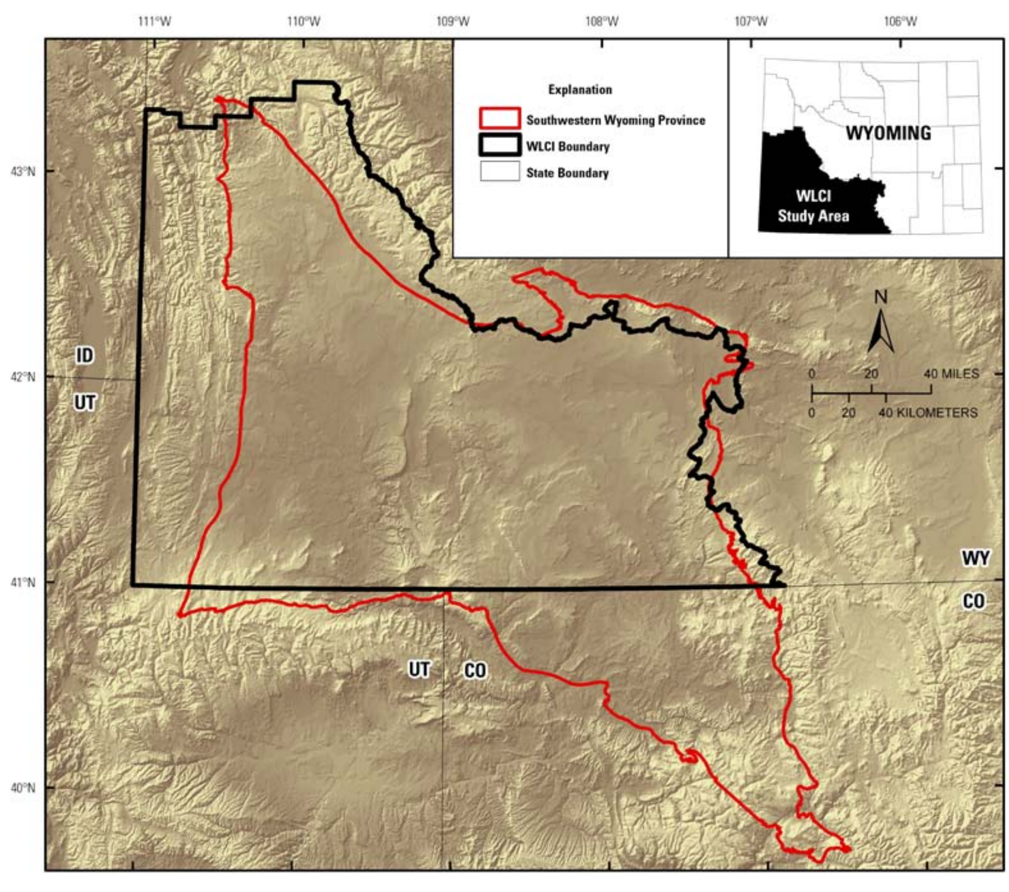


**Figure 3.** Southwestern Wyoming Province and its relationship to the WLCI region.

### *Work and Products Completed*

- Oil and Gas Development in Southwestern Wyoming—Energy Data and Services for the Wyoming Landscape Conservation Initiative (Biewick, 2009; see fig. 4).

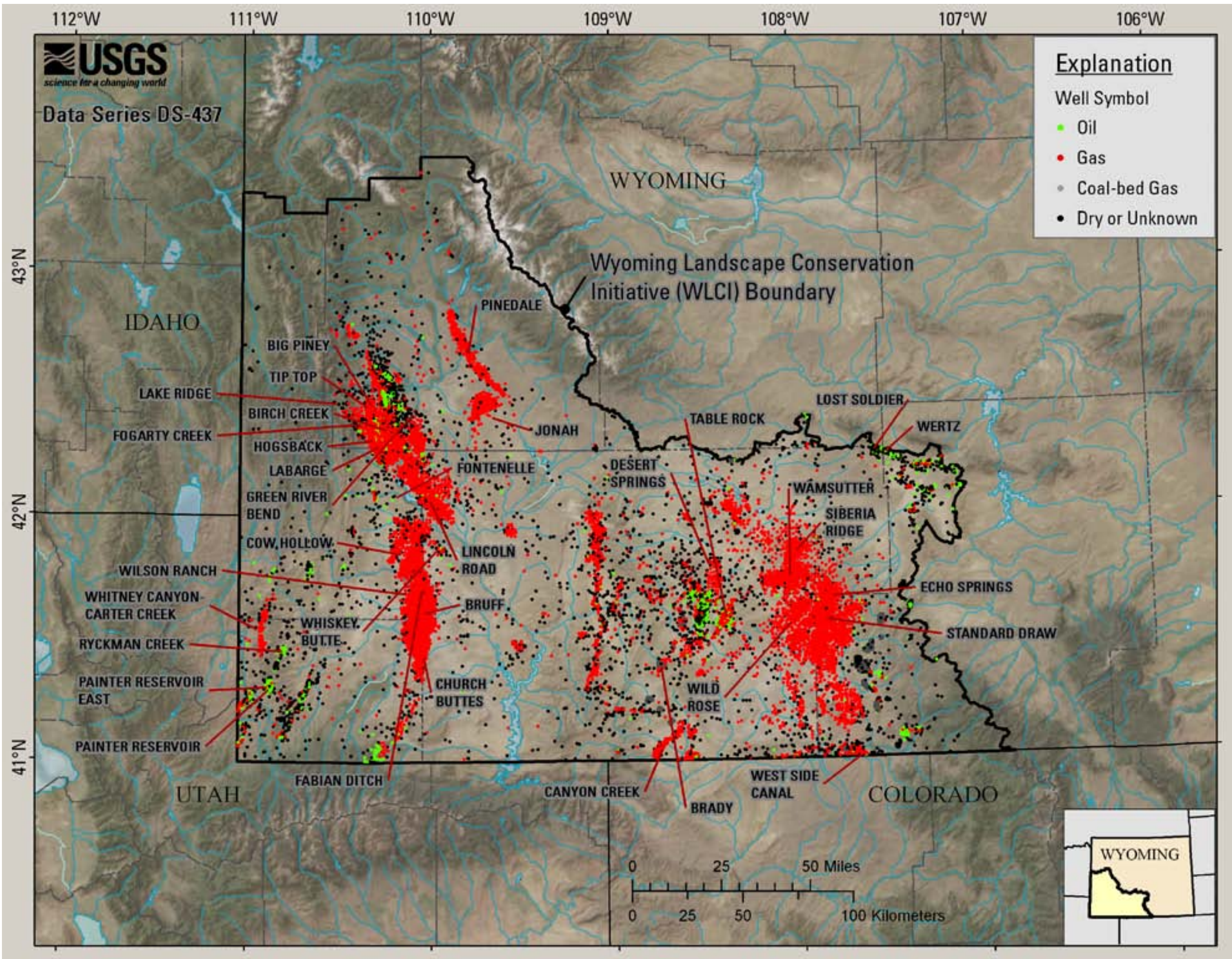


**Figure 4.** Using geographic information system (GIS) tools, energy data pertinent to the conservation decisionmaking process have been assembled to show historical oil and gas exploration and production in southwestern Wyoming. In addition to historical data, estimates of undiscovered oil and gas are included from the 2002 U.S. Geological Survey National Assessment of Oil and Gas in the Southwestern Wyoming Province (Kirschbaum and others, 2002). The well and assessment data can be accessed and shared among many different clients including, but not limited to, an online Web service for scientists and resource managers engaged in the WLCI (figure from Biewick, 2009).

## Mineral Resources

### *Scope and Methods*

Numerous mineral deposits are located within the WLCI area. This initial study focused only on metals such as copper, lead, zinc, silver, and gold. Of approximately 800 deposits (Wilson and others, 2001) listed in the USGS New MRDS that occur within the study area boundary, fewer than 100 are base- or precious-metal deposits. All or part of three metallic (base and precious metals) mineralized areas are within the WLCI boundary. During 2008, mine sites in these mineralized areas were visited and sampled. All of the sites visited were abandoned or inactive. Working copies of the revised databases and maps were made available for sharing internally among the USGS science team. Future work will expand the types of commodities considered and will include additional commodities, such as uranium, trona, and phosphate.

### *Objective*

- Provide an overview of known base- and precious-metal mineralized areas and the location of mines and prospects in the WLCI study area.

### *Study Area and Map*

Three mineralized areas containing base and precious metals are within or overlap the WLCI study area: Encampment, Seminoe, and Lake Alice (fig. 5).

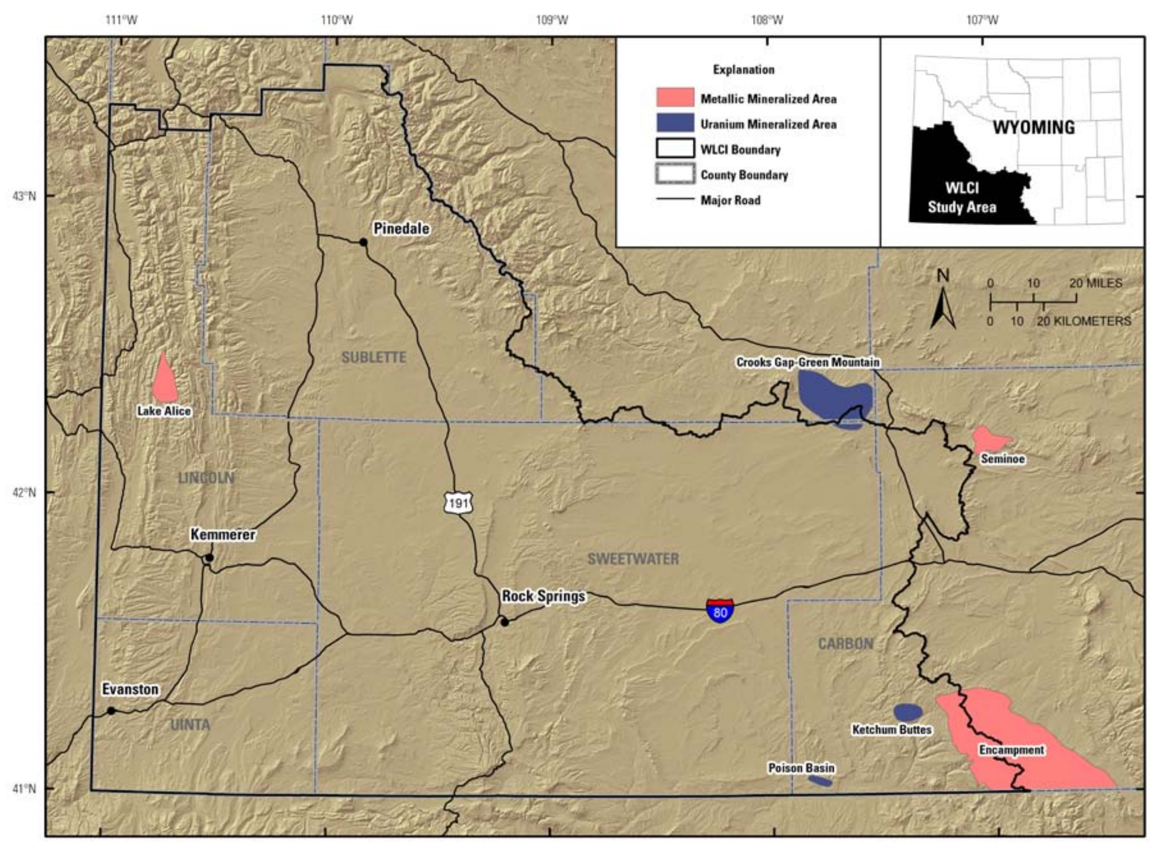


**Figure 5.** Mines, prospects, and mineralized areas in the WLCI study area.

### *Work and Products Completed*

- Revised records for the visited mines and prospects are in the internal USGS New MRDS database. Revisions and elimination of duplicate entries are currently in progress.
- Non-proprietary, unrevised versions of the database are available at *http://mrdata.usgs.gov/* and *http://pubs.usgs.gov/of/2001/ofr-01-0497/*.

## Social and Economic Evaluation Supporting Adaptive Management for the Wyoming Landscape Conservation Initiative

### *Scope and Methods*

The focus of this work is on creating a common understanding of the social and economic context for energy development and habitat conservation in the Green River Basin and on providing a basis for dialogue with the public through the entire adaptive management process. A social and economic assessment and literature review was drafted. Examining the literature produced during both the prior and current energy-development booms in southwest Wyoming made it possible to identify trends in socioeconomic effects, as well as how the effects and perceptions of those effects have changed. Review of the literature indicates that there are some predictable socioeconomic effects from energy-development booms, including those seen in Sweetwater County in the 1970s and in Sublette County in the 2000s. Previous literature had focused on economic issues while social or quality-of-life components received little attention. The results of this effort can be used to inform further research and assist communities affected by energy development. Two complementary research projects were developed for 2009 that will investigate (1) rancher perspectives and (2) the general public's attitudes towards quality of life issues associated with energy development

### *Objectives*

- Compile a basic social and economic assessment to provide a common context for the other issues addressed in the WLCI. The assessment of the WLCI area will be conducted by using baseline secondary data (such as that provided by the U.S. Bureaus of the Census, Labor Statistics, and Economic Analysis).
- Compile a complementary literature review on the social and economic research completed on energy development, with a focus on oil and gas development in the West.
- Identify locations of existing and potential future leases and wells in the Green River Basin as well as in the broader context of Wyoming, Montana, and Colorado.

### *Study Area and Map*

The WLCI boundaries overlap six counties in southwest Wyoming; however, only four counties fall completely or almost completely within the WLCI boundaries: Lincoln and Uinta (completely), and Sweetwater and Sublette (almost completely). Because the available data are summarized at the county level, the study area for this task is the four counties that fall completely or almost completely within the WLCI boundary (fig. 2).

### *Work and Products Completed*

- Current socioeconomic issues surrounding oil and gas development in the western United States—Stinchfield and others, presented at the 14th International Symposium on Society and Resource Management, June 11, 2008, Burlington, Vt.
- Socioeconomic effects of oil and gas development in the western United States: A literature review—Stinchfield and others, forthcoming U.S. Geological Survey Open-File Report 2009-xxxx.

## Assessing Wildlife Vulnerability to Energy Development

### *Scope and Methods*

The AWVED research task was established to help prioritize the management, monitoring, and research needs of Wyoming's numerous SGCN (listed in Wyoming's Comprehensive Wildlife Conservation Strategy [CWCS]; Wyoming Game and Fish Department, 2005). In May 2008, representatives of various State and Federal entities met to coordinate range mapping and modeling of Wyoming SGCN. The approach for range mapping developed by the AWVED researchers (see details in the AWVED section of appendix 1) was accepted as the standard. Approximately 1,066,489 occurrence records for 507 species were obtained and processed to be used for future range mapping and distribution modeling as part of this effort. Major sources include the Biotics database of the WYNDD, WGFD's Wildlife Observation System, museum specimens drawn from the Conservation Biology Institute, and bird observations from the Institute for Bird Populations. An initial range map was generated for each species by overlaying maps summarized by noted authorities (for example, the Birds of North America series, field guides, and species accounts) and rescaling the output to a common map unit (10-digit hydrologic unit codes [HUCs]). These "first-round" maps were reviewed by WYNDD staff biologists, who modify a species' Wyoming range by assigning each HUC an occupational status of "Known to Occur," "Suspected to Occur," or "Likely Absent" based on reported observations and knowledge of local habitat.

### *Objective*

- Before they become imperiled, focus conservation attention on the most vulnerable species by estimating species distributions and assigning preliminary risk ranks, which subsequently will be refined by conducting biological sensitivity analyses for potentially at-risk species.
- Assign preliminary risk ranks for species based on the relationship between their estimated distributions and current energy footprints.
- Refine initial ranking based on an assessment of species' sensitivity to energy development.

### *Study Area and Map*

Activities associated with this subtask apply to the entire WLCI region (fig. 2).

### *Work and Products Completed*

- Developed initial range maps for all 152 terrestrial vertebrate SGCN.
- Developed an online review tool for expert evaluation of the complete set of range maps as part of the Northwest Regional Gap Analysis Project (NWreGAP) in collaboration with WYNDD and the Wyoming Geographic Information Science Center.

- Obtained and processed roughly 1,066,489 occurrence records for 507 species.
- Obtained and processed a variety of predictor layers, including climate and other environmental data sets, for use in developing potential distribution models.

## Climate Change and Potential Future Vegetation Simulations

### *Scope and Methods*

Climate is a fundamental driver of ecosystem patterns and processes; therefore, naturally and anthropogenically derived changes in climate patterns are expected to be important drivers of ecosystem change. Understanding the potential effects of climate change on the species and landscapes of southwest Wyoming is key to developing appropriate long-term management and conservation strategies for the region. For the WLCI region, future climate and vegetation change datasets are being developed to assist conservation and natural resource managers with identifying important sensitivities to climate change among the species and landscapes that they manage. These datasets also will provide a first step in developing future change scenarios for the WLCI study area.

### *Objectives*

- Downscale existing datasets on future climate and vegetation change to the Wyoming and WLCI scales. Use these downscaled data to
  - model the potential impacts of climate and land-use changes on the species and landscapes of the WLCI study area;
  - develop integrated scenarios of potential future change for the WLCI region; and
  - evaluate potential future changes in climate, vegetation, and habitat within the WLCI region.

### *Study Area and Map*

The study area, which encompasses all of Wyoming and portions of surrounding states (approximately the entire area shown in fig. 6) was chosen for the climate and vegetation analyses because potential future changes in climate and vegetation across this larger area may have significant implications for species and landscapes within the WLCI study area.

### *Work and Products Completed*

- The USGS EFFECTS (Exploring Future Flora, Environments, and Climates Through Simulations) Project has developed downscaled monthly temperature and precipitation data for 1901–2002 at a 30-second resolution for the contiguous United States. These data will form the basis for the downscaled future climate data for the WLCI region that will be developed in 2009.

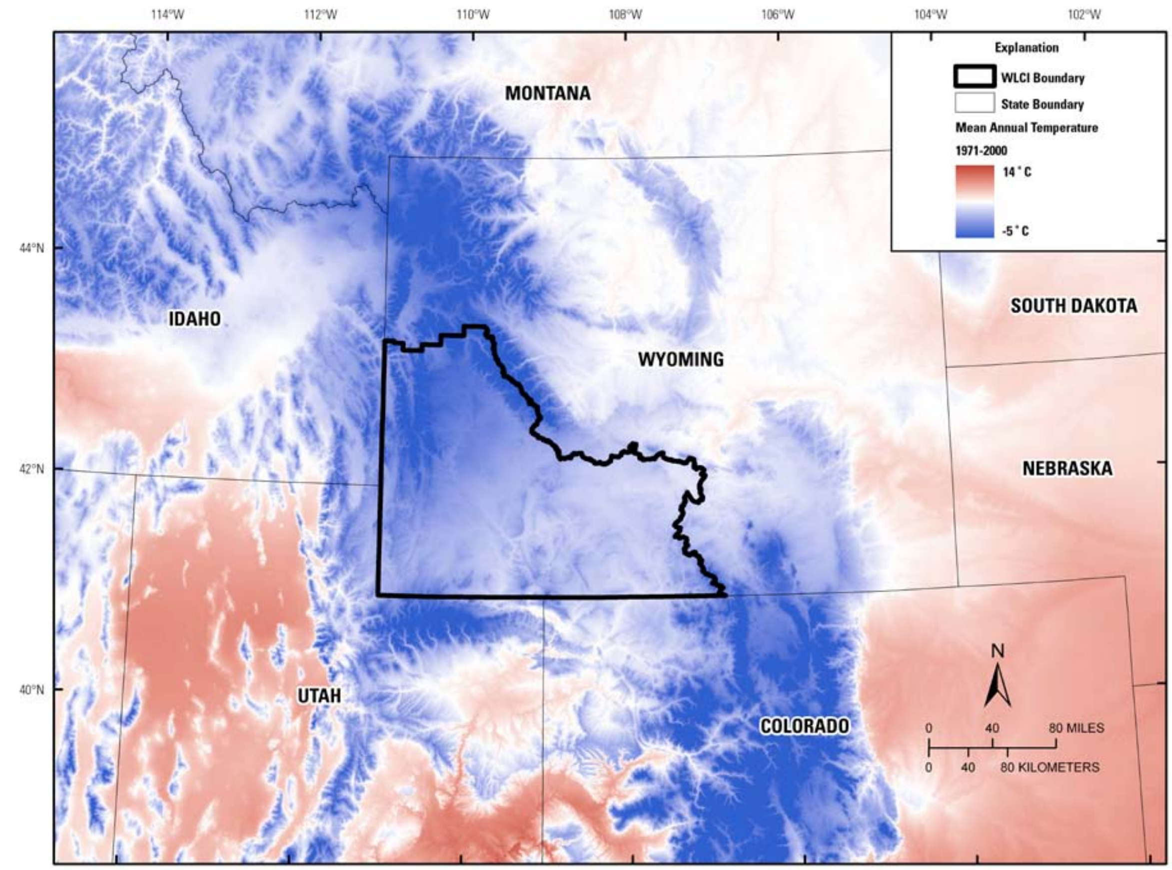


**Figure 6.** Mean annual temperature for 1971–2000 (30-year mean) interpolated to a 30-second spatial resolution from the Climatic Research Unit's 30-minute time series dataset, CRU TS 2.1 (Mitchell and Jones, 2005) using a climate interpolation method developed by P.J. Bartlein (University of Oregon, written commun., 2008). (Image created by Sarah Shafer, USGS, unpub. data; data file created by W. Gibson, NACSE, Oregon State University.)

## Conceptual Models and Indicators of Change: Effects of Energy Development and Climate Change on Ecosystems of the Wyoming Basin

### *Scope and Methods*

Initial conceptual models were developed to organize and document current knowledge about key ecosystems in southwest Wyoming. The objective of this work is to provide a scientific basis for identifying potential indicators of ecosystem change to be used in a long-term monitoring program. Models pertain to the atmospheric and human systems, and the focal ecosystems—aspen (*Populus tremuloides*) foothill woodlands, mixed mountain shrubs, sagebrush steppe, riparian, and aquatic—identified by WLCI partners. Additional models were developed to illustrate the effects of disturbances on wildlife habitat and populations. A hierarchy of models was used to illustrate key components and processes of native systems, and how systems respond to human-mediated stressors. Models were developed based on literature reviews, or were extracted from the literature and enhanced to accommodate the drivers and stressors of the WLCI study area. Individual system models were organized into an integrative model that additionally considers the interactions among systems and across scales. In 2008, preliminary conceptual models for terrestrial systems were developed and then reviewed by USGS Science Team members during a Conceptual Model Workshop. In 2009, these models will be refined and remaining models will be developed and reviewed. A final conceptual model report will be published in 2009 along with a report on indicators for use in monitoring ecosystem change. The workshop and a subsequent report documenting prioritized indicators were drafted to provide direction in planning 2009 monitoring efforts.

#### *Objectives*

- Create a useful set of conceptual models that organize and document current knowledge of key ecosystems and processes in southwest Wyoming and that can be used to help identify indictors for monitoring.
- Use conceptual models developed for WLCI and other information to identify indicators for monitoring ecosystem change. Indicators will include properties of habitat (for example, vegetation and soil attributes and landscape pattern) and wildlife species.
- Based on documented criteria, prioritize the monitoring indicators identified for immediate consideration in operational monitoring efforts.

#### *Study Area and Map*

Activities associated with this subtask apply to the entire WLCI region (fig. 2).

#### *Work and Products Completed*

- A conceptual model workshop was held August 19–20, 2008.
- A working draft of the conceptual model report was made available in October 2008.
- A draft of the procedures for selecting ecosystem and species indicators was made available in February 2009.

## Targeted Monitoring and Research

Targeted Monitoring and Research for WLCI is composed of three major tasks: Long-Term Monitoring, Effectiveness Monitoring, and Mechanistic Studies of Wildlife. Each major task and its components are described below.

### Overview of Long-term Monitoring

USGS scientists developed a landscape-scale monitoring framework using a spatially balanced design with random site selection to represent the WLCI landscape. This framework provides important context for management and research, as well as a powerful monitoring network for detecting changes in land use, vegetation, priority habitats, populations of priority species, and soil geochemistry across the region. To monitor vegetation and land-use changes, a multiscale approach was developed that links vegetation to remotely sensed data (Quickbird, Landsat, and Advanced Wide Field Sensor [AWiFS, a multi-spectral camera]). Pilot data for terrestrial indicators were collected and used to evaluate the cost and effectiveness of alternative monitoring designs. Limited water-quality and water-level data were collected and made available in a publically accessible real-time platform (USGS NWISWeb [National Water Information System Web site]).

Details of the Long-Term Monitoring work are provided below in the sections entitled (1) Terrestrial Monitoring: Vegetation, Birds, Small Mammals, and Soil Geochemistry, and (2) Surface Water and Groundwater Hydrology.

## Terrestrial Monitoring: Vegetation, Birds, Small Mammals, and Soil Geochemistry

### *Scope and Methods*

Long-term monitoring in the WLCI area is necessary for assessing cumulative effects at landscape scales and detecting trends for key indicators (for example, species, habitat, and land use) in response to development activities and other stressors (for example, climate change). When long-term monitoring is coupled with mechanistic research, modeling (as discussed throughout this document), and management, it has the potential to be used as an early warning system that can alert managers to deteriorating population or habitat trends before they reach critical levels that could require costly actions (for example, habitat protection versus reconstruction). Designing an effective and efficient long-term monitoring program that meets stated objectives requires a balance between extensive sampling across a heterogeneous resource and the power to detect significant changes in priority indicators. To meet these requirements, a spatially balanced, random sampling framework was used; this design approach has proven powerful for making inferences across large, heterogeneous resource targets, such as the WLCI area. Sampling protocols applied across this design will provide a comprehensive, extensive picture of current status and ongoing changes in land use, vegetation, priority habitats, populations of priority species, and soil geochemistry.

For soil geochemistry, the purpose of short-term monitoring is to define the natural variation in concentrations of major and trace elements in soils throughout the entire WLCI region. To accomplish this purpose, soil samples were collected from 139 sites chosen by using a generalized random tessellation stratified[1] (GRTS) sampling method. The sampling scheme used represents the same approach used in a continent-wide soil-sampling program. These sites were sampled during August and September 2008. The primary sample medium was soil from a depth of 0–5 cm. This surface soil is considered the material most likely to be affected by human activities, such as energy development, in the study area. At 39 of the sites, additional samples were collected. These samples represent the soil A horizon (the uppermost mineral soil) and the soil C horizon (generally the parent material for the surface soil). The samples were submitted to Colorado State University's Soil-Water-Plant Testing Laboratory to ascertain the pH, electrical conductivity, and sodium adsorption ratio. The samples were processed and analyzed. Statistical summaries of the data will be prepared in 2009 and published along with the entire data set.

For monitoring priority terrestrial habitats (sagebrush, aspen, riparian, and mountain shrub communities), a spatially balanced design was used to create a representative but random

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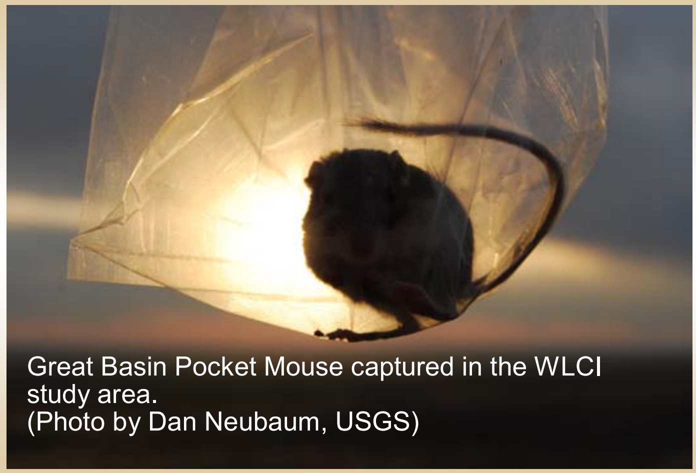
[1] The generalized random tessellation stratified (GRTS) sampling method provides a spatially balanced, probability-based sampling design that preserves random selection while ensuring a representative sample set from a heterogeneous landscape, thus overcoming some of the disadvantages of simple random and systematic sampling schemes. See *http://www.stat.colostate.edu/~nsu/starmap/pps/stevens.msts.pps#283,18, RANDOM-TESSELLATION STRATIFIED (RTS) DESIGN* for more information on the GRTS design.

distribution of samples. The approach also incorporates the use of multiscale sampling by linking field vegetation measurements to remotely sensed data (QuickBird, Landsat, and AWiFS) at several scales of resolution and extent. The new maps will facilitate analyses of land use and habitat changes at multiple scales for evaluating cumulative impacts and potential management decisions.

The spatially balanced framework also was used to collect pilot data on sagebrush-obligate birds (greater sage-grouse, sage sparrow [*Amphispiza bilineata*], Brewer's sparrow [*Spizella breweri*], and sage thrasher [*Oreoscoptes montanus*]) and small mammals (including three of Wyoming's SGCN: pygmy rabbit [*Brachylagus idahoensis*], Great Basin pocket mouse, [*Perognathus parvus*], and sagebrush vole [*Lemmiscus curtatus*]). The pilot data are being used for power analysis to determine sample sizes necessary for quantifying status and trends of key indicator species.



Great Basin Pocket Mouse captured in the WLCI study area.
(Photo by Dan Neubaum, USGS)

In addition to the aforementioned design, several alternative monitoring designs for vegetation, birds, and small mammals were being developed to specifically address a variety of management and monitoring objectives. Comparison and evaluation of the cost and information effectiveness, as well as implementation feasibility, of alternative monitoring plans are underway; objectives achieved by each plan will be identified and compared. The alternative plans will be presented to stakeholders for evaluation and selection. Implementation of selected monitoring programs is contingent upon the availability of funding.

### *Objectives*

- Develop a sampling framework that will form the basis for long-term monitoring sites.
- Assist in documenting current (baseline) landscape conditions in species, habitat, range, land use/infrastructure, water, and trace elements in soils.
- Incorporate priorities from the Conceptual Models and Indicators task with representative drivers of landscape condition to establish a landscape-scale, long-term monitoring program for priority indicators and key drivers of change.

### *Study Area and Map*

Monitoring of terrestrial habitats and vegetation, birds, small mammals, and soil chemistry is taking place across the WLCI study area (figs. 7–9).

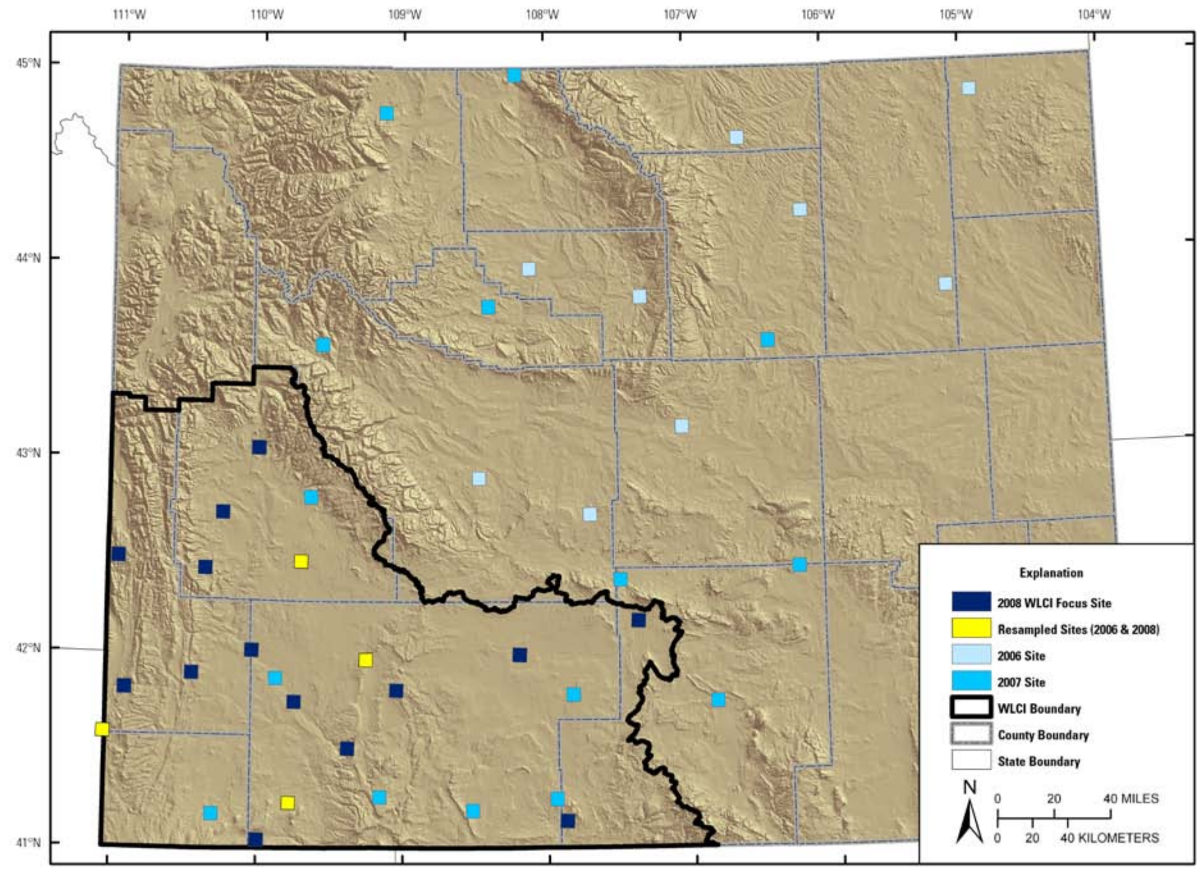



**Figure 7.** Sampling and validation sites for the 2006–2008 vegetation mapping component of the long-term monitoring work.

### *Work and Products Completed*

- Purchased remotely sensed data to support monitoring design and remote data collection: 22 QuickBird, 12 Ikonos, and 15 Landsat scenes.
- Sampled vegetation within 14 of the 17 WLCI QuickBird scenes where long-term monitoring is being conducted and within 59 independent sites for evaluating Landsat model predictions (874 samples). Permanent monitoring plots within four QuickBird scenes (244 samples) were re-sampled. Seasonal sampling (early summer, summer, and fall) in permanent monitoring plots was designed, implemented, and conducted at one QuickBird study site.
- Drafted 13 QuickBird-based models and four draft Landsat-based models for the WLCI area.
- Developed a pilot study to examine Landsat scenes for changes in sagebrush canopy between 1988 and 2006.
- Developed digital (hardcopy upon request) maps and tables representing WLCI long-term monitoring sites.

- Re-surveyed passerines (songbirds) at Wyoming Basin sample locations within the WLCI.
- Completed pilot surveys of sage-grouse at GRTS sample locations.
- Developed GIS distribution map of small mammal species abundances and community metrics among 24 sampled sites (12 QuickBird scenes).
- Developed optimal plot designs for passerine and greater sage-grouse monitoring.
- Completed soil sampling at 139 sites.
- Multiscale sagebrush rangeland habitat modeling in southwest Wyoming—Homer and others (2009), U.S. Geological Survey Open-File Report 2008-1027.
- Manuscript submitted to peer-reviewed journal for consideration: Pilliod, D.S., Aldridge, C.L., Arkle, R.S., Downs, J.L., Homer, C.G., Pyke, D.A., Salo, L.F., and Tagestad, J.D., Multiscale approaches for greater sage-grouse habitat monitoring.

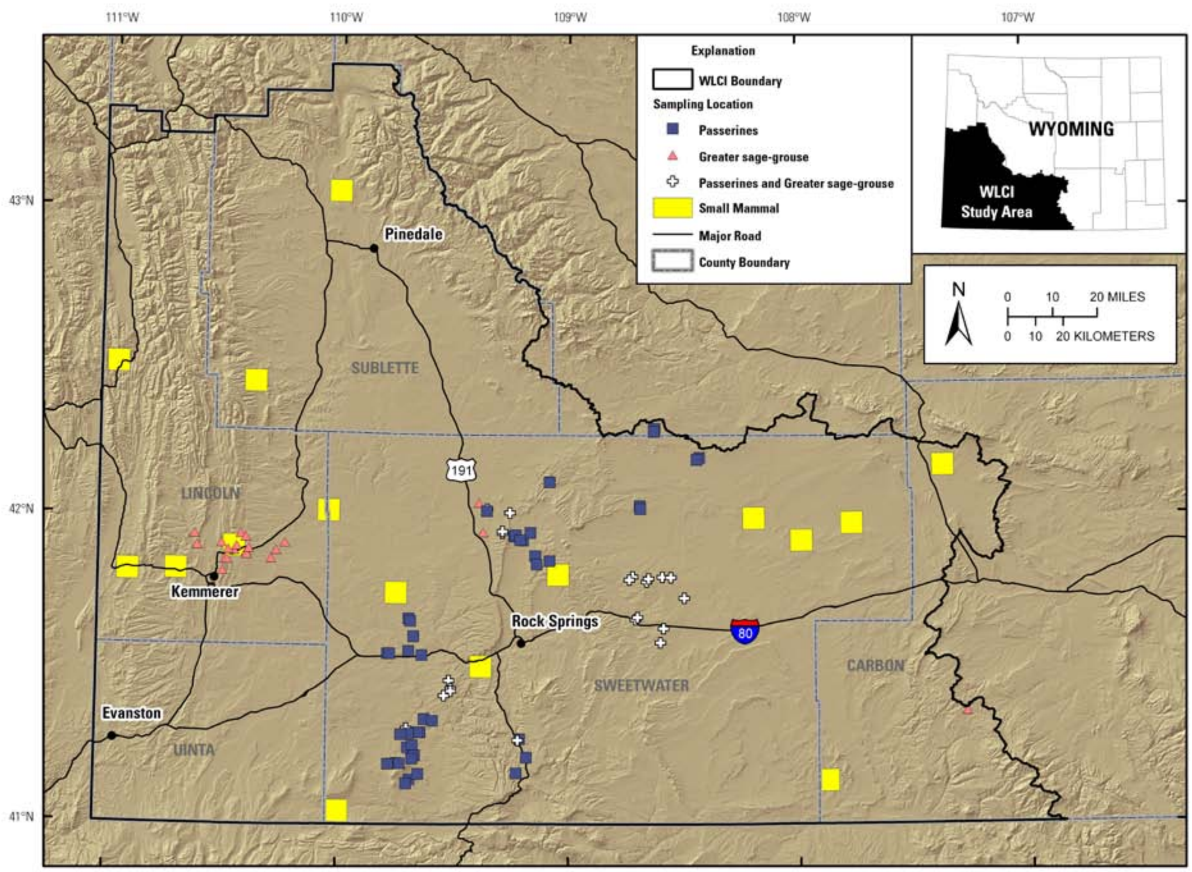



**Figure 8**. Sampling locations for passerines, greater sage-grouse, and small mammals (the sixteen 8- x 8-km QuickBird scene areas targeted in 2008; see fig. 7) for the WLCI's long-term monitoring program.

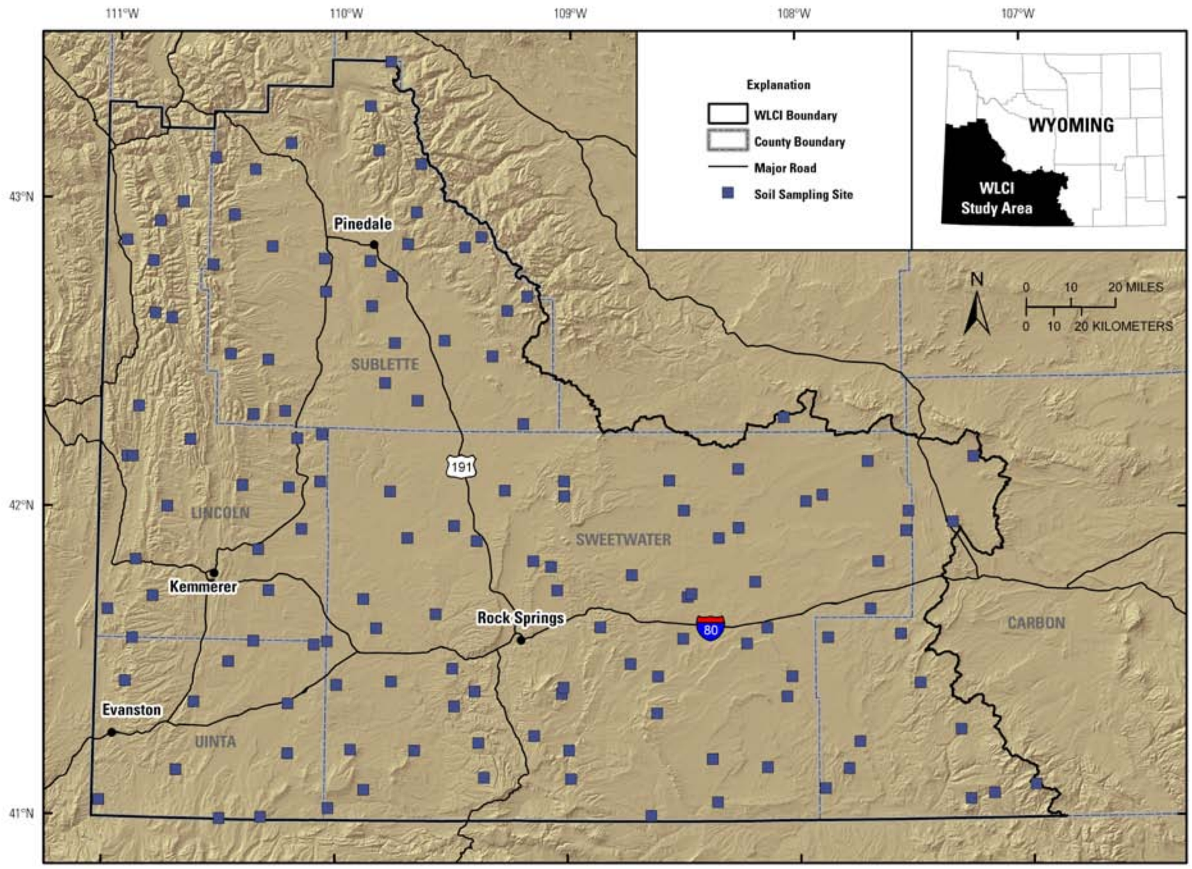



**Figure 9**. Soil geochemistry sampling locations for the WLCI's long-term monitoring program.

## Surface Water and Groundwater Hydrology

### *Scope and Methods*

Monitoring of surface-water quality was conducted at one site partially funded by WLCI. Data from 2007 were published in the USGS Annual Water-Data Report and 2008 data were collected according to USGS methods (U.S. Geological Survey, variously dated; Wagner and others, 2006), and preliminary 2008 data were made available online in real-time. Data collection and publication for this same monitoring site is planned for 2009 as well. Statistical relations between specific conductance and total dissolved solids concentration were determined for two sites. Computed total dissolved solids concentrations were made available online in real-time. A USGS report describing the relations and methods will be published in 2009.

Monitoring of groundwater levels was conducted at one site partially funded by WLCI. Preliminary 2008 data were made available online in real-time. Data collection is planned for 2009 at this site.

### *Objectives*

- Collect and publish monthly water-quality samples for the 09217000 Green River site near Green River, Wyo.
- Determine and publish statistical relations between specific conductance and total dissolved solids concentrations for the 09217000 Green River site near Green River, Wyo., and the 09258980 Muddy Creek site below Young Draw in the southeastern WLCI region.
- Provide publicly accessible (USGS NWISWeb) seasonal real-time water temperature, specific conductance, and computed total dissolved solids concentrations for the 09217000 Green River site near Green River, Wyo., and computed total dissolved solids concentrations for the 09258980 Muddy Creek site below Young Draw in the southeastern WLCI region.
- Provide publicly accessible (USGS NWISWeb) real-time water-level data for the 413850109150601 19-105-10bbb01 Rock Springs site, Rock Springs, Wyo.

### *Study Area and Map*

Figure 10 shows the monitoring locations for surface-water quality and groundwater levels (see the Surface Water and Groundwater Hydrology section in appendix 1 for a map of all current streamflow and reservoir gages and water-quality monitoring sites located within the WLCI region).

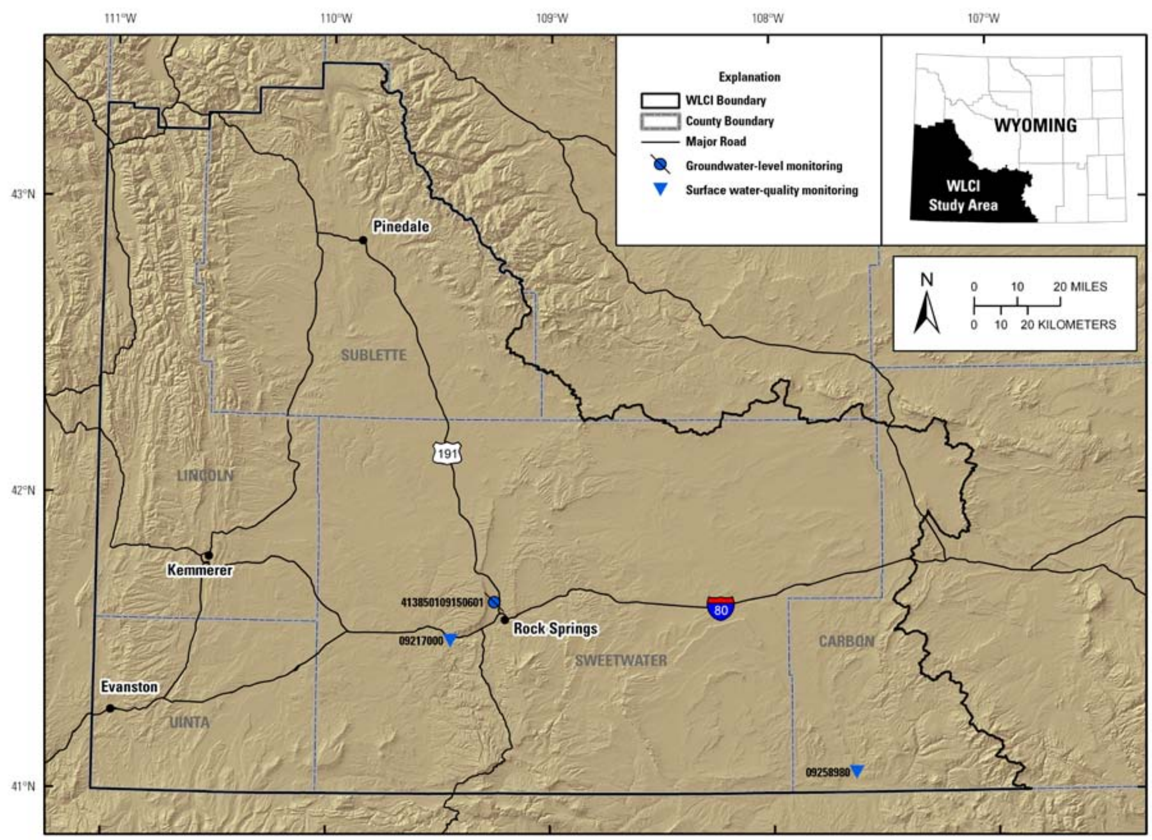



**Figure 10.** Location and station identifiers of surface water-quality and groundwater-level monitoring sites within the WLCI study area.

#### *Work and Products Completed*

- Published (USGS Annual Water Data Report online only) water-quality data from water year 2007 for 09217000 Green River near Green River, Wyo. (for example, *http://wdr.water.usgs.gov/wy2007/pdfs/09217000.2007.pdf*, pp. 4–8).
- Collected monthly water-quality samples for 09217000 Green River near Green River, Wyo.
- Determined statistical relations between specific conductance and total dissolved solids concentrations for 09217000 Green River near Green River, Wyo., and the 09258980 Muddy Creek site below Young Draw in the southeastern WLCI region.
- Provided publicly accessible (USGS NWISWeb) seasonal real-time water temperature, specific conductance, and computed total-dissolved solids concentrations for 09217000 Green River near Green River, Wyo. Computed total-dissolved solids concentrations for 09258980 Muddy Creek below Young Draw in the southeastern WLCI region.
- Provided publicly accessible (USGS NWISWeb) real-time water-level data for the 413850109150601 Rock Springs site near Rock Springs, Wyo. (for example, *http://waterdata.usgs.gov/wy/nwis/uv/?site_no=413850109150601*).

## Overview of Effectiveness Monitoring

Effectiveness monitoring was implemented to evaluate the efficacy of habitat treatments and to broadly assess the regional effects of conservation, mitigation, and other management activities coordinated through this initiative. Work in 2008 included collecting data associated with past and current habitat treatments (for example, herbicide treatments in sagebrush) to

- assess their effectiveness in meeting WLCI habitat conservation goals, and
- help guide the design of future habitat treatments and BMPs.

Effectiveness Monitoring included measuring vegetation and soil responses to treatments, developing methods for using remotely sensed estimates of productivity to evaluate habitat treatments, and investigating relations between energy development and soil and surface water salinity.

Details of the Effectiveness Monitoring work are provided below in the sections entitled (1) Vegetation and Soils, (2) Retrospective Vegetation/Cover Change, and (3) Soil Chemistry: Relationships between Energy Exploration/Development and Salinity of Soils and Waters.

### Vegetation and Soils

#### *Scope and Methods*

Federal, State, industry, and nongovernmental organizations have been funding habitat improvement treatments across southwest Wyoming. A primary goal of the WLCI is to assess the effectiveness of habitat treatments at individual sites and to evaluate their effectiveness in meeting landscape-level conservation goals, such as connecting fragmented habitats. Existing data associated with past and current habitat treatments were acquired and evaluated to assess their effectiveness in meeting WLCI conservation goals. As part of the USGS WLCI Effectiveness Monitoring effort, additional important information was and will continue to be collected to assess the effectiveness of a range of habitat treatments (for example, applying herbicide to sagebrush or thinning aspen stands). Assessments entail comparing historical treatments of different ages as well as before-and-after comparisons of new treatments. Effectiveness is being measured on the basis of multiple factors, including species composition and cover, bare soil cover, forestry metrics (aspen), and biotic and abiotic properties of soils. In addition, researchers are collaborating with those working on other funded projects to ascertain the effects of habitat treatments on wildlife use (for example, greater sage-grouse and elk [*Cervus elaphus*]), which is an essential measure of success resulting from individual and cumulative habitat treatments. This work is intended to help guide the design and development of future habitat treatments and to improve their ability to meet WLCI landscape conservation objectives.

Rick Shory (Colorado State University Research Associate) and Kendall Brunette (USGS Field Botanist) sample vegetation and surface soils on a sagebrush reduction treatment on the Pinedale Anticline, May 29, 2008.
(Photo by Geneva Chong, USGS)

### *Objectives*

- Inventory and evaluate the effectiveness of past habitat treatments.
- Develop strategies, approaches, and designs for conducting effectiveness monitoring on conservation projects and enhancements conducted as part of the WLCI.
- Initiate effectiveness monitoring on WLCI conservation projects conducted in 2007 and 2008 and pre-treatment monitoring of habitat treatments funded in 2009.

### *Study Area and Map*

The Effectiveness Monitoring study area encompasses the entire WLCI area (fig. 2). Specifically, work in 2008 included the Pinedale Anticline (BLM Pinedale Field Office), the Rock Creek Allotment (BLM Kemmerer Field Office), Bench Corral and Soda Lake elk feeding grounds (Wyoming Game and Fish), Muddy Creek and Blacks Fork (BLM Kemmerer Field Office), Muddy Creek and Sand Creek (BLM Rawlins Field Office), and areas within the Medicine Bow National Forest (aspen monitoring in the Sierra Madre), as indicated in figure 11.

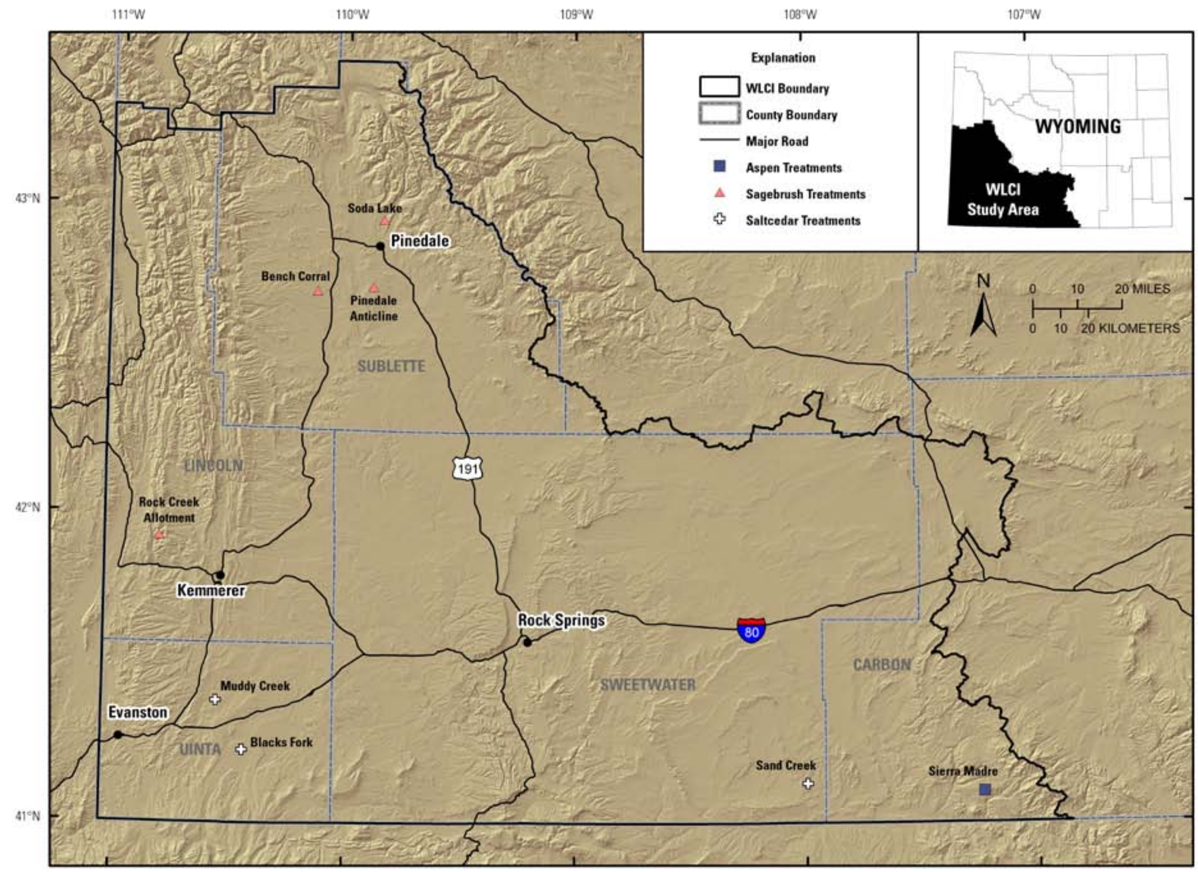



**Figure 11.** Locations of effectiveness monitoring for past and current habitat (sagebrush, aspen, and tamarisk) treatments.

### *Work and Products Completed*

- Developed an MSAccess database of multiscale plot ($n$ = 75; Barnett and others, 2007) data, including native and non-native plant species cover and height, spatial location, and digital photos (see Vegetation and Soils section in appendix 1 for additional information and example analyses).
- Completed basic soil analyses (C, N, texture of top 5 cm; Colorado State University, Natural Resource Ecology Laboratory).
- Took digital photos of each plot and its surroundings (available at the WLCI Website *http://www.wlci.gov*).
- Held three field training workshops (two in the Pinedale area, one in Kemmerer).
- Presented a talk on response of aspen to conifer removal for members of the Aspen Joint Venture.

- Developed maps associated with aspen treatment area (see fig. 12) and provided them to WLCI partners and loggers associated with the treatment project.
- Developed maps identifying tamarisk (*Tamarix* spp.) populations. These maps will be provided to WLCI affiliated county weed and pest specialists for treatment. Maps also were provided to the FWS to use to support its efforts in locating tamarisk from fixed-wing aircraft.

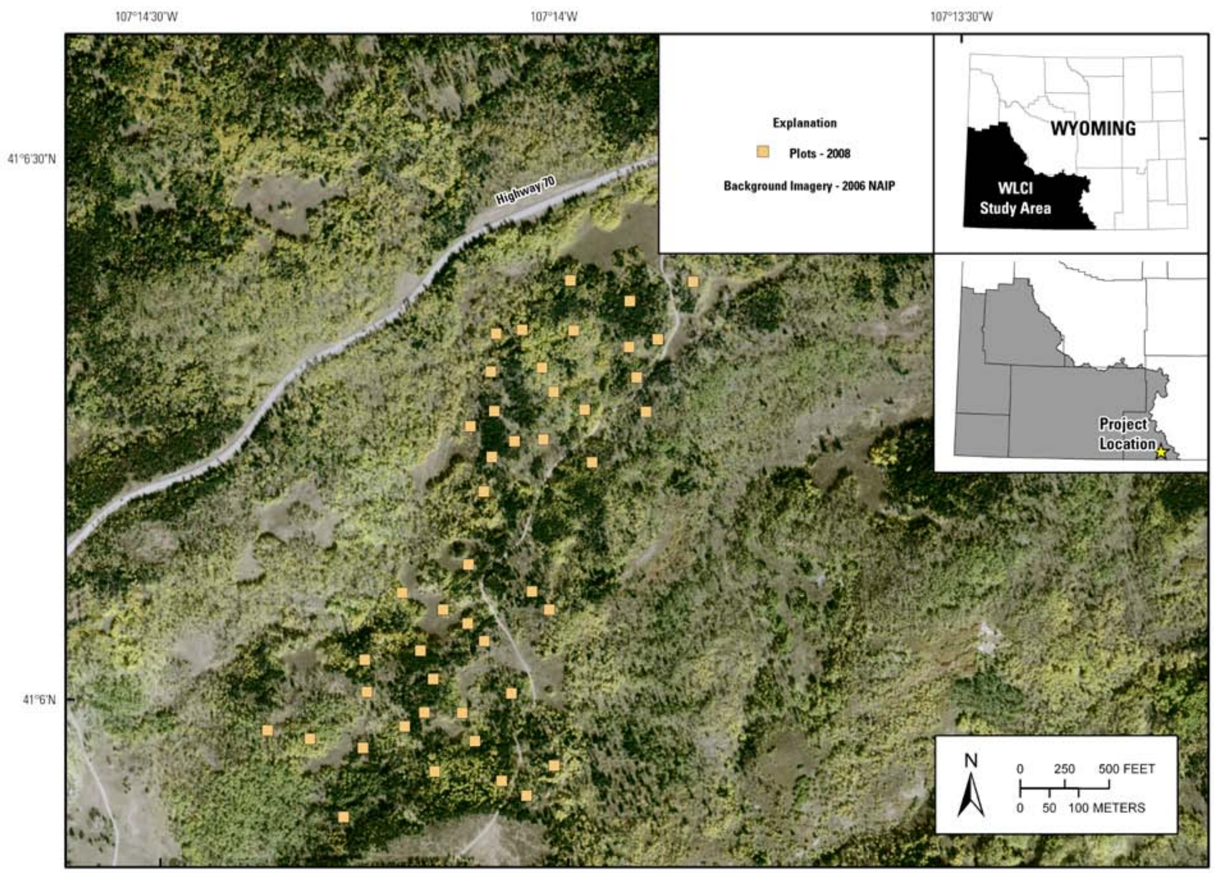



**Figure 12.** Location of aspen treatment plots being monitored for treatment effectiveness within the WLCI region.

## Retrospective Vegetation/Cover Change

### *Scope and Methods*

Mapping vegetation productivity from satellite imagery provides key information to WLCI scientists studying the effectiveness of vegetation treatments in the field. This information provides comparable measures among treatments, which can be used in concert with field-based observations to evaluate effectiveness. Also, maps of productivity can be used to locate treatment areas otherwise not documented in existing records. As a test case, the Rocky Mountain Geographic Science Center (RMGSC) mapped NDVI (Normalized Difference Vegetation Index) from 2007 SPOT imagery for use by field scientists in their study of treatment effectiveness (fig. 13). The NDVI maps showed promise as a tool for identifying historic vegetation treatments. In 2009, mapping of NDVI for additional SPOT scenes will continue.

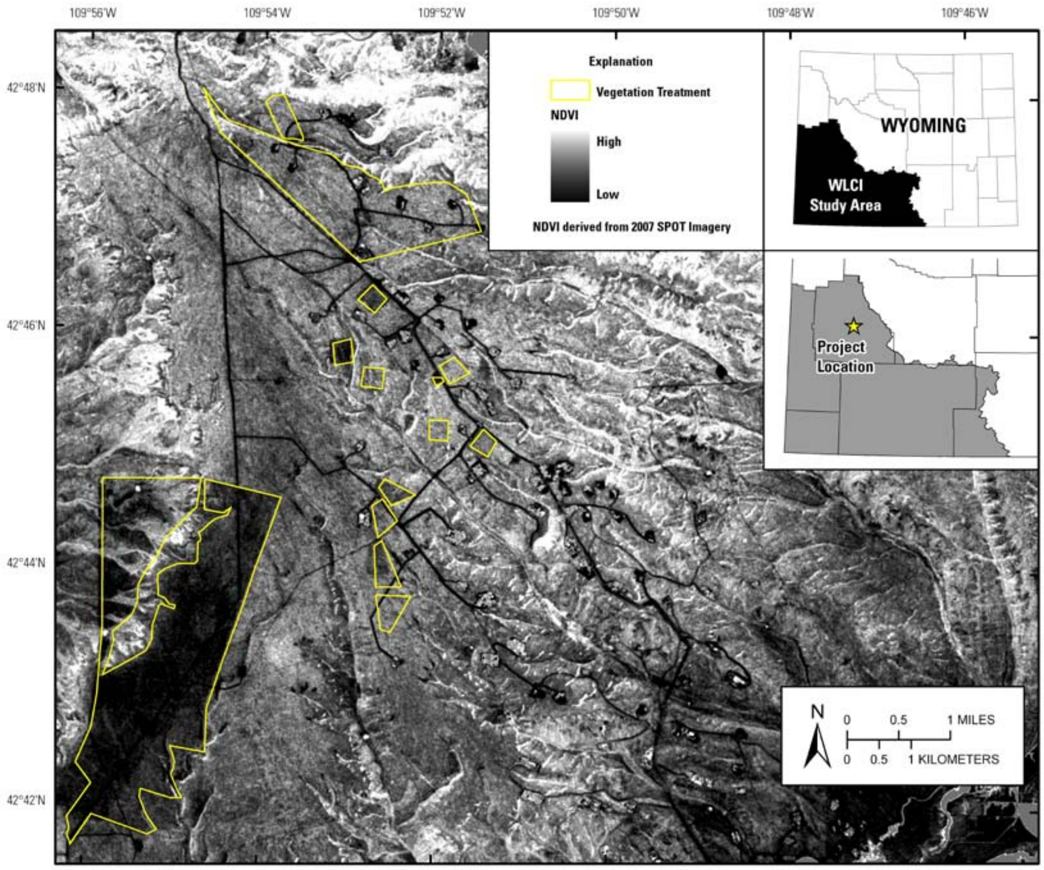



**Figure 13.** An NDVI image (rescaled to better show different levels of vegetation productivity, or “greenness”) from SPOT imagery (10-m resolution) for an area of the Jonah Gas Field. Yellow polygons indicate known vegetation treatments; darker areas are less green and lightest areas are greenest. Because greenness can change during the growing season, however, it is important to note that this image was taken on July 30, 2007.

### *Objective*

- Identify regional and landscape-scale variability in vegetation characteristics using NDVI.

### *Study Area and Map*

An example of the NDVI mapping across the WLCI region (fig. 2). An example of the products associated with this subtask is illustrated in figure 11.

### Work and Products Completed

- Developed an NDVI map of a subsection of the Jonah Gas Field.

## Soil Chemistry: Relationships between Energy Exploration/Development and Salinity of Soils and Waters

### Scope and Methods

Near the headwaters of Muddy Creek in Carbon County, Wyoming. Note typical white, ephemeral salts (bottom right) on disturbed ground. (Photo by Dick Grauch, USGS)

The original focus of this work was to evaluate effects of tamarisk on soil and water salinity. After conducting a literature search/review, developing a refined research work plan, and submitting a pre-proposal for this research to the Colorado River Salinity Control Forum, the Forum shifted its focus away from research and a full proposal was not submitted. As a result, this project shifted away from tamarisk to address the influence of energy exploration and development on soil and surface water salinity. It was decided that Muddy Creek subbasin in Carbon County, Wyoming, would serve as a test system for this new focus. In October 2009, a scoping trip was conducted to

- meet with USGS water scientists in the Water Resources Discipline (WRD), researchers at the University of Wyoming, and BLM personnel at the Rawlins Field Office in Wyoming; and
- make a site visit to Muddy Creek to better understand the nature of the issues there and to obtain a small suite of samples for preliminary study.

### Objectives

- Develop an understanding of soil and water salinity in the Muddy Creek subbasin, Carbon County, Wyo., and the influence of energy exploration and development on salinity.

### Study Area and Map

The study area encompasses the Muddy Creek subbasin, Carbon and Sweetwater Counties, Wyo. (fig.14).

### Products and Work Completed

- A literature search/review for research related to tamarisk, soil salinity, and quality of groundwater and surface water.
- A work plan for research on tamarisk management as it relates to soil and surface water salinity.

- A pre-proposal regarding the effects of tamarisk on soil and water salinity was submitted to the Colorado River Salinity Control Forum.
- Preliminary soil/salt samples were collected from a limited portion of the Muddy Creek subbasin.

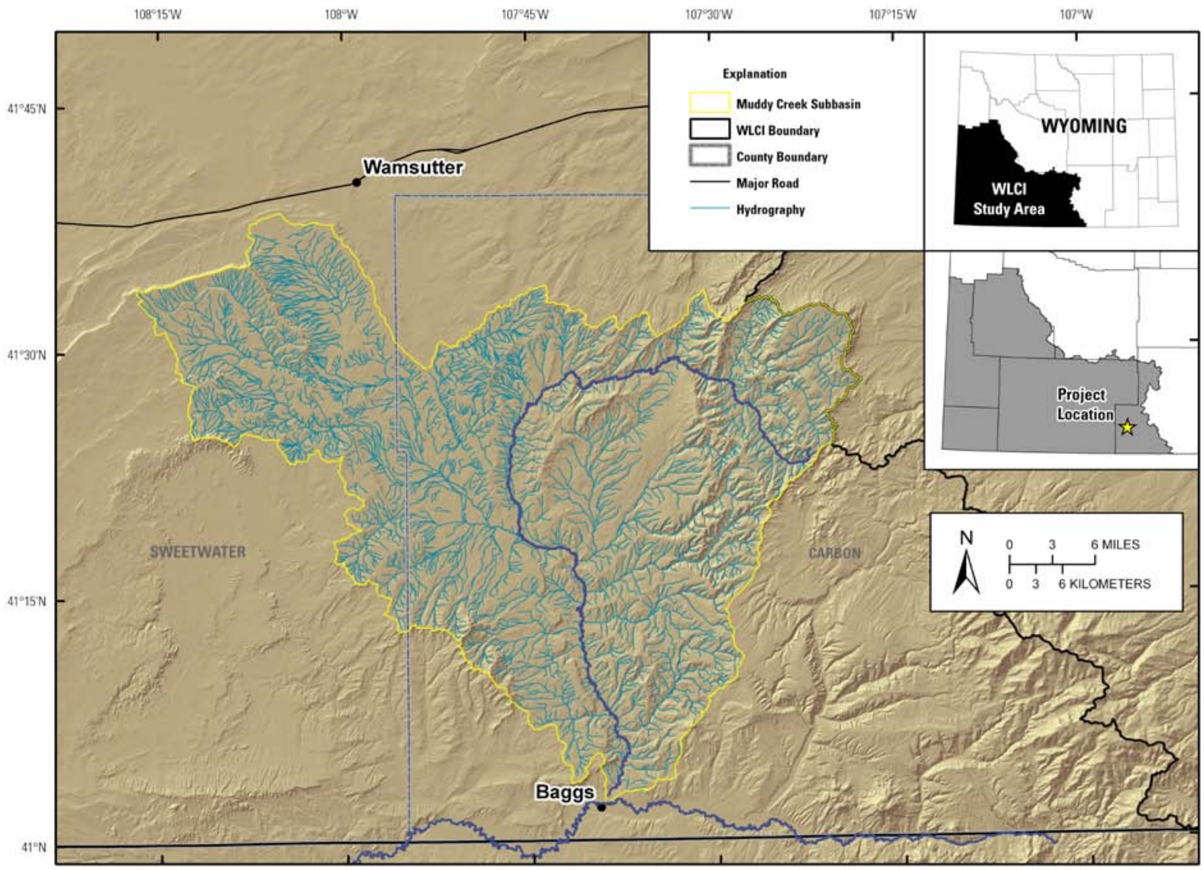



**Figure 14.** Location of the Muddy Creek subbasin study area.

## Overview of Mechanistic Studies of Wildlife

Mechanistic research provides a more detailed understanding of the relationships among important and protected species, their habitats and distributions, and energy related land-use patterns.

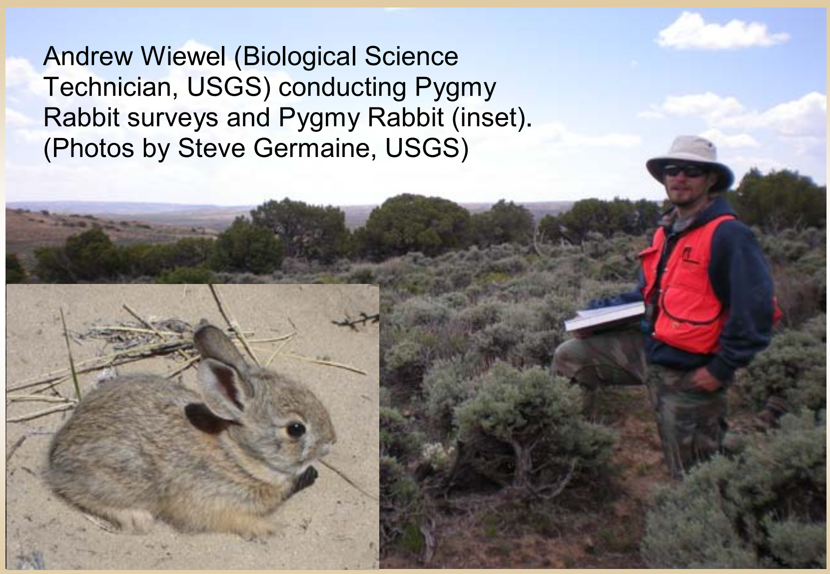
- A pygmy rabbit study is focusing on enhancing our understanding of the habitat requirements of pygmy rabbits and their distribution in Wyoming. Field data were collected and are being used to validate and refine existing pygmy rabbit habitat models.
- A sage-grouse study entails developing spatial models to evaluate landscape-wide changes in sage-grouse habitat and populations. Available data were compiled and preliminary analyses to support model development were completed.

- A study on sagebrush-obligate songbirds (Brewer’s sparrow, sage sparrow, and sage thrasher) includes investigating breeding bird density and nest success information relative to a gradient in energy-development intensity. Initial data were collected and data analyses are in progress.
- A study on ungulates uses a Brownian bridge movement model to identify migration routes used by priority species (mule deer [*Odocoileus hemionus*], elk, moose [*Alces alces*], and pronghorn [*Antilocapra americana*]). Maps of migration routes and segments of routes used for foraging, resting, and movement were developed. Subsequently, maps of prioritized migration routes were developed, immediate applications of which included identifying potential conflicts with roads and other development plans.

Details of the Mechanistic Studies of Wildlife work are provided below in the sections entitled (1) Pygmy Rabbit, (2) Sage-Grouse, (3) Songbird Community, and (4) Mule Deer.

## Pygmy Rabbit

### *Scope and Methods*


Andrew Wiewel (Biological Science Technician, USGS) conducting Pygmy Rabbit surveys and Pygmy Rabbit (inset). (Photos by Steve Germaine, USGS)

Throughout their range, pygmy rabbit populations have declined as sagebrush habitats have been reduced and fragmented. Because of range-wide habitat loss and corresponding population decline, pygmy rabbits are now being considered for Federal Endangered Species Act listing. Relatively little is known about the ecology of this sagebrush obligate, and numerous information gaps must be filled in order to effectively manage for pygmy rabbit conservation. Further, because of the high level of difficulty involved with studying this species, listing and management decisions into the foreseeable future will likely depend on site occupancy information. USGS scientists are collaborating with the WYNDD to (1) provide survey-based validation for the existing range occupancy model for Wyoming and (2) develop a model capable of predicting both site occupancy and site vacancy based on landscape-level habitat attributes. Through this work, the existing model will be refined by modeling new, relevant variables, such as anthropogenic disturbances, sagebrush patch metrics, and updated climate information. In addition, the model results will provide managers with a new tool for informing permit-related decisions. Finally, survey data collected in this effort will contribute to development of the long-term monitoring program, and efforts to backcast and forecast wildlife population trends.

### *Objectives*

- Improve our knowledge of the distribution of pygmy rabbits in Wyoming.
- Collect ground-truth survey data.
- Validate the predictive occupancy model developed by the WYNDD.
- Generate a new model capable of accurately classifying both occupied and unoccupied sites accurately.

### *Study Area and Map*

Figure 15 illustrates the extent and distribution of pygmy rabbit survey areas.

### *Work and Products Completed*

- GIS distribution map of occupied and vacant sites (fig. 15).

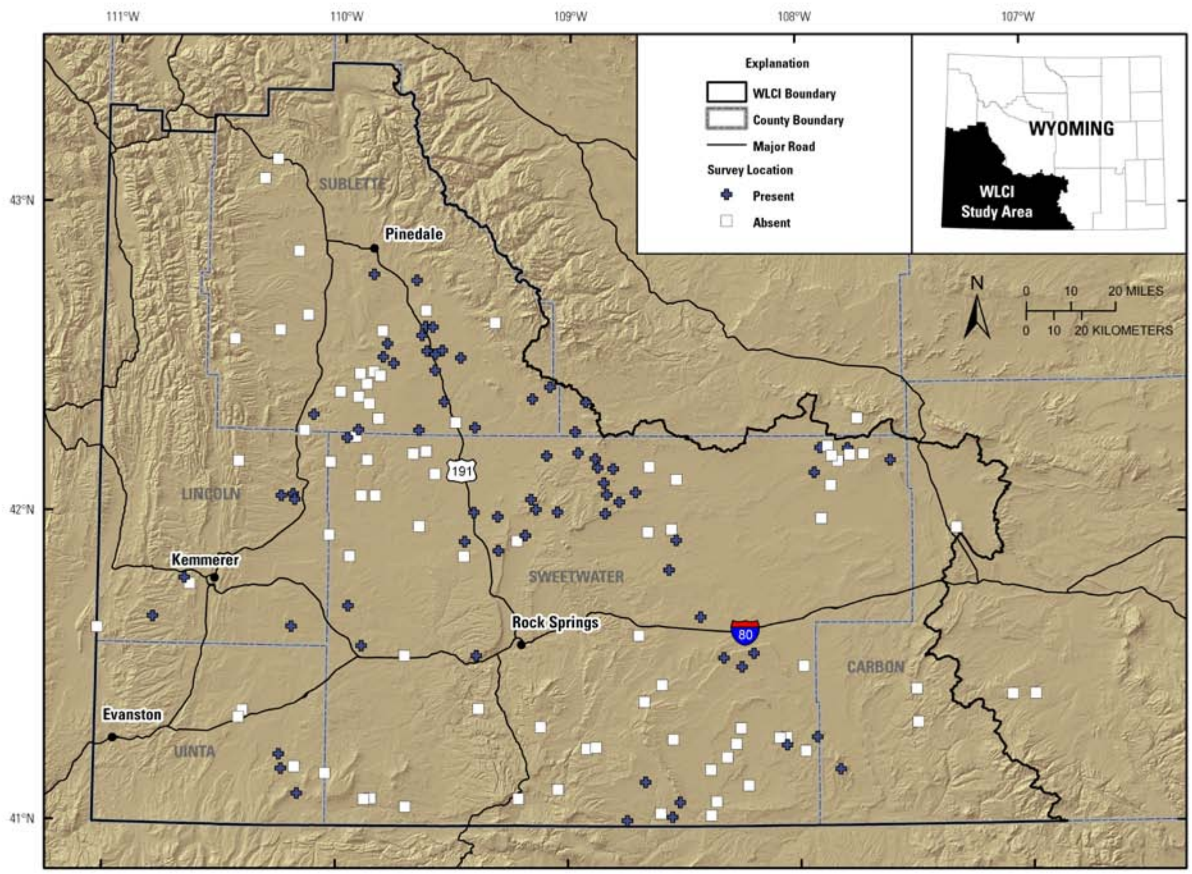



**Figure 15.** Locations where pygmy rabbits and(or) their sign (pellets, burrows) were observed (present) or not observed (absent).

- Wyoming Pygmy Rabbit Working Group was established with members representing the University of Wyoming; WEST, Inc.; WYNDD; BLM Field Offices in Wyoming; and USGS (and attempts are underway to include WGFD and other interested parties).
- "USGS 2008 Accomplishments," presented to BLM Field Offices of southwest Wyoming to describe the USGS pygmy rabbit work.

## Sage-Grouse

### Scope and Methods

Persistence of the greater sage-grouse is dependent on the quantity, quality, and distribution of habitat within its range (semi-arid sagebrush steppe). Recent work on greater sage-grouse has focused on developing spatial models assessing sage-grouse responses across large landscapes. A long-term analysis of population trends across the WLCI area and the rest of Wyoming was conducted to identify key time periods in historical sage-grouse population fluctuations and to quantitatively address many analysis concerns associated with using very large time-series databases. These studies provided a solid foundation and will inform research for 2009 by providing greater focus on the timing and mechanisms that influence population fluctuations, specifically climate and energy development. In addition to this work, our major efforts for 2009 will focus on the development of predictive habitat selection models for sage-grouse.

### Objectives

- Develop spatial models assessing sage-grouse responses to energy development and climate variation across large landscapes using existing population data from lek (a ritual congregation area where males display and breed) counts.
- Compile data from previously conducted and ongoing biotelemetry studies, both within WLCI and across Wyoming.

### Study Area and Map

Work is taking place across the entire WLCI study area (fig. 2).

### Work and Products Completed

- Organized transfer of the WGFD's long-term lek database to the FORT scientist working on this project.
- Carried out extensive database quality assurances and controls.
- Analyzed lek trend data for Wyoming using generalized additive models identifying key years in which the rate of population change increased or decreased.
- Used bootstrapping[1] procedures to analyze the effect of repeated counts on the accuracy of population trend models.
- Manuscript in preparation: "Monitoring Wyoming greater sage-grouse populations: the importance of repeated counts and the influence of scale."
- Presentation at the annual meeting of the Wyoming Chapter of The Wildlife Society.

[1] In statistics, bootstrapping is a resampling technique used to obtain estimates of summary statistics.

- Acquired and developed lek-specific monthly climate data for Wyoming at 1-km resolution.
- Developed time-stamped well data for Wyoming.

## Songbird Community

### Scope and Methods

Sagebrush-obligate songbirds (Brewer's sparrow, sage sparrow, and sage thrasher) are showing range-wide population declines as sagebrush habitats throughout North America are altered and reduced by human activities such as energy development. The focus of this study is to evaluate the abundance, diversity, nest success, and offspring quality of sagebrush-obligate songbirds across a gradient of energy development intensity. The first year of field data was collected during May–August, 2008. Avian abundance and diversity were evaluated using replicated point-count sampling. Twelve nest-search plots were intensively monitored and data on clutch sizes, rates of nest abandonment, nest predation, and nest success were collected from 249 nests. Distance to the nearest road and well pad also were recorded for each nest to assess potential responses to human disturbance. Size measurements were taken for 226 nestlings to investigate whether energy development leads to habitat-quality changes that influence food availability and, therefore, offspring quality. Several habitat features were measured at 238 nest and 240 point count locations to account for habitat effects. Data analysis is ongoing. Data from the project will provide information on the impacts of habitat fragmentation and human disturbance associated with energy development on avian population and community dynamics.

### Objectives

- Evaluate the influence of energy development on the songbird community within sagebrush habitats of the Green River Basin, Wyo.
- Measure avian community structure (abundance, diversity) and productivity (nest success) across gradients of energy development intensity (well pad density).

### Study Areas and Maps

Songbird study areas were established in three areas that represent a gradient of energy-development intensities (fig. 16).

### Work and Products Completed

- GIS maps of study area and locations of point counts and nests.
- Dataset consisting of avian abundance, diversity, nest success, nestling quality, habitat, and distance from and extent of disturbance information.
- Oral presentation at the Wyoming Wildlife Society meeting, Sheridan, Wyoming (November 20, 2008, by Michelle Gilbert).

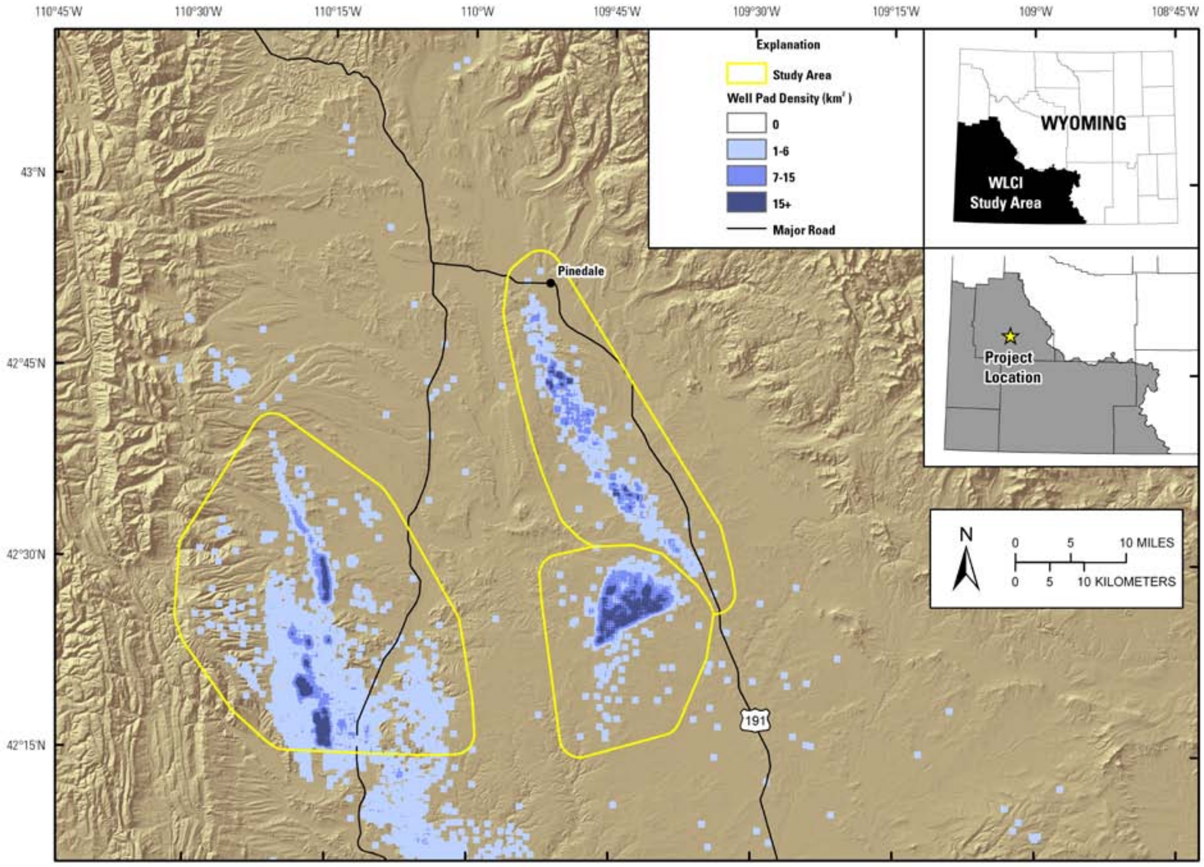



**Figure 16.** Three separate energy-development areas where songbird sampling occurred. Colored squares within the study areas illustrate well pad density per $km^2$.

## Mule Deer

### *Scope and Methods*

As habitat loss and fragmentation increase across ungulate ranges, identifying and prioritizing migration routes for land-use planning and conservation has taken on a new urgency. A general framework using the Brownian bridge movement model was designed to (1) provide a probabilistic estimate of the migration routes of a sampled population, (2) identify which segments of the route function as foraging and resting areas versus those used primarily as movement corridors, and (3) prioritize routes for conservation based upon their proportional use by the sampled population. This approach was applied to a migratory mule deer population in a pristine area of southwest Wyoming, where 2,000 gas wells and 1,609 km of pipelines and roads were proposed for development. Our analysis provides information about where migration routes occur relative to proposed development. The methods developed for this application should be transferable to a wide range of species that inhabit regions where migration routes are threatened or poorly understood, contested, and being modified. Findings from this study are currently being used to inform land-use decisions by the BLM in the Atlantic Rim Project Area.

Mule Deer buck
(Photo by Mark Gocke,
Wyoming Game and Fish
Department)

### *Objectives*

- Identify migration routes used by key ungulate species (mule deer, elk, moose, and pronghorn) and develop methods for analyzing corridor use to inform conservation decisionmaking.
- Develop the capacity to identify and predict the availability of alternative migration routes.

### *Study Area and Map*

Migratory assessment work in 2008 focused on the Atlantic Rim Project Area (fig. 17), which is part of the Baggs Mule Deer Herd Unit in southwest Wyoming.

### *Work and Products Completed*

- Developed maps of migration routes (see fig. 17).
- Developed maps of migration segments used as foraging/resting habitat and those used for movement.
- Developed maps of high priority migration routes.
- Manuscript in preparation for a peer-reviewed journal.

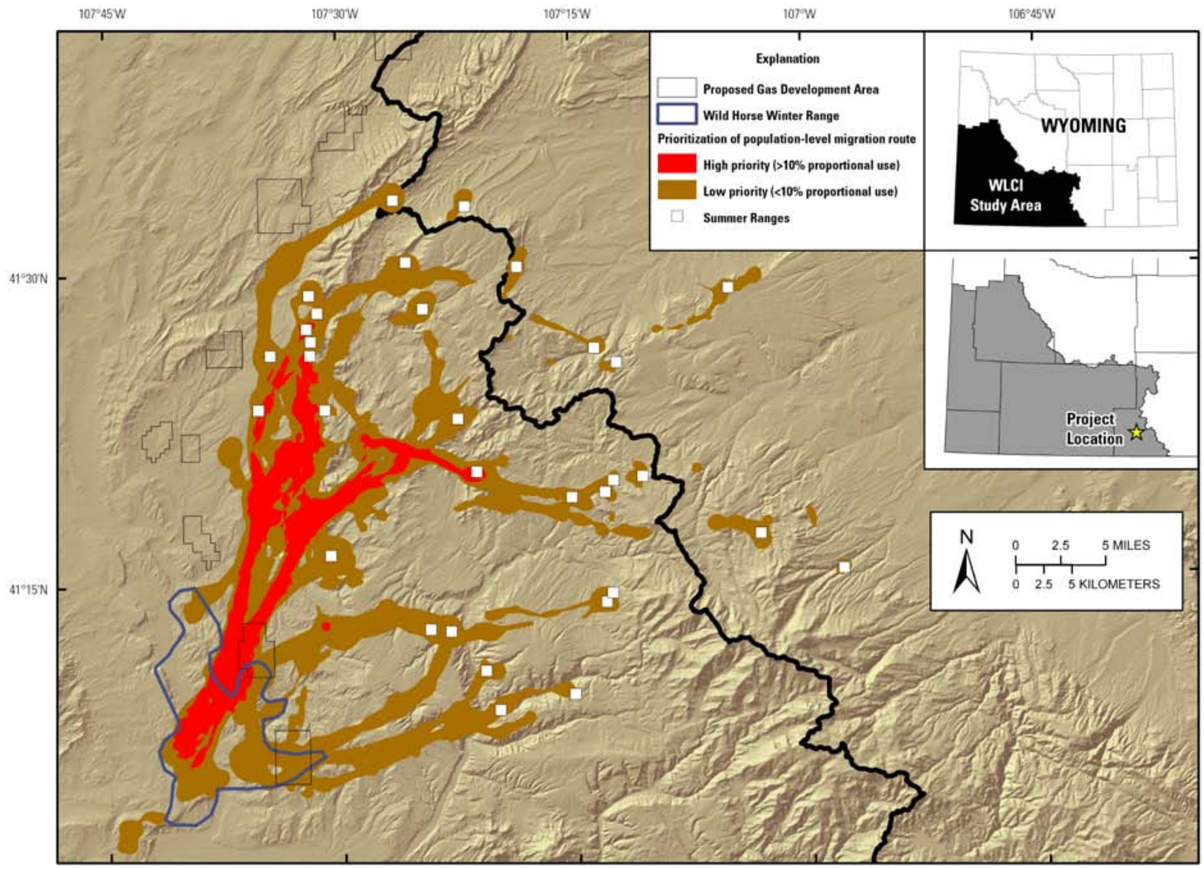



**Figure 17.** Location of mule deer study in the WLCI region and estimated population-level migration route and relative amounts of use for mule deer in the Wild Horse Winter Range, southwest Wyoming. Prioritization of migration routes was based on the proportion of sampled mule deer population (greater than 10 percent) using route segments across the wild horse population-level migration route (Sawyer and others, in press).

## Integration and Coordination

### Overview

Integration and Coordination activities continue to be critical components of USGS involvement in WLCI. In 2007, when the initiative was still developing, USGS hired a full-time scientist to work with the CT and provide direct technical assistance for the initiative. In addition to providing direct technical assistance to multiple WLCI teams and leading the organization of Local Project Development Teams (LPDT), this individual serves as a direct personal connection between local managers, project developers, and administrators, and as a liaison for the scientific information and technical capabilities available through USGS and others. Products developed with collaborators on the CT included a framework for conservation planning, a WLCI Strategic Plan, and a WLCI Operation Plan. Numerous members of the WLCI Science Team and CT provided dozens of briefings and field tours for various partners and supporters of the initiative to promote collaboration and information sharing.

Details of the Integration and Coordination work are provided below in the section entitled Wyoming Landscape Conservation Initiative Interagency Coordination.

## Wyoming Landscape Conservation Initiative Interagency Coordination

### *Scope and Methods*

A project as large and complex as the WLCI requires significant coordination at various levels to maintain communications between partner agencies and project collaborators. To that end, a USGS representative was hired to serve on the WLCI CT and foster project collaboration through communications at public meetings and maintaining contact with the leaders developing habitat projects. The USGS representative works with the CT to develop a conceptual framework for the WLCI conservation planning process. The CT also developed several documents to guide WLCI activities, including the WLCI Strategic Plan, which describes the goals and objectives of the WLCI and the strategies needed to successfully accomplish the WLCI mission, and the WLCI Operation Plan—a direct extension of the WLCI Strategic Plan—that will guide the CT in its efforts to achieve the WLCI goals. Additional important 2008 activities included

- drafting a "Heritage Trust" memorandum of understanding (MOU) for managing contributions made to the WLCI that could be used in leveraging additional funding for WLCI science and conservation projects;
- developing strategies and objectives for WLCI committees, subcommittees, Science Technical Advisory Committee (STAC), Monitoring Team (MT), CT, Data and Information Management Team (DIMT), and LPDTs;
- developing a new partner MOU that incorporates county commissioners and conservation districts;
- assembling four LPDTs, comprising biologists, range managers, conservation district personnel, landowners, county commissioners, and other interested parties, to foster and facilitate local involvement in and support for WLCI projects;
- drafting evaluation criteria for proposed 2009 projects and revising the criteria for 2010 projects;
- providing technical support for ranking WLCI habitat treatments for 2008 and 2009 that are used by the WLCI Executive Committee (EC) for final project selection;
- producing fall and spring WLCI 2008 newsletters and other WLCI briefing materials; and
- providing on-site tours for USGS management teams to familiarize participants with WLCI issues and science needs, and to discuss work that USGS is doing to address the issues.

Accomplishments in 2008 also included many outreach efforts through participation on committees and teams, including the WLCI CT, DIMT, and STAC. Data and information for use by interested parties is being made available on the USGS intranet and WLCI Web site. The USGS CSC, which has the ability to map and store various types of data, also will be used to track science and conservation projects, monitoring activities, and project proposals.

### *Objectives*

- Provide coordination for planning and work among multiple research and management projects to maximize efficiency in meeting the goals of the initiative.
- Provide direct technical assistance to multiple WLCI teams and committees.
- Ensure that the interdisciplinary knowledge, expertise, and work of USGS and other scientists are available to support the work of WLCI managers and decisionmakers.

### *Study Area and Map*

Activities associated with this subtask apply to the entire WLCI region (fig. 2).

### *Work and Products Completed*

- Developed a conceptual framework for the conservation planning process. This includes a 5-step process for developing, implementing, and evaluating conservation actions.
- Developed the WLCI Strategic Plan. This document describes the goals and objectives of the WLCI and the strategies needed to successfully accomplish the WLCI mission. It also identifies its relationship to other documents and processes associated with WLCI operation, such as using science to support management decisions, data management and sharing, and communication.
- Developed the WLCI Operation Plan. This plan is a direct extension of the WLCI Strategic Plan and specifically addresses the goals and objectives achieved by implementation of the strategies through immediate or short-term actions. It will guide the CT in achieving WLCI goals, and it will guide the establishment of internal and external involvement in the WLCI and the creation of a process for planning and prioritizing conservation projects and identifying actions necessary to accomplish the stated goals of the WLCI. Specific actions and timelines for completing this work will be documented in regular updates to this Operation Plan.
- Developed the Wildlife Heritage Trust of Wyoming MOU to handle private contributions to the WLCI that could be used to leverage additional funding for WLCI science and conservation projects.
- Developed the myUSGS intranet (*http://my.usgs.gov/csc/wlci/*) and WLCI (*http://www.wlci.gov/*) Web sites for data storage and management. Data and information are available for interested parties on the myUSGS and WLCI Web sites. Accessible through myUSGS is the USGS CSC, which can map and store various types of data and may be used to track science and conservation projects, monitoring activities, and project proposals.
- Evaluation criteria for proposed projects. Criteria for evaluating habitat treatment projects were drafted and used to rank/prioritize 2008 and 2009 projects and to develop recommendations to WLCI EC for final project selection. The draft criteria will be revised for 2010 proposed projects.
- Produced two WLCI newsletters (Spring and Fall, 2008) and other WLCI briefing materials.
- Developed a new partnership MOU incorporating membership of southwest Wyoming County Commissioners and Conservation Districts.

## Data and Information Management

### Overview

Three Data and Information Management tasks were conducted in 2009: (1) development of a Data Management Framework and Clearinghouse; (2) development of a Conservation Project Data Model, and (3) development and refinement of Outreach and Graphics Products. The primary focus of Data Management Framework and Clearinghouse work was developing protocols for assembling, cataloging, and serving datasets associated with WLCI. The WLCI Data Clearinghouse (part of the USGS Comprehensive Science Catalog) is a searchable online database that enables use of WLCI data and products (for example, maps, locations, and information on science and habitat projects, key results, and summaries). The Conservation Project Data Model task developed an online system to display habitat and science project locations on a map with descriptive (attribute) information. Outreach and Graphics Products included developing a Web site that serves as a nexus of information on WLCI and includes documents, maps, newsletter updates, and access to the Data Clearinghouse and Project Database.

Details of the Data and Information Management work are provided below in the sections entitled (1) Data Management Framework and Clearinghouse, (2) Science and Conservation Projects Database, and (3) Outreach and Graphics Products.

#### Data Management Framework and Clearinghouse

##### *Scope and Methods*

Primary tasks associated with managing and providing information for the WLCI are (1) discovering and taking advantage of existing data and information, (2) cataloging new data and information, and (3) making these resources available online to the public and WLCI researchers. During 2008, USGS data management efforts for the WLCI focused on acquiring data resources for the WLCI Data Clearinghouse (*http://my.usgs.gov/csc/wlci/*, part of the USGS Comprehensive Science Catalog [CSC], a broad data repository) from publicly available national datasets, on-the-ground BLM monitoring projects, USFS grazing allotment information, WGFD biological surveys, and other sources. Data records provided for the WLCI Data Clearinghouse were generated for numerous projects by multiple investigators working for separate agencies with varying levels of completeness and compliance with accepted data standards. Basic metadata are lacking for many data records, which precludes their inclusion in the CSC. Currently, the USGS is working to

- identify data ownership and level of privacy (available to the public or WLCI community only) that the data owners want assigned to data records;
- identify minimum metadata information that must be available for each data record for inclusion in the WLCI Data Clearinghouse/CSC;
- classify records according to data accuracy and completeness to inform users; and
- identify data integration problems, formulate potential solutions, and present findings to the WLCI DIMT, which will adjudicate data management decisions for presentation to the WLCI EC for final approval.

### *Objectives*

- Identify the existing availability, content, scale and resolution of data for resources relevant to the WLCI.
- Establish protocols for assembling data originating from monitoring and scientific fact-finding efforts for the WLCI Data Clearinghouse.
- Build and maintain a WLCI Data Clearinghouse.

### *Study Area and Map*

Activities associated with this subtask apply to the entire WLCI region (fig. 2).

### *Work and Products Completed*

- WLCI Data Clearinghouse Web application (*http://my.usgs.gov/csc/wlci/*) provides a searchable context view of WLCI data available to internal and external audiences. Non-public data access requires authentication and authorization through the WLCI online community.
- Hosted and provided for online access of 114 individual data sources—these primarily include geospatial data layers available for online viewing and download as shapefiles; data are available through the Data Clearinghouse application interface, and supplemental data resources are continually being added.
- Extended the security model for the WLCI Interagency Web Portal to enable subgroups, such as the USGS Science Team, within the online community space to have protected areas for document management.
- Extended the document management space in the Interagency Web Portal to allow posting of publicly available documents by authorized groups within the WLCI (for example, the WLCI CT and the Communication Team).

## Science and Conservation Projects Database

### *Scope and Methods*

One of the central goals expressed by WLCI partners and stakeholders during the 2007 Science Partner Workshop is to make accessible the descriptive information and locations of (1) "on-the-ground" conservation projects managed through the WLCI CT and (2) science projects being conducted by USGS and other science agency partners. In response to this need, the WLCI Project Database Map was developed in 2008 and is available on the WLCI home page (*http://www.wlci.gov/*; fig. 18). This system provides an interactive map environment, which enables data users to click on geospatially placed points, view project information, and link to additional resources. The Project Database Map is also available in a separate page within the site, where its utility will be expanded to include search and filter capabilities. Science and conservation project information is stored in a geodatabase, which includes point and polygon footprints, and a simple set of attributes used to describe the projects (title, description, responsible entities, funding year[s], and so on). During 2009, as additional WLCI project information is provided to the USGS, the database structure used by the Project Database Map will be enhanced to reflect the needs of the WLCI community.


**Figure 18.** A screen capture of the WLCI Web site home page.

### *Objectives*

- Develop an online system to display habitat and science project locations on a map with descriptive (attribute) information.
- Develop more comprehensive and robust methods for capturing project information during the proposal period to produce a functional long-term dataset.
- Utilize relevant data sources and methods developed for the JIO Project Tracking System for the WLCI.

### *Study Area and Map*

Activities associated with this subtask apply to the entire WLCI region (fig. 2).

### *Work and Products Completed*

- Developed a project database in a geodatabase format and hosted it via an ArcGIS server for map display. The database is maintained by authorized staff in Denver and Fort Collins, Colorado, and contains project footprints and a basic set of attributes.
- Developed a map view of WLCI project locations on the WLCI Website (*http://www.wlci.gov*; fig. 18).

## Outreach and Graphic Products

### *Scope and Methods*

Developing a usable and content-rich Web presence for the WLCI is critical for communication and for information dissemination to users interested in learning about the WLCI and tracking its progress. In December 2008, the revised WLCI Website was released and replaced the original site that was established in 2007. Development of the Project Database Map and the WLCI Data Clearinghouse, both of which are accessible through the WLCI Web site, will continue. Augmentation of these resources will be enhanced by user input, as community members employ these online resources in WLCI-related activities. Web site resources (Bibliography, News, Highlights) will be populated by WLCI community members, and they will assume enhanced ownership of the Web site. The WLCI CT and Communication Team are jointly responsible for maintaining site content and regularly updating information.

### *Objectives*

- Develop and maintain a public Web site providing information about WLCI goals and activities.
- Implement a simple content management mechanism that will allow the WLCI CT and Communication Team to directly manage content for the WLCI website and enable immediate posting of news items, event listings, new documents, and other dynamic content.

### *Study Area and Map*

Activities associated with this subtask apply to the entire WLCI region (fig. 2).

*Work and Products Completed*

- Development and ongoing maintenance of the WLCI Web site (*http://www.wlci.gov*; fig. 18) and enabling the WLCI CT and Communication Team to directly post online content.
- Additions to the content management application to facilitate the housing and maintenance of content specific to the WLCI Web site.
- Discussions with WLCI teams and USGS leadership helped produce a framework for a redesigned WLCI Web site, including new content areas and plans for editable regions of the site.

## Decisionmaking and Evaluation

Decisionmaking and evaluation efforts are focused on improving the efficient integration of science and technical assistance into decisions and on iteratively improving science relevance by evaluating what and how information is being used in planning and decisionmaking (fig. 19). This includes facilitating evaluation of work by multiple partners to ensure that both science and management activities are supporting WLCI goals. As our knowledge base builds from ongoing integrated resource assessments, monitoring, research, and on-the-ground habitat treatments, USGS science and technical support will provide critical information to help WLCI partners evaluate the costs and benefits of energy development under alternative management scenarios, which will help determine how to minimize or mitigate the negative effects of energy and other development on Wyoming's natural resources.

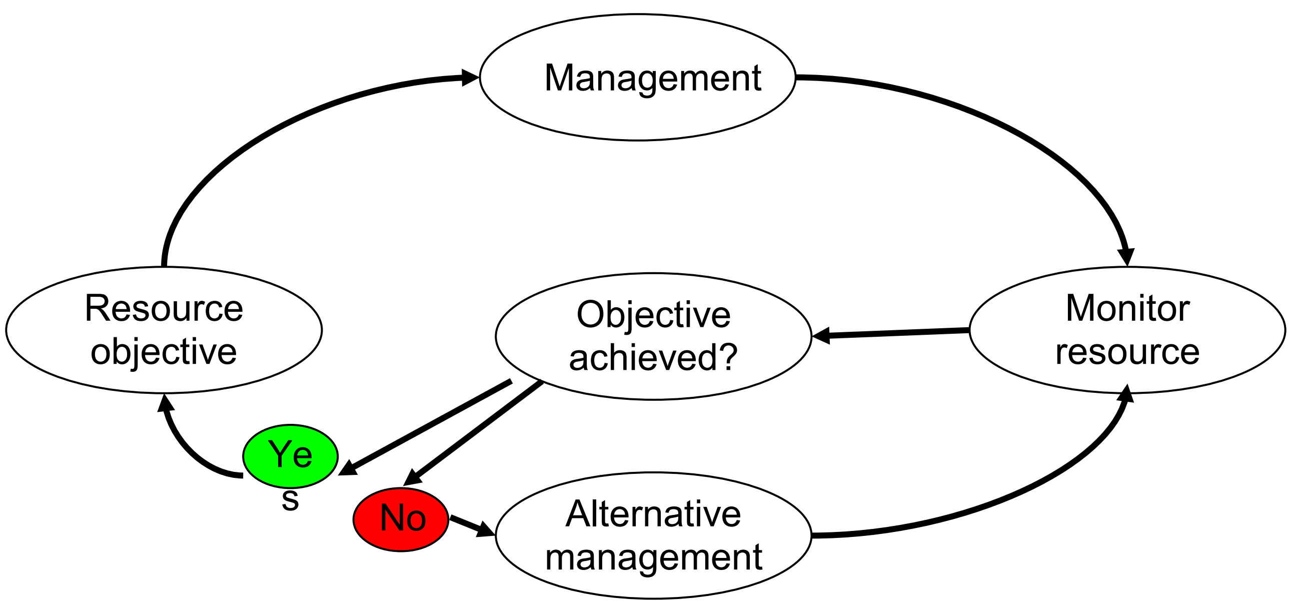



**Figure 19.** Illustration of the adaptive management cycle (Elzinga and others, 2001).

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# Appendix 1. Additional Information on Selected Projects

This appendix provides additional or more detailed information on methods and(or) progress and findings for the work activities presented in the Science and Technical Assistance summary section.

## Baseline Synthesis

### Application of Comprehensive Assessment Data to Support WLCI Decisionmaking and Conservation Actions

#### *Additional Background and Methods Information*

Spatial data representing the habitats, infrastructure, and important physical, natural, and economic resources of southwest Wyoming exist but have not been compiled for analyses with spatial data that represent the interests of all WLCI partners. The lack of a common GIS database that provides these features and values makes some fairly straightforward questions difficult to answer. Such questions might include, "Where are the WLCI priority habitats located, what are the threats to these habitats, and where should future restoration, mitigation, and conservation projects be implemented?" To address these questions, the USGS is conducting an assessment designed to characterize important resources in the WLCI area.

The Comprehensive Assessment, as applied in this task, is a hierarchical process that applies broad-scale information to finer-scale areas by assessing the condition of the ecosystem and risks to its status from natural events and management actions, and it provides scientific support to conserve and restore the ecosystem. Multiscaled assessments provide a comprehensive basis for sustainable land management.

#### *Additional Progress and Findings Information*

During 2008, this work focused on acquiring and reviewing multiscaled spatial data that would help describe the physical, vegetative, aquatic, and riparian setting of the WLCI. This included gathering information on current and past disturbances, areas of interest defined by WLCI partners, important resource data, low- and high-resolution imagery data, energy infrastructure, past and current conservation projects, and science being conducted (for example, short-term and long-term monitoring) and data being collected by WLCI partners.

Data mining work was initiated by identifying appropriate contacts for each of the WLCI partner agencies. A prioritized list of the kinds and types of data available was developed and discussed with WLCI partners. In addition, a data form designed to help locate and identify additional data sources and appropriate contacts was developed and distributed to agency personnel and attendees at WLCI public meetings. Known and subsequently identified monitoring and research activities were entered into an MSAccess database, which was provided to the WLCI STAC for distribution to each of the represented agencies. For data received from partners, landscape characterization themes were developed to help support analysis of key baseline data at the watershed level. These files are currently being used to characterize the status of, and potential threats and risks to, priority habitats and species, and to identify key landscape components in the WLCI area. Numerous multiscale ecosystem assessment approaches were reviewed. An approach for assessing resource data potential for supporting management decisions is being developed. This approach is based on modifications of the Interior Columbia Basin Ecosystem Management Project (Quigley and others, 1999), the Conservation Success Index approach developed by Trout

Unlimited (Williams and others, 2007), and the ecological risk assessment approach used by the former USGS BEST Program.

Correspondence and detailed notes were prepared for all data submitted, and apparent gaps in the information on species, habitats, infrastructure and other surface disturbances, and conservation treatments were identified and documented. During 2009, a list of the information gaps will be provided to WLCI partners for them to verify that they are true gaps and, if not, the list will help focus subsequent data mining efforts. Recommendations will be developed to prioritize data gaps and to direct efforts to acquire the missing information. During 2009, assessments to characterize important resources in the WLCI area (data/information on important ecological systems/species/priority habitats/migration routes, infrastructure/developed areas, and locations of past/current conservation projects) will continue. Work with WLCI partners and the DIMT also will continue to identify and prioritize the acquisition of data, develop criteria to evaluate data for inclusion in the WLCI Science Catalog, and prioritize data gaps and make recommendations to fill important data gaps.

## Land Use/Land Cover Change

### *Additional Progress and Findings Information*

Feature recognition methods were identified as efficient means of identifying and extracting human disturbances (infrastructure) from satellite imagery. Once SPOT imagery (10-m resolution) was selected as the imagery of choice, SPOT images from 2007 were purchased for the entire WLCI study area. Methods within the Feature Analyst software package were developed to extract total land disturbances from SPOT. De-cluttering and manual editing procedures were further developed to provide maps of disturbed and non-disturbed areas. Two priority images were identified by WLCI scientists (fig. 20), and in 2008 maps of total disturbance were produced from these images (fig. 21).

## Energy Futures

### *Additional Background and Methods Information*

The Greater Green River Basin is currently in the midst of a natural gas boom, which entails exploiting a basin-centered gas exploration concept. Related production, exemplified by the Jonah and Pinedale anticline gas fields, is from unconventional gas reservoirs in that the production is from a geologic unit that is distributed over a broad area of the sedimentary basin (as opposed to being concentrated in smaller subsurface geologic containers). Well spacing is commonly tight in such fields, and the fields are large in area. Although the USGS has estimated that there could be 84 trillion cubic feet of undiscovered natural gas resources in southwest Wyoming (U.S. Geological Survey Southwestern Wyoming Province Assessment Team, 2005), petroleum geologists are not able to precisely predict the sites of future fields analogous to Jonah and Pinedale. Planning is underway to develop strategies for presenting possible scenarios for future gas development, based on geologic knowledge of emerging play concepts and other factors. It is particularly instructive to examine geologically based assessment units that were defined in the USGS oil and gas assessment of the Southwestern Wyoming Province in 2002 (Kirschbaum and others, 2002), and to compare the 2002 production footprint with the development that has occurred in the intervening six years, targeted at the specific reservoir intervals assessed.

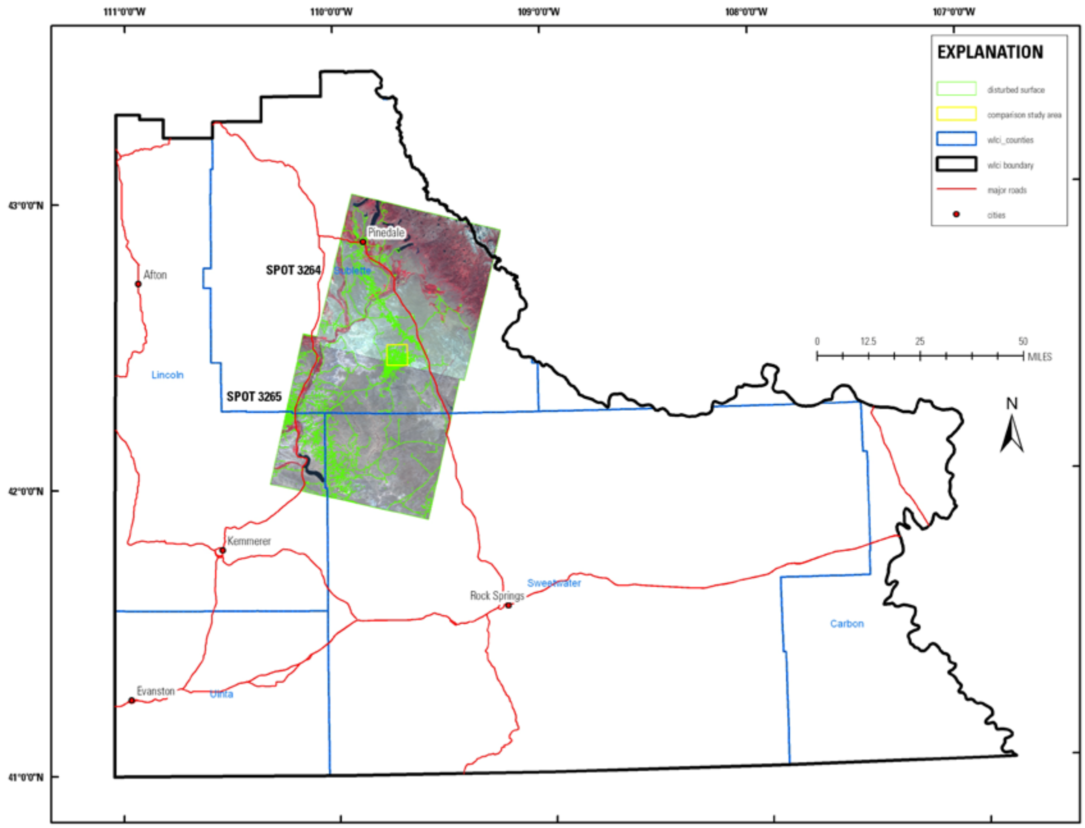



**Figure 20.** Location of the two 2007 SPOT images used in the 2008 development of total-disturbance extraction procedures.

The rich oil shale deposits in the Green River Formation of the Greater Green River Basin in Colorado, Wyoming, and Utah are the subject of ongoing studies by USGS energy geologists. The goals are to refine the understanding of the physical and chemical characteristics of the oil shale deposits and to assess the volume of the existing resource, which will lead to enhanced estimates of recoverable volumes of recoverable oil from oil shale. The new studies likely will improve the understanding of the hypothetical areal extent of possible future shale oil extraction. This has great bearing on the future effects of energy resource production in southwest Wyoming.

In their efforts to understand the origin of coalbed methane in low-rank coals of Wyoming basins, USGS coalbed methane researchers are studying properties of the coal, the coalbed gas, and the produced waters within coalbed methane-producing areas of the Powder River Basin and Green River Basin. This involves extensive sampling of the coal, gas, and produced waters, and laboratory analyses of all of these. Bacteria from coalbed wells are sampled to study the role of these microorganisms in producing methane. The researchers are developing an extensive coalbed methane database and new concepts and understandings relative to the geological and biological factors on coalbed methane accumulations in the Green River and Powder River Basins; in addition, chemical characteristics of the produced waters are cataloged in a growing database that will be of great value in assessing environmental effects.

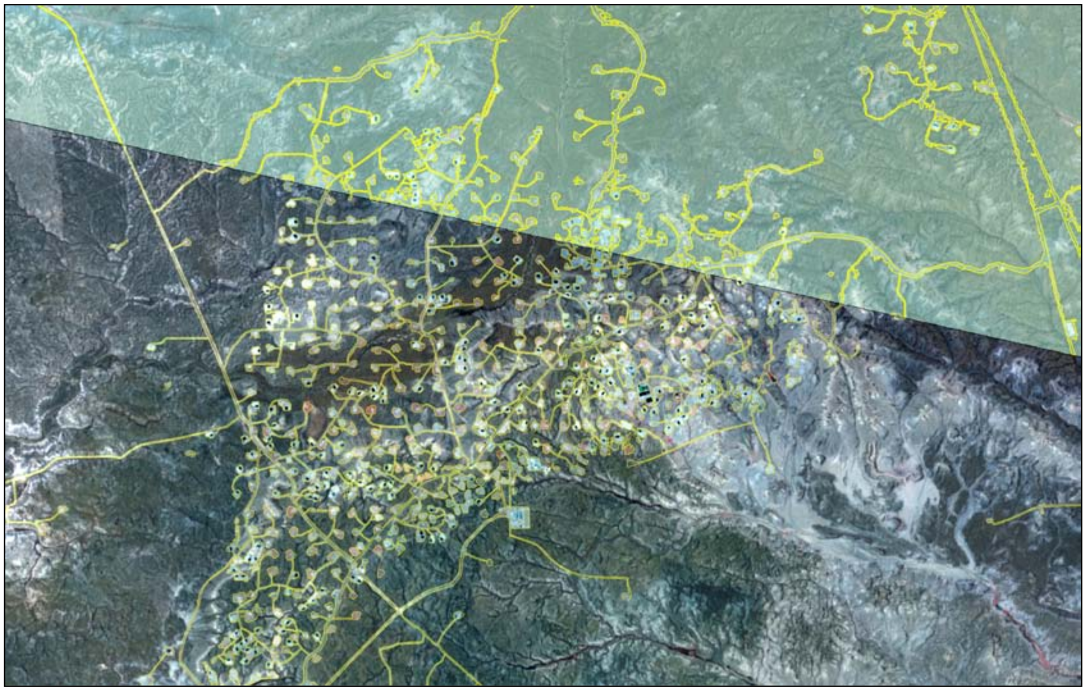


**Figure 21.** Total disturbance map produced using the Feature Analyst software package. This map is an enlargement along the boundary of the two SPOT scenes and shows roads and well pads in yellow and ponds in blue.

## Mineral Resources

### *Additional Background and Methods Information*

About 800 known mines and prospects were extracted from the USGS databases (New MRDS, *http://mrdata.usgs.gov/*; Wilson and others, 2001) and plotted on simplified geologic base maps. In September 2008, many of the accessible sites were visited, as well as sites identified as uranium occurrences in Poison Basin. Access to many sites was problematic due to road closures, locked gates, private property, or it was not possible to find them because they were poorly mapped or described in the literature.

Scientists visited eight mine sites on the western part of the Encampment district, three mine sites in the eastern part of the Seminoe district (outside the WLCI boundary), and attempted to visit six mine sites in the Lake Alice district, although none were reached. At all the sites that were visited, a GPS unit was used to record latitude and longitude coordinates, which were used to verify or correct their locations in the New MRDS database. At many of the mine sites, dump samples were collected for geochemical analysis, GPS lat/long coordinates were obtained, and the geology and mineralogy of the ores were noted. Selected samples will undergo geochemical analysis for trace elements.

### *Additional Background and Methods Information*

The socioeconomics of the Green River Basin of southwest Wyoming are interactively challenged by expanding energy development. In 1986, a socioeconomic study on natural resource development in Montana indicated that although two-thirds of the respondents believe natural resource development to be essential for Montana's economic health, respondents also indicated that the primary disadvantages or costs associated with this type of development would be environmental impacts, population growth, and boom-and-bust economic cycles (Wallwork and Johnson, 1986). A recently released study examining the benefits and costs associated with northwest Colorado's boom in natural gas development highlights how energy development has resulted in lower unemployment and greater property values, wages, and tax revenues while also increasing concerns about crime, traffic, scarcity of housing, and impacts on the quality of life and the environment (Redifer and others, 2007). Additionally, energy development can have secondary effects on the local social and economic environment, including increased housing development, need for more infrastructure (roads, electrical lines, and so on) and social services (such as police and healthcare). These social and economic impacts can then increase pressure on the existing natural resources, including increased demands for water resources and hunting and fishing opportunities, and cause greater habitat loss due to housing developments (The Energy and Biodiversity Initiative, 2003).

Support for future energy development in the Green River Basin depends on understanding potential socioeconomic effects as well as the effects on wildlife. Several of the key drivers of change identified in the WLCI Science Strategy pertain to social and economic issues, and the work of this project will provide the necessary social and economic context while also providing a strategy for public engagement in the dialogue surrounding energy development and wildlife/habitat concerns.

The objectives for this work are to create a common understanding of the social and economic context for energy development and habitat conservation in the Green River Basin, and to provide a basis for dialogue with the public through the entire adaptive management process. Detailed objectives of this work follow.

- Using baseline secondary data (such as that provided by the U.S. Bureaus of the Census, Labor Statistics, Economic Analysis), compile a basic social and economic assessment to provide a common context for the other issues addressed in the WLCI. Activities that affect natural resources, such as energy development, also can affect communities at all levels, including social interactions, economics, and land uses. Although it would not be possible to assess all dimensions of potential changes, there are "sociological dimensions [that reflect that] fundamental and important characteristics of a community [that can be measured]" (Burdge and Johnson, 1998). For this project, our assessment will include (1) current population; (2) population projections; (3) population density; (4) urban/rural nature; (5) residency and housing characteristics, including second home ownership; (6) age and school enrollment (money from energy development potentially going to schools); (7) racial diversity and poverty (as required by Executive Order 12898, 1994, to determine whether or not energy development raises environmental justice issues); (8) lifestyle/land use, including farming/ranching statistics; (9) employment trends, including personal income, earnings (to better understand changes in earnings, which industries are sources of growth in labor income, and which industries are sources of decline), and (10) unemployment. To generate data for the overall WLCI area, this assessment will include information at three levels: State, individual county (for counties that make up the WLCI area), and the aggregate of WLCI counties.

- Conduct a literature review that complements the social and economic assessment research completed on energy development, with a focus on oil and gas development in the West. Documenting the impacts and lessons learned from the 1970s boom provides a starting point for assessing and projecting how residents are coping with the socioeconomic impacts of the 2000s boom. The literature review highlighted the current state of knowledge concerning socioeconomic issues pertaining to oil and gas development in the broader context of Wyoming, Montana, and Colorado. The review identified impacts on infrastructure, including roads, schools, healthcare systems, and housing. Regional economic effects from oil and gas development include strains on employment pools, tourism, hunting, public services, sustainability of ranching operations, and taxes. Also studied were variables that affect sense of place for area residents, including traditional land uses, changes in ranching practices, and alteration of viewsheds, quiet, solitude, and aesthetics.
- Identify locations of existing and potential future leases and wells in the Green River Basin, as well as in the broader context of Wyoming, Montana, and Colorado.

Overall the goal of these objectives and the associated maps is to create an understanding of the social and economic context of existing areas with oil and gas development as well as to highlight the main socioeconomic issues surrounding oil and gas development in the western United States. The results will highlight important issues that communities with current or potential oil and gas development may want to consider.

### *Additional Progress and Findings Information*

A draft version of the social and economic assessment and literature review was revised and completed by mid-winter 2008/2009. Below is a brief summary of some of the current findings discussed in the literature review, with a focus on population, employment and income, and social well-being effects.

The last boom in the 1970s and early 1980s was driven by scarce oil supplies and high prices, as well as the construction of numerous coal-fired power plants and their accompanying coal mines. The current boom is also partially a result of soaring oil prices, accompanied by significant increases in natural gas prices. By late 2008, oil prices had reached almost $140 per barrel. Though the increase in natural gas prices does not seem to be as extreme, the price of gas has more than tripled since the late 1990s (Energy Information Administration, 2009). Production of gas in the West also increased as demand in the U.S. rose.

There has been some debate as to the validity of some of the early boomtown research. Some authors have criticized certain scholars for reporting negative impacts of energy development on communities with little empirical evidence (for example, Wilkinson and others, 1982), while others have defended the legitimacy of such research (for example, Albrecht and others, 1982). Since then, scholars also noted that few of these early studies were longitudinal (a long-term study in which data are collected at regular intervals) or comparative, making their findings less useful for understanding the long-term socioeconomic impacts (Smith and others, 2001); however, despite any deficiencies that may exist in the older body of research, it describes the last big oil and gas boom and provides the best available picture of how current energy development may impact communities.

Despite these arguments, there is overwhelming evidence that energy booms do result in negative socioeconomic impacts in many communities. They also bring positive change or, sometimes, very little change. The extent and longevity of these impacts depends on the communities. Differences seem to be based on various factors, such as the rate of growth and the financial and institutional capacities of the communities. Between the prior boom and the current boom, there also have been changes in the importance of various impacts. For example, the condition of the environment as it relates to amenity development and to sense of place has become a much more prominent concern during this boom; however, social well-being, gender, and local government issues have faded somewhat. There are several socioeconomic impacts that were important during the prior boom and remain so today, including taxes and royalties, employment and incomes, housing, infrastructure, education, social services, and crime.

Sweetwater County (fig. 2) was the site of one of the earlier energy booms of the 1970s due to the construction of a power plant and an increase in trona mining (Blevins and others, 2004). Currently, natural gas development in adjacent Sublette County (fig. 2) is impacting Sweetwater County, but not to the extent of the last boom. By contrast, Sublette County was not heavily affected by the energy boom of the 1970s, but by 2000 was experiencing rapid growth from increased natural gas extraction in the Jonah and the Pinedale Anticline fields, and it was continuing as of early 2009. The fastest growth occurred from 1970 to 1974 (the boom period), although growth continued for the rest of the decade.

The primary characteristic of an energy boom is rapid population growth fueled by an influx of workers. During both the 1970s and 2000s booms, population increased rapidly in southwest Wyoming. In Sweetwater County, the annual growth rate reached almost 20 percent from 1970 to 1974. The 2000s boom has resulted in growth rates approaching 10 percent for Sublette County (2,000 new residents from 2000–2008), an increase of almost 34 percent. Since 1990, the population has increased more than 50 percent (almost 25 percent from 2000–2006 alone), while the State's population has increased just 14 percent and 4 percent, respectively, over those same time periods (Ecosystem Research Group, 2008). Growth rates, however, do not take into account people who temporarily live and work in Sublette County, so the numbers may be much higher (Blevins and others, 2004). It is estimated that over half of the oil and gas workers in the county live in motels or work camps; thus, they would not be included in the population estimates (Ecosystem Research Group, 2008). Pace of development is a driving factor in population growth and is of great concern to those in Sublette County (SocioEconomic Task Group, 2005). The faster the development of oil and gas fields, the more temporary workers arrive in a shorter period of time, exacerbating socioeconomic impacts.

Energy development tends to impact employment in rural areas in predictable ways. At the beginning of development, few locals are hired and the majority of the workers are transient (Summers and Branch, 1984). Later, more locals are hired, but typically for the lower-paid, less-skilled jobs. Development not only brings new jobs directly to an area, but also frequently spawns support jobs. For example, a study in La Plata County, Colorado, indicates that in 2003 over 300 people were employed by the natural gas industry, but 600 more were employed in industry-related jobs (Walker and Sonora, 2005). In Campbell County, Wyo., employment in the oil, gas, and coal industries increased more than ten-fold from 1966–1981 (Isserman and Merrifield, 1987). This increase was accompanied by expansion in other sectors, such as service and retail, which composed about half of the businesses (at least 50 employees) in the county in 1981. The indirect impact of development also tends to increase as development continues (Summers and Branch, 1984).

Another aspect of the employment issue is local businesses being faced with a dearth of workers willing to work for much lower wages than those offered in the energy industry. Jurado (1980, cited in Merrifield, 1984) estimated that about 30 percent of the local workforce switches from local service jobs to oil and gas jobs when they become available. Employers outside the energy industry are forced to raise wages to retain workers, which, in turn, forces them to raise the prices of the goods and services they provide (Cortese and Jones, 1977). Energy development can bring in new businesses, which provide more jobs, but which also compete with existing local establishments (Merrifield, 1984). Cortese and Jones (1977) also noted that many business owners were initially excited about the potential prosperity brought by a boom; however, some of them could not adapt to the more demanding way of doing business in a boomtown and finally sold or closed their businesses despite being quite successful economically.

In Sublette County, the proportion of employment in mining, construction, and manufacturing increased from 37 percent in 2001 to 49 percent in 2005 (Ecosystem Research Group, 2008). Though the number of jobs in other sectors, such as arts, food, and accommodation (lodging and associated services) is increasing along with those in mining and construction, the proportion of employment in those sectors is decreasing. In 2005, unemployment in the county was approximately 1.8 percent, which was lower than Wyoming's 3.2 percent and the national 4.6 percent. The lack of available, affordable workers in the county has caused some businesses to close, despite the healthy economy.

Residents' perceptions of social well-being in areas affected by energy development can change significantly over the course of a boom-bust cycle. In some cases, energy development does not even have to begin for social well-being to be affected. Residents who are aware of the experiences of other boomtowns may feel stressed before the development occurs in their communities (Kassover and McKeown, 1981). During booms, Cortese and Jones (1977) found that long-term residents felt their communities had become less relaxed, friendly, traditional, isolated, harmonious, and run down, while becoming more expensive, difficult, progressive, and competitive. Research has shown that social well-being often decreases during a boom, but then tends to increase again once the boom is over. A comparative and longitudinal study conducted in the communities of Delta, Vernal, and Tremonton (all in Utah), and in Evanston, Wyo., addressed issues of social well-being in boomtowns (Greider and Krannich, 1983; Brown, Geertsen, and Krannich, 1989; Smith, Krannich, and Hunter, 2001; Hunter, Krannich, and Smith, 2002; Brown, Dorius, and Krannich, 2005). At least four surveys were conducted in these communities over a period of time from 1975 to 1995. Several indicators of social well-being were examined, including perceived social integration, relationships with neighbors, trust of community residents and community satisfaction. Patterns in these indicators were similar in Delta and Evanston. During the peak boom years, perceived social integration, relationships with neighbors, trust of residents, and community satisfaction all diminished among residents; by 1995, however, the levels of these indicators had returned to or exceeded pre-boom levels. In Vernal and Tremonton, the levels of these indicators did not fluctuate significantly over the time period. Smith, Krannich, and Hunter (2001) noted that Vernal experienced a much lesser boom than Delta or Evanston, which might account for its similarity to Tremonton—a non-boomtown—in social well-being patterns.

Boomtown residents were more likely to feel that their communities were less friendly, less helpful, provided a worse family environment, and more lacking in community spirit than were the residents of non-boomtowns. Additionally, the number of people residents know is not necessarily related to the extent of interaction among residents. Greider and Krannich (1985) found that residents of boomtowns in Utah and Wyoming knew fewer of their neighbors but were actually more likely to interact with those they did know than residents of a non-boomtown. Residents of boomtowns, however, were less likely to count on their neighbors for social support (for example, watching their house while on vacation, confiding in them about personal problems) than those in non-boomtowns.

The literature review indicates that there are certainly some predictable socioeconomic impacts from energy booms, which could be seen in both Sweetwater County in the 1970s and in Sublette County in 2008. There are certain impacts, however, that may occur only in some communities. The emphasis in the literature has shifted somewhat from a focus on quality of life and community interactions during the 1970s boom to a focus on economic issues in the 2000s boom. One of the reasons for this shift may be the lack of academic publications addressing the 2000s boom. Most of the literature has been produced by private consulting firms or government entities and tends to focus more on economic issues.

Examining the literature from both the older boom and the newer boom allowed for the identification of trends in socioeconomic impacts, as well as the identification of how impacts and the perception of those impacts have changed. This information can now be used to guide further research designed to inform communities affected by energy development.

## Assessment of Wildlife Vulnerability to Energy Development

### *Additional Progress and Findings Information*

Work on the first stage of AWVED began and focused primarily on (1) logistical coordination with key players in this effort, (2) developing the methodological framework for creating range maps and distribution models, and (3) compiling and preparing background data necessary to generate models.

**1) Interagency Logistics**

There are currently four major parties interested in accurate range and distribution mapping of vertebrate animals in Wyoming: the USGS regional Gap Analysis Program, the USGS portion of the WLCI, the WGFD, and the WYNDD. A meeting with representatives of these entities was held in May 2008 to discuss synergies in range mapping and modeling. The group agreed to work together on a consistent set of maps and decided that the approach developed by WYNDD would be accepted as the standard.

**2) Methods Development**

WYNDD staff spent roughly three person-months in 2008 researching ways to efficiently map occurrence of a large suite of species across Wyoming and an additional six person-months developing the computational infrastructure to implement the methods that ultimately were selected.

*Mapping Strategy*—Two levels of species biogeographic occurrence were identified as being useful for mapping and analysis for the above-noted projects: range and distribution. Range is the total areal extent occupied by a given taxon defined by geographic space only, with little consideration of underlying environmental variation, thus containing little interdigitation of occupied and unoccupied space. In contrast, distribution is the spatial arrangement of environments suitable for occupation by individuals of a given taxon, which is therefore finer in grain than range maps and exhibits interdigitation of suitable and unsuitable environments.

*Range Mapping*—Because range mapping considers only known or strongly suspected occupation of rather coarse map units, it is best pursued with deductive approaches. Initial drafts of each species' range map were created by overlaying maps summarized by noted authorities (for example, Birds of North America, field guides and species accounts) and tessellating the output to a common map unit (10-digit HUCs). These "first-round" maps were reviewed by WYNDD staff biologists, who modify Wyoming species' ranges (second-round maps) by assigning each HUC an occupational status of "Known to Occur", "Suspected to Occur", or "Likely Absent", based on reported observations and knowledge of local habitat. Once these second-round maps are complete, species experts, including staff of the WGFD, will be able to review and comment on them via an online tool specifically developed for this purpose (see "Computational Infrastructure" below).

*Distribution Modeling*—For most vertebrates, distribution mapping requires fine-scale consideration of the intersection of multiple environmental gradients. Inductive modeling of geo-referenced species' occurrences is a powerful way to identify suitable environments on continuous and ordinal variables. To map distribution of most target taxa, the plan is to overlay inductive models of continuous and ordinal variables with deductive models of categorical variables and to limit the extent of the final model to the maximum range of the taxon. Inductive models will be created by assessing environmental attributes from locations of known occurrence (see "Occurrence Layers" below). These attributes will be statistically integrated via algorithms designed to condense multiple input signals into probabilistic models of species presence (for example, Maximum Entropy or Random Forests). The predictive success of the resulting models will be evaluated, and suitable models will be extrapolated across the state. Species experts, including staff of the WGFD, will be able to review and comment on these models using an online tool specifically developed for this purpose (see "Computational Infrastructure" below).

*Computational Infrastructure*—As part of NWreGAP, WYNDD collaborated with the Wyoming Geographic Information Science Center to develop an online review tool for the species maps. This password-protected tool allows reviewers to access the complete set of range maps and to suggest modifications based on their personal expertise with the species in question. All modifications are attributed to the reviewer and additional information is collected for ranking the reviewer's level of expertise with respect to the species and area in question. Modifications from all reviewers will be integrated into a final map. The accessibility of this tool will enable us to collect and integrate detailed information from a variety of sources. It is currently available only to biologists who are generating second-round range maps, but will be made available to a larger audience of experts once the second-round maps are created.

**3) Background Data**

*Occurrence Layers*—Knowing locations of species occurrence is necessary for both range mapping and modeling (see fig. 22). It has taken approximately five person-months of effort to compile and reconcile known locations of species occurrence from a variety of datasets. To date, roughly 1,066,489 occurrence records of 507 species have been obtained and processed. Major sources include WYNDD's Biotics database, WGFD's Wildlife Observation System, museum specimens drawn from the Conservation Biology Institute, and bird observations from the Institute for Bird Populations. All these sources vary in terms of data structure, accuracy, and the type of biological data they contain. This necessitates exhaustive effort reconciling differences to form a single, logically consistent dataset.

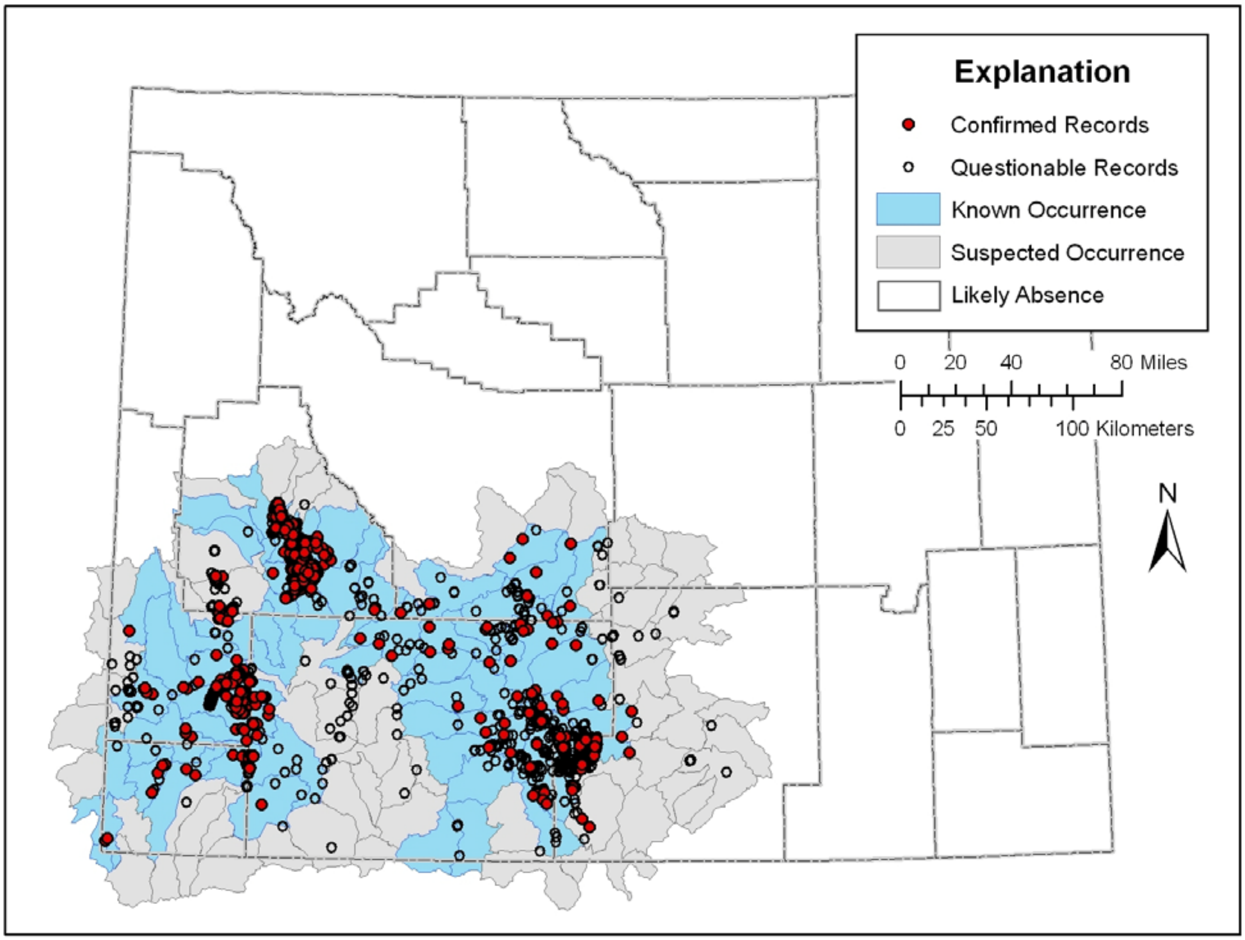



**Figure 22**. Range maps, such as this draft generated for the pygmy rabbit (*Brachylagus idahoensis*) in Wyoming (by 10-digit hydrologic units), will be produced for the Assessment of Wildlife Vulnerability to Energy Development.

*Predictor Layers*—A variety of predictor layers were obtained for use in developing potential distribution models (see fig. 23). All such layers were processed to conform to the standards necessary for modeling, which took roughly four person-months of effort. Thirty-two climate variables were reduced to a subset of six variables (using principal components analysis) that are likely to be most useful in developing predictive distribution models and will compose the base set of climate data used to develop those models. There are 15 additional environmental datasets, roughly categorized into topography (five variables), soils (three variables), water (three variables), and disturbance (three variables).

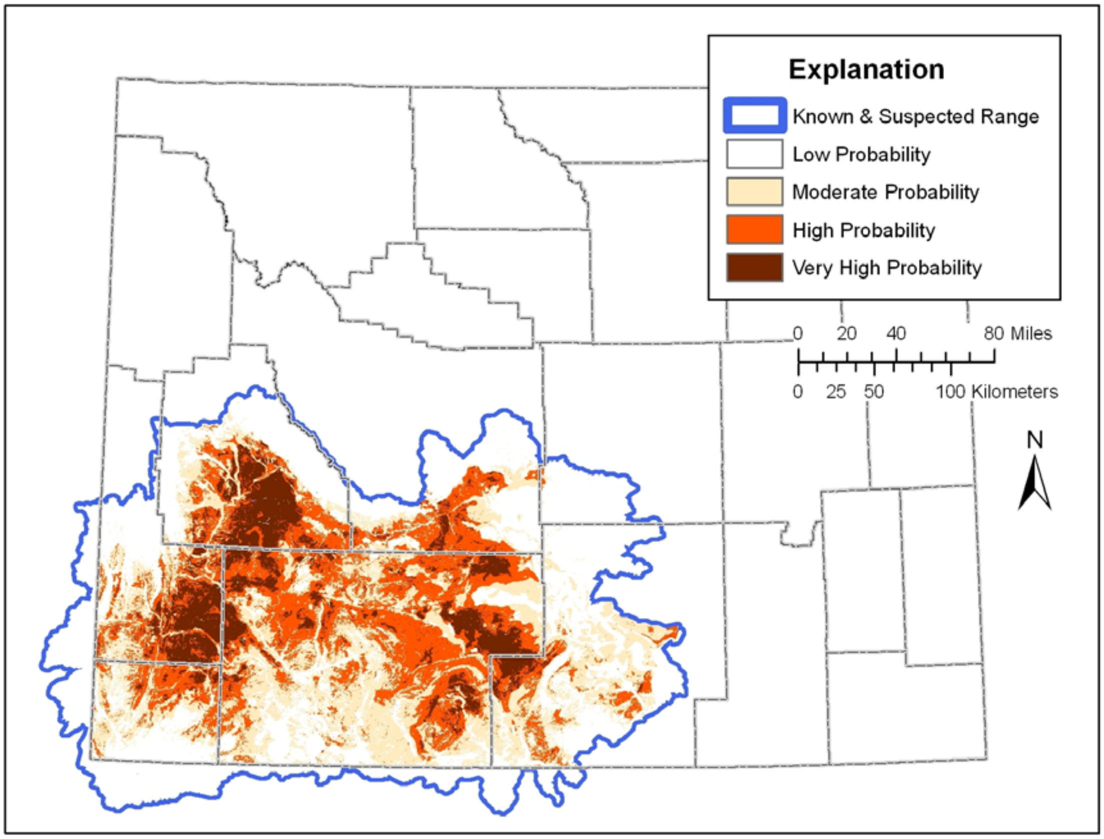



**Figure 23.** Predictive species distribution models, such as this draft generated for pygmy rabbit (*Brachylagus idahoensis*), will be produced for the Assessment of Wildlife Vulnerability to Energy Development.

## Climate Change and Potential Future Vegetation Simulations

### *Additional Background and Methods Information*

Projected future climate changes will affect the wildlife and habitats of southwest Wyoming. Understanding these potential effects and how they might interact with future land use changes is important for anticipating the effects of climate change on the region's ecosystems. This work will produce downscaled simulations of future climate change for the WLCI study area. These climate data will be used as input data for other modeling efforts, such as simulating future vegetation change for the region, and will help to identify the potential effects of future climate change on the species and landscapes of southwest Wyoming. The simulated climate and vegetation data produced by this research also will contribute to the overall objective of forecasting the cumulative effects of land uses (for example, energy development and livestock grazing) and climate change on the region's species and landscapes.

To investigate potential future climate change effects, climate simulations from three or more coupled atmosphere-ocean general circulation models (AOGCMs) produced under three different future greenhouse gas emissions scenarios will be downscaled to an approximately 1-km grid of the WLCI study area. The AOGCM simulations were produced as part of the World Climate Research Programme's Coupled Model Intercomparison Project phase 3 multi-model dataset. These simulations were used in the recent Intergovernmental Panel on Climate Change Fourth Assessment Report and are among the most advanced simulations of future climate available today. By using climate data from multiple AOGCMs simulated under multiple emissions scenarios, an attempt will be made to capture the projected range of potential future climate changes for the WLCI region.

As part of this work, the downscaled climate data will be used to simulate potential future vegetation change for southwest Wyoming using a dynamic global vegetation model, such as LPJ (Lund-Potsdam-Jena; Sitch and others, 2003). These vegetation simulations will provide a first approximation of potential future habitat changes across the WLCI region.

## Conceptual Models and Indicators of Change: Effects of Energy Development and Climate Change on Ecosystems of the Wyoming Basin

### *Additional Background and Methods Information*

A key feature in developing the WLCI long-term monitoring effort is the identification of specific attributes (ecological indicators) to monitor. Ecological indicators are defined as a subset of environmental attributes (or variables) that, when monitored over the long run, indicate trends in the quality, health, or integrity of the larger system to which they belong (Noon, 2003; see *http://science.nature.nps.gov/im/monitor/Glossary.cfm*). Human dimensions indicators include a subset of the physical, chemical, biological, and socio-economic and political elements and processes indicative of a given social system. As with all monitoring efforts, time and budget constraints limit the number of indicators than can be measured and the frequency of observations that can be made. Selecting a parsimonious set of indicators that provide unambiguous information on system dynamics, and which inform management decisionmaking and for which data collection is affordable given limited funding for monitoring, is fundamental to an effective monitoring program.

Although only a handful of indicators are likely to be included in the initial operational monitoring phase, it is cost-effective to assemble and prioritize a comprehensive list of plausible indicators. Monitoring resources will determine the indicators included in the initial operational phase. When additional resources become available, this list will help guide the selection of indicators to add to ongoing monitoring efforts. Also, this list can be used to identify partnership efforts that complement core monitoring efforts.

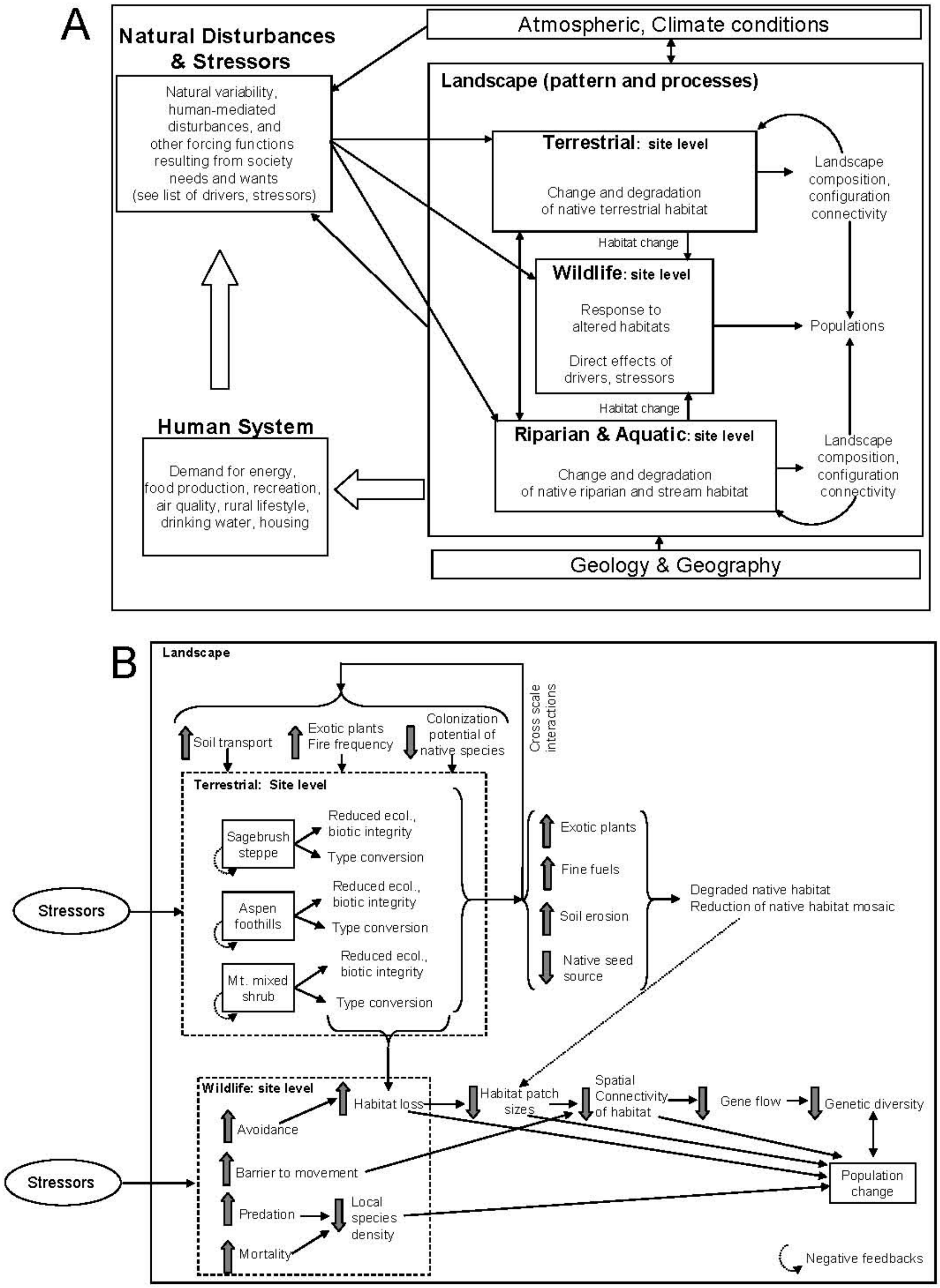
*WLCI Indicator Selection Process*—This effort entails the selection of indicators for the WLCI long-term monitoring effort. Developing a process for the selection of indicators is a precursor to indicator selection. In 2008, a preliminary process was employed during the latter half of the WLCI Conceptual Model Workshop (August 19-20), with moderate success. Results of this initial effort motivated further development of procedures, which are outlined below. These procedures are still in draft form and are subject to review and enhancement by Science Team members. Once finalized, procedures will be used in a future workshop to select and prioritize which indicators to use in a monitoring program.

Indicators are being selected to provide early warning of changes in (1) ecosystems/landscapes (habitat) and (2) wildlife populations. Both indicator categories were selected and prioritized using casual network concepts (Niemeijer and de Grott, 2008). A causal network captures the range of causes and effects by illustrating the inter-relations of system components (indicators). In practice, this network is the collection of conceptual models developed (for example, fig. 24), with additional consideration of among-system and cross-scale interactions. Identifying key nodes in the causal network and the degree of connectedness of nodes helps to define the information content of individual indicators. In general, root nodes are drivers and stressors, central nodes pertain to the patterns and processes that result from forcing agents, and end nodes are the responses (for example, habitat degradation, species' population change). Frequency counts of components in the pathways from drivers and stressors to ecological responses, then to Human Systems, provides measures of component importance among the focal systems (for example, fig. 24). These components are in essence potential indicators. It is unrealistic to assume that indicators from just one type of node will provide comprehensive information about the causes and effects of system change; thus, an underlying intent is to select indicators from all three types of nodes.

The example in figure 24 illustrates the hierarchical network approach for viewing connections among the focal systems. In this example, the WLCI Integrated Model framework is expanded for the Terrestrial and Wildlife component models, with further expansion to the conceptual stressor models for the sagebrush steppe ecosystem. When fully developed, graphical illustrations will be provided for all focal ecosystems (aquatic, riparian, aspen foothill woodlands, mountain mixed shrub, and sagebrush steppe) for use in assessing indicators. Developing an approach that provides coherent visualization of the inter-relationships among all the focal ecosystems and that allows assessments of nodes and associated indicators is a challenge. To facilitate assessments, the graphical representation likely will be augmented by a matrix indicating the number of linkages for each human-system component, driver and stressor, pattern and process component, and response. It is important to note that the graphic and tabulated information are only guides or tools. Conceptual models forming the causal network are simplifications of reality, with underlying assumptions and varying levels of certainty that are described in model narratives. The experience and expert opinion of WLCI scientists will still play a role in the interpretation of the illustrated causal pathways and in the final selection of information-rich indicators.

*WLCI Indicator Prioritization Process*—Proposed criteria for prioritizing indicators follow the summary provided in Niemeijer and de Groot (2008; table 1). An additional criterion is the ability to detect a desired minimum level of change per unit of time in measures of an indicator, given budgetary and logistical constraints. Criteria will be fine-tuned through the Science Team review process. Indicators selected from the causal network approach will be scored (for example, high, medium, low) according to the final list of criteria, providing a prioritized list of plausible indicators for monitoring.

*Special Considerations for Wildlife Species*—Additional criteria are required for selecting and prioritizing wildlife species. The causal network illustrates pathways of degradation of native habitat, as well as indirect effects (avoidance) of disturbances on wildlife in general. Wildlife response to habitat loss and fragmentation, and to indirect effects, however, depends on species-specific sensitivities. Additionally, species' regional status, socio-political concerns, and other knowledge play important roles in selecting and prioritizing species for a long-term monitoring program. Previous efforts have entailed identifying species of special concern over spatial extents that include the WLCI study area (Wyoming Basins Ecoregional Assessment [WBEA]; Leu and others, 2007), the CWCS for Wyoming (Wyoming Game and Fish Department, 2005), and the Assessment of Wildlife Vulnerability to Energy Development (Keinath and others, 2008). An earlier multiagency workshop (D'Erchia, 2008) identified top priority species for WLCI to begin to monitor.


A
Natural Disturbances & Stressors
Natural variability, human-mediated disturbances, and other forcing functions resulting from society needs and wants (see list of drivers, stressors)
Atmospheric, Climate conditions
Landscape (pattern and processes)
Terrestrial: site level
Change and degradation of native terrestrial habitat
Landscape composition, configuration connectivity
Habitat change
Wildlife: site level
Response to altered habitats
Direct effects of drivers, stressors
Populations
Habitat change
Riparian & Aquatic: site level
Change and degradation of native riparian and stream habitat
Landscape composition, configuration connectivity
Human System
Demand for energy, food production, recreation, air quality, rural lifestyle, drinking water, housing
Geology & Geography
B
Landscape
Cross scale interactions
Soil transport
Exotic plants
Fire frequency
Colonization potential of native species
Terrestrial: Site level
Sagebrush steppe
Reduced ecol., biotic integrity
Type conversion
Aspen foothills
Reduced ecol., biotic integrity
Type conversion
Mt. mixed shrub
Reduced ecol., biotic integrity
Type conversion
Stressors
Exotic plants
Fine fuels
Soil erosion
Native seed source
Degraded native habitat
Reduction of native habitat mosaic
Wildlife: site level
Avoidance
Habitat loss
Habitat patch sizes
Spatial Connectivity of habitat
Gene flow
Genetic diversity
Barrier to movement
Predation
Local species density
Mortality
Stressors
Population change
Negative feedbacks

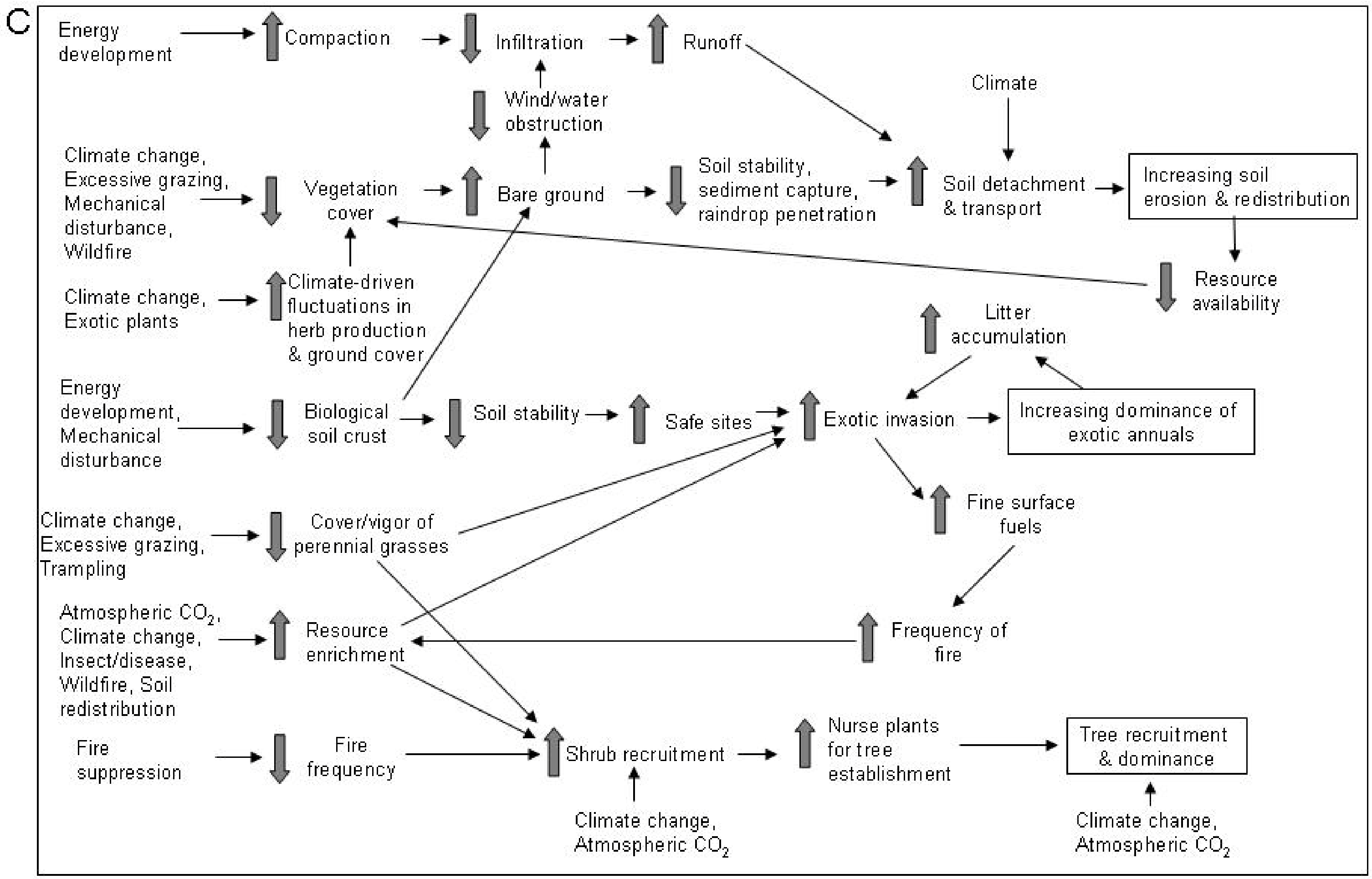



**Figure 24.** Working example of conceptual models for the WLCI region, illustrating causal pathways among system components of southwest Wyoming. (A) Integrative Model Framework; (B) expansion of the terrestrial and wildlife components in A; and (C) stressor models for the sagebrush-steppe component in B.

**Table 1.** Common criteria for selecting environmental indicators (modified from Niemeijer and Groot, 2008).

| Criterion | Description |
|---|---|
| Scientific dimension | |
| Analytical soundness | Strong scientific and conceptual basis |
| Credible | Scientifically credible |
| Integrative | Suite of indicators should cover key components across scales |
| Importance | Relevant to a fundamental process or widespread change |
| Historic dimension | |
| Historical record | Historical data for comparative purposes |
| Reliability | Proven track record |
| Systematic dimension | |
| Anticipatory | Signify an impending change in key system components |
| Predictable | Respond in a predictable manner to drivers and stressors |
| Robustness | Insensitive to expected sources of interference |
| Sensitive to stressors | Sensitive to stressors |
| Space bound | Sensitive to changes in space |
| Time bound | Sensitive to changes within policy time frames |
| Uncertainty about level | High uncertainty increases information gain from monitoring |
| Intrinsic dimension | |
| Measurability | Measurable (qualitative, quantitative) |
| Portability | Repeatable and reproducible in different contexts |
| Specificity | Unambiguously definable |
| Statistical properties | Have statistical properties that allow unambiguous interpretation |
| Universality | Applicable to many areas, situations, and scales |
| Financial and practical dimensions | |
| Costs, benefits, and cost effectiveness | Benefits of indicator information should outweigh monitoring costs |
| Data requirements and availability | Manageable data requirements (collection) or availability of existing data |
| Necessary skills | Do not require excessive data collection skills |
| Operational simplicity | Simple to measure, manage, and analyze |
| Resource demand | Achievable in terms of the available resources |
| Time demand | Achievable in the available time |
| Policy and management dimensions | |
| Comprehensible | Simple and easily understood by target audience |
| International compatibility | Compatible with indicators used in other regions |
| Likable to societal dimension | Linkable to socio-economic developments and societal indicators |
| Links with management | Links with specific management practices |
| Progress towards targets | Links to quantitative or qualitative targets set in policy documents |
| Quantified | Information can be quantified so that its significance is apparent |
| Relevance | Relevant to the issue and target audience |
| Spatial and temporal scales of applicability | Provide information at the right spatial and temporal scales |
| Thresholds | Thresholds that can be used to determine when to take action |
| User driven | Driven by target audience |

Collectively these efforts have taken into account species' sensitivity to energy development and habitat loss, and their current population levels. Preliminary guidelines for species' selection and prioritization were based on these previous efforts and are presented below. These guidelines admittedly require more explicit definition, and decisions regarding weighting need to be made.

Guidelines are being reviewed and enhanced by the WLCI Science Team members, then they will be applied as criteria in the future Indicator Selection workshop.

- Scale of species' response to key stressors: Species respond to their environments at different scales (Holland and others, 2004). Disturbances will affect habitat at both local and landscape scales. Selecting and prioritizing species that respond to fine- and coarse-scale habitat patterns, and to both scales combined, will be considered. Inherent in this criterion is the consideration of the potential vulnerability of species' populations to energy development and to habitat loss and fragmentation.
- Relevance to program goals and the spatial extent of management concerns: Given the arbitrary nature of the WLCI boundary, most species exist both inside and outside of the WLCI study area. If a major program goal is to prevent listing species under the Endangered Species Act, then species could be identified and prioritized based on how impacts within the WLCI area may influence a given species' viability across its entire range. Alternatively, the focal area for assessing endangerment, and thus selection and prioritization, may be the state of Wyoming, or confined explicitly to the WLCI study area.
- Economic and political concerns: These factors can be as important as biological factors in selecting species for monitoring. The importance of these "external" factors will be considered when selecting and prioritizing species for monitoring.
- Extent of current knowledge about species populations: The CWCS for Wyoming listed 235 of 279 species as special concern due to insufficient information regarding habitat conditions and population status; thus, information necessary to address most of the above criteria may be limited for a large number of species. Weighting criteria need to be determined, but weights may be similar for species known to be impacted by human disturbances and for species lacking habitat and population information.

## Targeted Monitoring and Research

### Long-term Monitoring

#### Terrestrial Monitoring: Vegetation, Birds, Small Mammals, and Soil Geochemistry

##### *Additional Background and Methods Information*

The long-term monitoring project entails developing a comprehensive, region-wide blueprint for sampling indicators, detecting change, understanding land-cover/land-use patterns and, especially, how priority species and habitats respond to ecosystem changes. This process includes developing and comparing alternative sampling designs. The effectiveness, efficiency, and feasibility of potential monitoring designs will be assessed in terms of WLCI objectives and funding projections. A monitoring framework developed for the BLM (Kotliar and others, 2008) is being used to guide these efforts. The initial approach focuses on developing a sampling design that will enable inference to the entire WLCI landscape and be sensitive to changes in land use, vegetation, priority habitats, and populations of target species.

*Overall Design*—The entire WLCI area (fig.2) was encompassed in the monitoring design. To meet the objectives identified by stakeholders (D'Erchia, 2008), a spatially balanced design was developed, based on techniques developed by U.S. EPA (Environmental Monitoring and Assessment Program) for efficient sampling across large, heterogeneous areas. This approach overcomes limitations of a stratified design, which is impractical for the WLCI area due to its size and high inter-site variability (that is, it would result in low power for detecting trends). Generalized random tessellation sequencing (GRTS; Stevens and Olsen, 2004) was used to distribute sample points across the WLCI. This is a comprehensive and statistically valid design that will allow inference across broad spatial and temporal scales. This GRTS approach was used for sampling vegetation, vertebrates, and soil geochemistry. Ground and surface water monitoring is addressed by existing gaging stations and groundwater wells.

*Vegetation and Vertebrate Sampling Framework*—To optimize sample sizes for a broad spatial extent that will have adequate power for detecting trends in priority indicators, a sensitivity analysis of four alternative sampling design criteria—based on existing vegetation maps (LANDFIRE)—was conducted. Four important landscape-scale ecosystem drivers were compared as surrogates for habitat gradients to use in selecting sample locations: (1) elevation, (2) precipitation, (3) surface geology and soils, and (4) current vegetation/surface disturbance. It was determined that simple, yet representative distribution would be based on weighted elevation classes. The elevation classes were used to represent the regional gradient in vegetation patterns and habitat conditions (climate zones, for example); they provided greater resolution than climate data, but did not excessively control site distribution. This occurred with surface geology and soils which included too many classes (more than 100) to adequately represent in a design given the budget and objectives. Changes in spatial extent of vegetation, land-use patterns, and habitat quality are primary indicators of interest, therefore it is inappropriate to use these as a basis for selecting sample locations.

Because sagebrush, aspen, riparian, and mountain shrub communities are priorities for monitoring, the target area was narrowed to include only areas below 8,530 feet (2,600 m). The new target area includes foothills and lower montane communities, but excludes montane and subalpine forests, which have limited representation within the WLCI boundary.

Where possible, co-locating sampling sites (vegetation and vertebrate population, for example) is built into the approach to allow comparisons of detailed information across large spatial scales. The vegetation mapping classifies (“trains”) multiscaled, remotely sensed data. This approach includes extrapolation between scales using statistical models to increase the information available across large regions. Because the amount and distribution of habitat for species of concern is of high importance, the high-resolution vegetation maps serve as the basis for all other monitoring and will facilitate monitoring vegetation, disturbance, and habitat for target species across the WLCI. The design will allow valid inferences about the status and trends in these communities and populations across the entire WLCI.

*Soil Geochemistry Sampling Framework*—Objectives specific to the soil geochemistry monitoring are to provide baseline data, summary statistics, and geochemical maps for soils in the WLCI region. After discussing with USGS ecologists the various options for conducting soil geochemistry monitoring in the WLCI region, it was decided that the best approach for 2008 would be to conduct sampling over the entire 15-million-acre study area. The North American Soil Geochemical Landscapes Project, which already had established 39 sampling sites in the WLCI region, is currently conducting a soil geochemical survey of the North American continent. The sampling and analytical protocols of that project are compatible with both the goals of the WLCI work and the sampling protocols described above for vegetation, birds and small mammals. To improve coverage of the WLCI area, USGS geologists added another 100 sampling sites, for a total of 139 sites (fig. 9).

*Additional Progress and Findings Information*

*Vegetation*—To establish vegetation monitoring protocols for the WLCI, recently developed remote sensing techniques were applied for more accurate mapping of sagebrush-steppe across a broad range of spatial scales (fig. 25; Homer and others, 2009). The technique links field data to high-resolution QuickBird (QB) imagery (2.4-m resolution) to model vegetation across an entire QB image (a 64-$km^2$ area). The QB vegetation models are then used to model vegetation at larger spatial scales using Landsat (30-m resolution; 32,000 $km^2$ area) and AWiFS (56-m resolution; total area = 547,600 $km^2$) imagery. This produces vegetation maps at 30- and 56-m resolutions across the majority of sagebrush habitats in Wyoming, including the entire WLCI region (fig. 26).

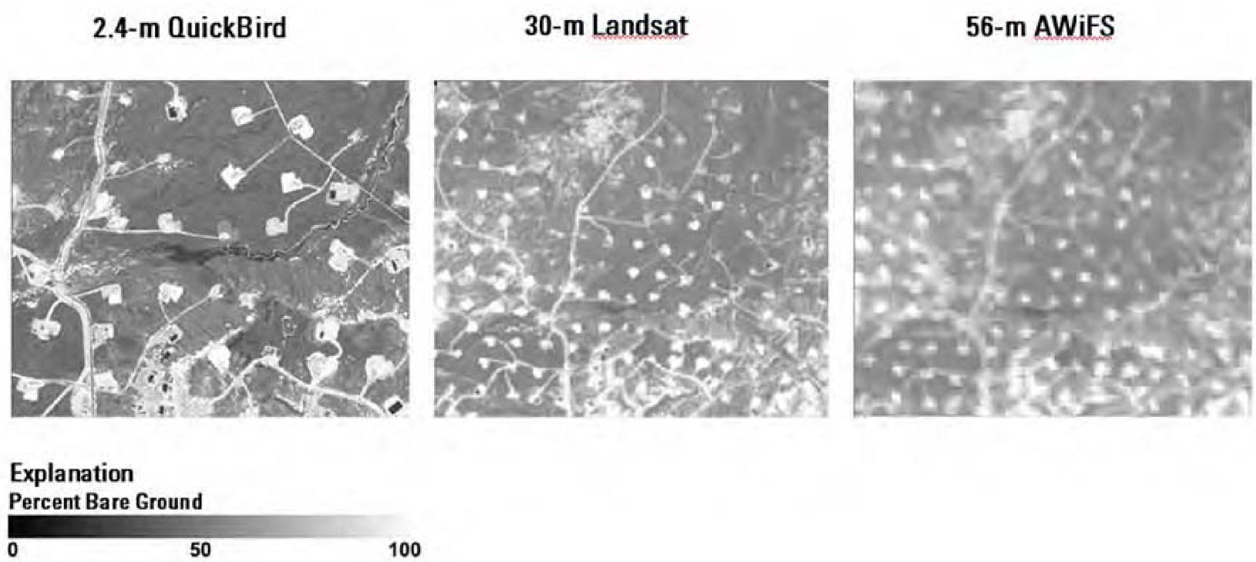



**Figure 25**. Example of available imagery being used to develop cover predictions, building the information from detailed resolution imagery (QuickBird) to large-area applications (Landsat and AWiFS) with reduced fine-scale resolution. (Figure from Homer and others, 2009).

The WLCI and Wyoming Basin maps provide continuous cover estimates, in contrast to traditional cover-type mapping (for example, LANDFIRE) that only provides categorical vegetation cover classes. Continuous cover estimates are provided for a suite of vegetation variables, or "components": shrubs, herbaceous, litter, bare ground, sagebrush, big sagebrush (*A. tridentata* ssp.) and Wyoming sagebrush (*A. t. wyomingensis*). It also provides an estimate of overall shrub height. The new maps provide the level of detail necessary for monitoring and quantifying vegetation and land-use changes from small to large spatial scales. In addition, the continuous cover estimates will allow improved assessments of habitat quality and quantification of habitat changes for many species, including priority sagebrush obligates (for example, greater sage-grouse and pygmy rabbit).

In 2008, an analysis was conducted to determine the optimal number of monitoring locations necessary for detecting changes in the four priority vegetation cover types (sagebrush, aspen, riparian, mountain shrub) and in surface disturbance. Based on preliminary assessments, it was determined that the initial design should include 45 64-$km^2$ monitoring locations. To decrease

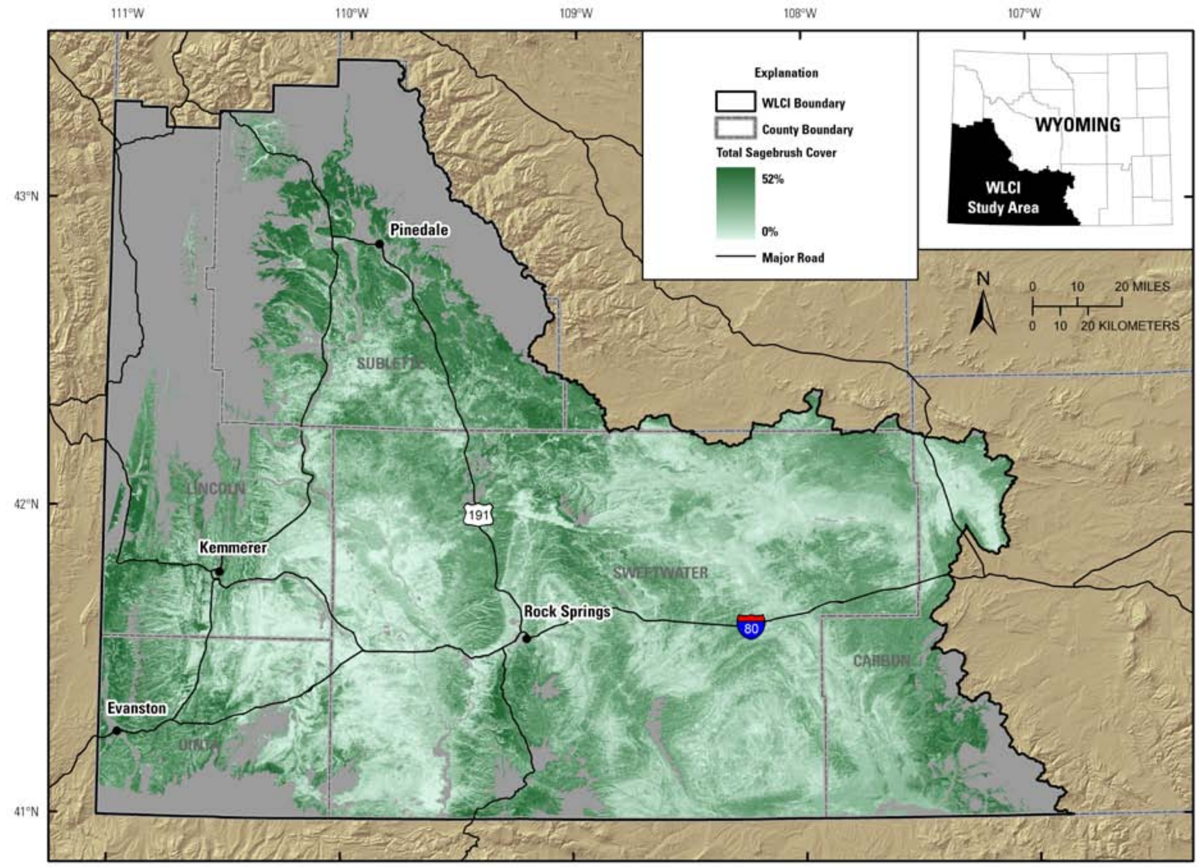



**Figure 26.** Draft prediction of total sagebrush percent cover extrapolated from QuickBird to Landsat (30 m) pixels across four Landsat scenes contained within the WLCI boundary. Predictions are restricted to model inference space (non-gray), based on Homer and others (2009).

costs and maximize coverage across the entire WLCI, a rotating panel design was chosen, such that 15 monitoring locations (individual QB scenes and associated ground data) will be sampled each year, requiring four years to sample the full set of monitoring locations (several sites from the previous year's set will be re-sampled each year, reducing the number of new sites and extending the rotation cycle). Using regression tree classification, vegetation measurements were used to model predictions for all eight vegetation components in each QB scene. To represent the full aerial extent of the WLCI, the QB model predictions were subsequently used to classify the eight components using Landsat imagery. In addition, the QB vegetation models were used to classify the eight vegetation components using AWiFS imagery for the Wyoming Basin.

Repeat imagery and field samples were obtained for four QB scenes originally sampled in 2006. This will allow us to assess the power of our sampling design to detect subtle changes in vegetation components within sagebrush ecosystems. Initial work in designing a pilot study to analyze historical sagebrush canopy change between 1988 and 2006 also was completed.

*Birds*—Activities in 2008 targeted sagebrush obligate species: greater sage-grouse, sage sparrow, Brewer's sparrow, and sage thrasher. To capitalize on existing data for the target species, survey-point data previously collected as a part of the Wyoming Basin Ecological Assessment (Rowland and others, 2006; fig. 7) were revisited in 2008. The three years of sampling data (2005–2006, 2008) will provide estimates of temporal and spatial variation in populations that will be used in power analyses for their ability to detect change.

Point counts for passerine species (sage sparrow, Brewer's sparrow, and sage thrasher) and pellet counts for greater sage-grouse were conducted. For both survey types, a variety of plot configurations and survey durations were tested to determine the most efficient designs. In addition to the spatially-balanced sampling design, several alternative monitoring designs were developed to collectively address a variety of management and monitoring objectives.

*Small Mammals*—Primary activities in 2008 included the initial collection of small mammal community data from sampling sites allocated using the spatially balanced design. To identify an optimal sampling methodology, several live trapping techniques for small mammals were evaluated. The pilot data will provide an estimate of spatial variation in the WLCI region and are being used for a power analysis. These analyses will estimate sample sizes needed for detecting population- and community-level changes through space and time.

Small mammals were live-trapped at 24 sites randomly located within 12 (of 16) 8- × 8-km target areas that were selected for the long-term monitoring design and which were distributed throughout the WLCI area (fig. 8). The 2008 trapping efforts at these sites included comparing several trapping designs and evaluating species accumulation rates as a function of survey-days of effort. Fifteen species of small mammals (2,498 individuals; table 2) were captured over 19,079 trap-nights (the number of traps set times the number of nights the traps were set) of effort (13.1 percent trap success). Evaluation of optimal sampling design is ongoing. Power analyses were conducted during late 2008.

*Soil Geochemistry*—In July 2008, USGS geologists discussed with USGS ecologists several study design options suitable for monitoring soil geochemistry. These options ranged from high-density sampling within the 8- × 8-km monitoring sites already established to broad-scale sampling throughout the entire 15-million-acre study area. The latter was chosen as the most useful approach for the first year's work. As a result, 139 sites were selected by a GRTS design (fig. 9). Soil samples were collected at each of these sites during August and September 2008. At each of the 39 sites that were part of the North American Soil Geochemical Landscapes Project, three soil samples were collected: (1) at a depth of 0–5 cm; (2) a composite of the soil A horizon, and (3) a composite of the soil C horizon. At the other 100 sites, only the 0–5 cm sample was collected because it is considered the material most likely to be affected in the study area by human activities, such as energy development. The samples were air-dried at ambient temperature, disaggregated to break up clods, and sieved to less than 2 mm. Then the less than 2-mm fractions were pulverized to less than 150 µm prior to submittal to the USGS laboratories for chemical analysis of a broad suite of major and trace elements. The analytical protocol is as follows:

1. inductively coupled plasma-mass spectrometry and inductively coupled plasma-atomic emission spectrometry, following a near-total 4-acid extraction, for the following elements: Al, Ca, Fe, K, Mg Na, S, Ti, Ag, Ba, Be, Bi, Cd, Ce, Co, Cr, Cs, Cu, Ga, In, La, Li, Mn, Mo, Nb, Ni, P, Pb, Rb, Sb, Sc, Sn, Sr, Te, Th, Tl, U, V, W, Y, and Zn (see *http://www.webelements.com/* for an interactive periodic table of elements that also defines the element codes and provides element descriptions);
2. hydride-generation atomic absorption spectrometry for As and Se;

3. cold-vapor atomic absorption spectrometry for Hg;
4. total C by combustion;
5. inorganic (carbonate) C by coulometric titration; and
6. organic C by the difference of 4 and 5 above.

In addition, samples will be submitted to the Colorado State University Soil-Water-Plant Testing Laboratory for assessing pH, electrical conductivity, and sodium adsorption ratio. Analyses should be complete by early 2009.

**Table 2.** Scientific names, species abbreviations, and common names of small mammals captured within the WLCI study area in southwestern Wyoming from July 7 to August 28, 2008. Total small mammals captured (*n*), overall sex ratios of adults (M:F), evidence of reproduction (Reproduction) in females (Y = yes, N = no, U = unknown), and numbers of juveniles captured (no. juveniles) are also given for all capture records at all sites combined (U = unknown).

| Species | Common name | *n* | M:F Ratio | Reproduction | No. juveniles |
|---|---|---|---|---|---|
| *Dipodomys ordii* | Ord's kangaroo rat | 35 | 0.5:1 | Y | 0 |
| *Lemmiscus curtatus* | Sagebrush vole | 60 | 1:1 | Y | 12 |
| *Microtus longicaudus* | Long-tailed vole | 4 | 1:0.3 | N | 0 |
| *Microtus montanus* | Montane vole | 7 | 0.5:1 | Y | 0 |
| *Microtus pennsylvanicus* | Meadow vole | 1 | 1:0 | N | 0 |
| *Mustela frenata* | Long-tailed weasel | 1 | U | U | U |
| *Neotoma cinerea* | Bushy-tailed woodrat | 1 | 0:1 | N | 0 |
| *Onychomys leucogaster* | Northern grasshopper mouse | 8 | 1:0.2 | N | 1 |
| *Perognathus fasciatus* | Olive-backed pocket mouse | 6 | 1:2 | N | 0 |
| *Perognathus parvus* | Great Basin pocket mouse | 68 | 0.9:1 | Y | 12 |
| *Peromyscus maniculatus* | Deer mouse | 2154 | 1:0.9 | Y | 429 |
| *Spermophilus armatus* | Uinta ground squirrel | 5 | 0.4:1 | N | 0 |
| *Spermophilus tridecemlineatus* | Thirteen-lined ground squirrel | 8 | 1:0 | N | 6 |
| *Sylvilagus audubonii* | Desert cottontail | 1 | U | U | 1 |
| *Tamias minimus* | Least chipmunk | 140 | 1:0.8 | N | 1 |

## Surface Water Quality and Groundwater Levels

### *Additional Background and Methods Information*

The USGS Wyoming Water Science Center, in cooperation with State, Tribal, county, municipal, and other Federal agencies, collects data by water year (the 12-month period from October through September), to describe the water resources of Wyoming. These data (summarized by water year) comprise records of stage, discharge, and water quality of streams; stage and contents of lakes and reservoirs; and levels and quality of groundwater. Additional water data, collected at various sites that are not part of the systematic data collection program, are published as miscellaneous measurements. Accumulated during many water years, the water data prove invaluable for developing an improved understanding of Wyoming's water resources; thus, these data are published and made readily available to interested parties outside of the USGS in an annual report series entitled "Water Resources Data—Wyoming." The Wyoming water data are collected at a network of streamflow stations and surface water-quality monitors (fig. 27).

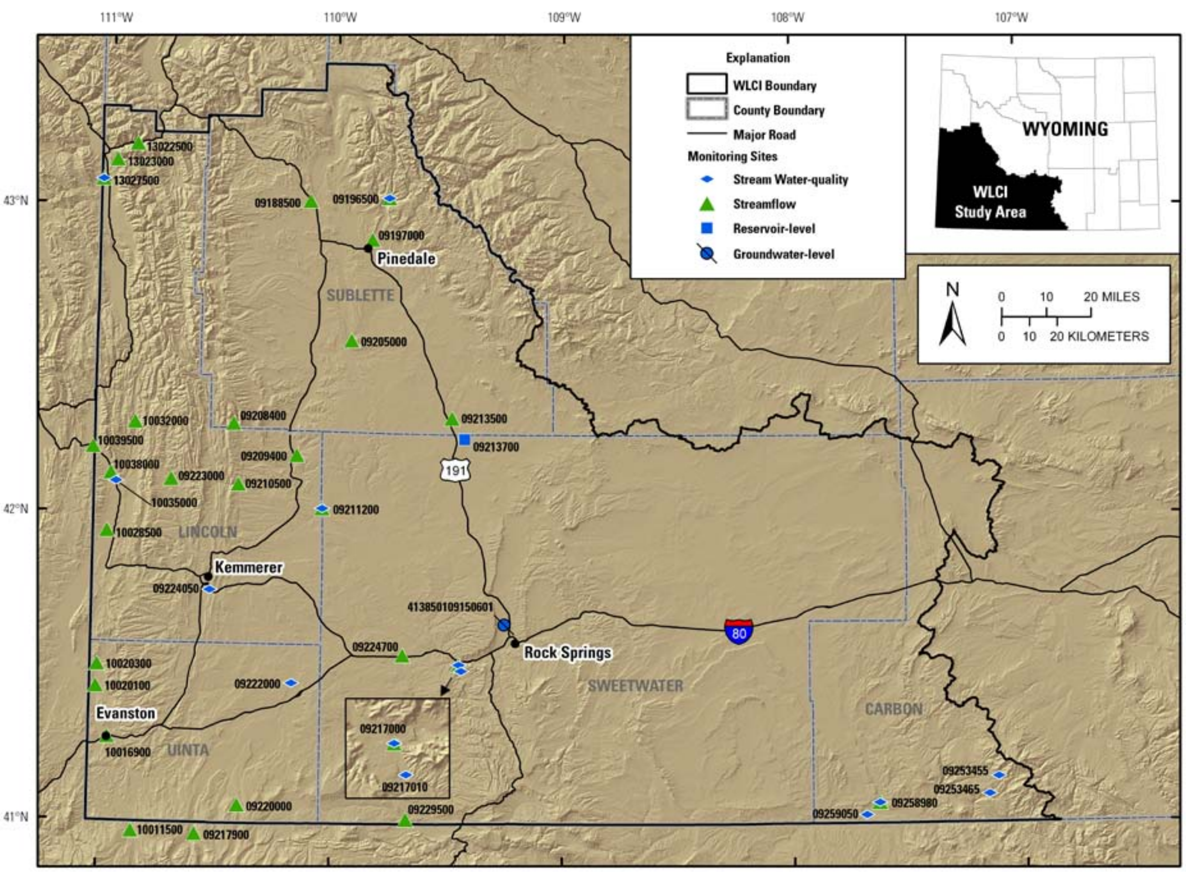



**Figure 27.** Locations of streamflow and reservoir gages and water-quality monitoring sites in the WLCI region.

### Additional Progress and Findings Information

In 2008, USGS water scientists focused their efforts on the two fixed gaging stations that were partially funded by WLCI[1]: "09217000 Green River" near Green River, Wyo., and "09258980 Muddy Creek" below Young Draw in the southeastern WLCI region (fig. 10). Watersheds integrate landscape changes over a broad range of time and space; thus, as a basin integrator for much of the upper Green River basin (26 percent of the overall WLCI study area, and more than 60 percent of the Green River Basin drainage in Wyo.), the water-quality monitor at 09217000 Green River near Green River, Wyoming, will provide scientists and managers with information on cumulative upstream effects of both natural and anthropogenic impacts. Field samples are collected monthly and analyzed for a comprehensive suite of inorganic constituents. A continuous water-quality monitor is operated during ice-free months and real-time water-quality data are disseminated to the public via the USGS NWISWeb site. Data from 2008 were finalized, approved, and published in the 2008 USGS Annual Water Data Report.

Using results from periodic water-quality samples collected at both Green River and Muddy Creek, statistical relationships between dissolved constituents and specific conductance were developed. Using this relationship in tandem with data from continuous water-quality monitors, dissolved constituent concentrations are estimated and made publicly available in real-time via the USGS NWISWeb site (*http://waterdata.usgs.gov/nwis*). This information can be used by scientists and managers to monitor the integrated flux of dissolved constituents emerging from the 16,000-$km^2$ source basin.

A retrospective analysis of available groundwater and hydrogeologic information in the Green River Basin (which includes the Great Divide Basin and Little Snake drainage basin) began in 2008. The USGS, with funding from the Wyoming State Geological Survey, and in cooperation with the Wyoming Water Development Office and University of Wyoming Water Resources Data System, indentified wells in each aquifer of the Green River Basin that had sufficient construction, lithology, and completion information to serve as monitoring wells for water levels and water quality. Observation well 413850109150601, 19-105-10bbb01 Rock Springs, was operated throughout 2008.

## Effectiveness Monitoring

### Vegetation and Soils

### Additional Progress and Findings Information

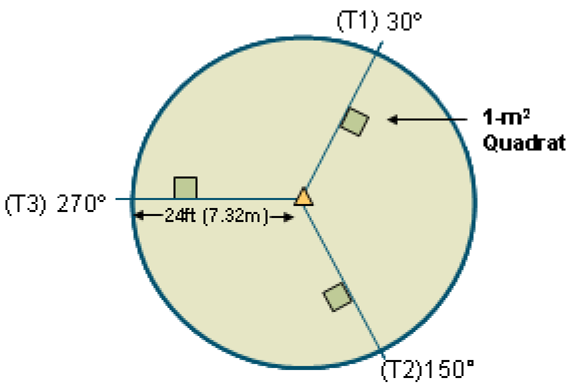
*Sagebrush Treatments*—The general study area included sagebrush communities treated by sagebrush removals (prescribed fire, Spike© herbicide, mowing, and so on) in Sublette and Lincoln Counties (fig. 11). Study site locations were based on the 2007 Wyoming Wildlife Consultants report on historic treatments (*http://gf.state.wy.us/downloads/pdf/AnnualReports/2006/AN06Pinedale.pdf*) and on communications with the BLM's Kemmerer and Pinedale Field Offices. Sampling sites were

[1] Funding for operation and maintenance of the 09217000 Green River streamflow-gaging station is provided by the USGS National Streamflow Information Program. Funding for operating and maintaining the streamflow-gaging station and water-quality monitor at 09258980 is provided by the BLM, and funding for analyzing the water-quality samples is provided by the Wyoming Department of Environmental Quality and the USGS Cooperative Water Program.

selected on the Pinedale Anticline, on the Rock Creek Allotment of the Kemmerer Field Office, and on two elk feeding grounds. Selection criteria included treatment types, dates of application, greenness (identified via NDVI), and accessibility. Sampling methods were based on the modified Forest Inventory and Analysis multi-scale plot (Barnett and others, 2007 and *http://www.niiss.org/cwis438/websites/niiss/home.php?WebSiteID=1*; see fig. 28a).

USGS scientists met with partners to confirm sample sites and local objectives that could be met as treatment effects were quantified. Four field botanists underwent training (one WLCI seasonal in Pinedale, two Chicago Botanical Garden Interns at the Kemmerer Field Office, and one USGS climate change/ungulate disease researcher working on elk feed grounds in the WLCI study

A




B


**Figure 28**. Sampling design and analysis results of sampling efforts for vegetation and soils studies. (A)The multi-scale plot design used to collect vegetation and soil data (168 $m^2$ total; 3 1-$m^2$ subplots). For more information see *www.niiss.org* (Barnett and others, 2007). (B) ANOVA results: Wyoming big sage (*Artemisia tridentata* ssp. *wyomingensis*) tends to be taller ("HT_CM", $p$ = 0.077) and has significantly greater percent cover ("COV_PCT, $p$ = 0.009) in the unsprayed area. There is also significantly more bare soil inside the sprayed area (SOIL_COV, $p$ = 0.000).

area). Field sampling was completed, and plot ($n$ = 75) data and digital photos are contained in an MSAccess database. Unknown plant samples were identified at the Colorado State University herbarium (Rick Shory, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colo., written communication with Geneva Chong, February 2009), and basic soil analyses (texture, total C, inorganic and organic C, if necessary, and total N) were completed at the Natural Resource Ecology Laboratory (Heidi Steltzer, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colo., written communication with Geneva Chong, February 2009). In addition, reconnaissance surveys in Sweetwater and Lincoln Counties were conducted to identify additional treatment areas for 2009 studies. Preliminary results from one 49-year-old herbicide treatment indicate persistent differences in sagebrush cover and height and bare soil (figs. 11, 28b).

*Aspen Treatments*—A total of 45 plots were randomly selected to evaluate response of aspen regeneration in areas that had been affected by conifer encroachment. Fifteen plots were located in pure aspen stands and 30 plots were located in aspen stands representing a gradient of conifer densities and canopy cover. Sampling methods were based on the modified Forest Inventory and Analysis multiscale plot and method protocols associated with the Aspen Delineation Program. Sample metrics included (1) aerial conifer and aspen cover, (2) herbaceous and woody cover and diversity, (3) stem density and diameter of aspen and conifers (1-m height), (4) herbaceous biomass, and (5) soils.

*Tamarisk Treatments*—Reconnaissance surveys of tamarisk were conducted on Muddy Creek and Blacks Fork of the BLM Kemmerer Field Office and on Muddy Creek, Willow Creek, and Sand Creek of the BLM Rawlins Field Office. Locations of tamarisk plants were mapped with a GPS unit and past treatment areas were surveyed for re-sprouting. Mapping techniques were assessed to determine their applicability for addressing tamarisk density and stand age (seedling, immature, mature). Results from these applications will be used to further develop mapping techniques for assessing future tamarisk invasions. Maps from these efforts will be provided to WLCI-affiliated county weed and pest control staff to aid in their efforts to apply tamarisk treatments.

## Retrospective Vegetation/Cover Change

### *Additional Progress and Findings Information*

NDVI provides a measure of vegetation productivity and can be used to identify landscape areas that are disturbed, partially vegetated, or undergoing restoration. Identifying areas undergoing habitat restoration is critical for personnel tasked with studying the extent and effectiveness of remediation measures. To aid in identifying re-vegetated areas, NDVI is generated from 10-m SPOT imagery (2007) to provide a relatively fine-resolution map for use by field personnel. An NDVI map was produced for a section of an energy field in the WLCI study area and successfully used by field personnel to identify vegetation-treatment areas on the landscape.

## Soil Chemistry: Relationships between Energy Exploration/Development and Salinity of Soils and Waters in the Muddy Creek Drainage, Carbon County, Wyoming

### *Additional Progress and Findings Information*

Originally, this project was designed to evaluate the relationships between tamarisk management and soil/water salinity in the Upper Colorado River basin of the western WLCI region. Subsequently, the potential funding entity that would have subsidized WLCI funding for this work decided to shift its focus away from research. Thus, the emphasis of this project shifted to evaluating the relationships between energy exploration and development and soil/water salinity. Accomplishments for this new emphasis entailed (1) discussions with USGS water scientists in the Water Resources Discipline (WRD), researchers at the University of Wyoming, and BLM personnel at the Rawlins Field Office in Wyoming; (2) selecting Muddy Creek in Carbon County, Wyoming, as a test site for this work; and (3) making a site visit to Muddy Creek to better understand the system and to obtain a samples for pilot study.

## Mechanistic Studies of Wildlife

### Pygmy Rabbit

#### *Additional Progress and Findings Information*

USGS scientists overlaid 207 random points on the WYNDD predictive range map for pygmy rabbits in Wyoming and then began occupancy surveys (following Ulmschneider and others, 2004) in summer 2008. Occupancy surveys were completed at 104 sites; Pinedale BLM Field Office staff (Dale Woolwine) completed 17 additional surveys ($n = 121$). Sixty-three sites were in areas classified as unoccupied by the WYNDD model and 58 sites were areas predicted to be occupied. Assessment of predictive success is ongoing, with additional surveys planned for 2009. Year 1 data suggest that the WYNDD model under-predicts unoccupied sites and predicts occupied sites more effectively, but this information is preliminary.

### Sage-Grouse

#### *Additional Background and Methods Information*

The goal for this work is to assess critical, limiting habitat requirements and individual-to-population-level responses to landscape change in areas of energy development. These assessments would occur along energy chronosequences and intensity gradients, and at control sites with no development. Biotelemetry research was proposed to assess resource selection and fitness across life stages for sage-grouse, developing models to identify key habitats for conservation, and provide an understanding of sage-grouse responses to anthropogenic developments. To initiate a biotelemetry study across energy chronosequences and intensity gradients will require about $240,000/year, but funds for this work in 2008 were about 25 percent of that. Therefore, work focused on developing spatial models assessing sage-grouse responses across large landscapes using existing population data from lek counts, and attempting to compile data from previously conducted and ongoing biotelemetry studies, both within WLCI and across Wyoming.

#### *Additional Progress and Findings Information*

To understand the mechanisms affecting sage-grouse populations, first a detailed description of historical fluctuations in sage-grouse populations had to be developed. The first step in assessing population trends was to obtain historical sage-grouse lek data from the WGFD. The "lek database" is a very large time series database with information collected by many different people on more than 2,000 lek sites over 60 years. To ensure that the data were as accurate as possible, extensive database quality assurances and controls were conducted and implemented, respectively. Wyoming greater sage-grouse populations are monitored through several methods. Lek counts involve counting the number of males attending a lek during the breeding season and are the most widespread means of monitoring greater sage-grouse. Male attendance at leks varies throughout the breeding season and, therefore, monitoring efforts entail counting birds at leks a minimum of three times during a breeding season to obtain a maximum count of males at each lek. The way in which these repeated counts affect the assessment of population trends is not yet clear, however. Generalized additive models and simulation techniques were used to determine the effect of repeated counts on the accuracy of population trend estimates using Wyoming's lek count data. These methods can be used to estimate detailed changes within population trends and identify years in which the rate of decline or increase changes significantly (fig. 29). The hypothesis that repeated counts have less influence on the accuracy of population trend estimates as the number of sites monitored increases was tested, thus decreasing the need to repeatedly sample individual sites. The results suggested scales at which repeated counts may not result in significant increases in the accuracy of population trend estimation. These results will be used to inform data rarification (refinement) for proposed analyses in 2009.

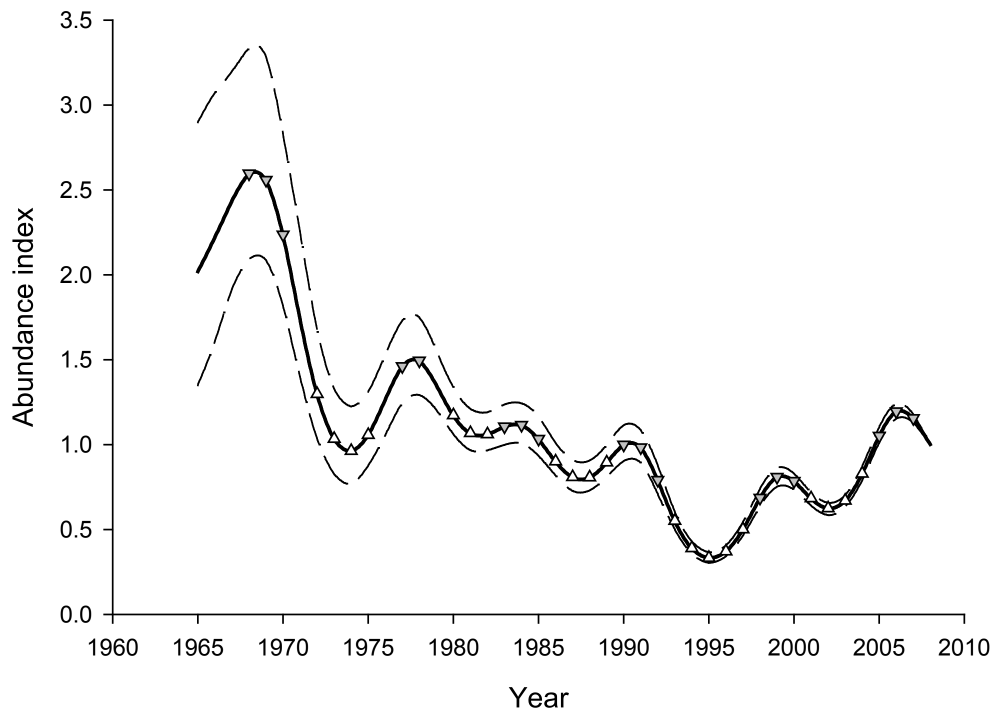



**Figure 29.** Index of greater sage-grouse population trends in Wyoming inferred from counts of males displaying at leks from 1965 to 2008. The response variable represents the number of males at a particular lek site in $year_i$ per number of males in 2008; thus, an abundance index value of 1 represents no change between a given year and the base year of 2008. The dashed lines represent the 95 percent confidence intervals determined from 199 bootstrap replicates. The triangles represent statistically significant change points. The downward gray triangles represent significant downturns and the upward white triangles indicate significant upturns. The change points represent significant differences in the rate of increase or decline (see Fewster and others, 2000).

## Songbird Community

### *Additional Background and Methods Information*

Songbird species that breed within western North American sagebrush habitats have been showing marked declines, commensurate with ongoing changes to sagebrush-steppe systems (Sauer and others, 2008). Little is known about how sagebrush-obligate songbirds are influenced by energy development, although such disturbances have the potential to increase physiological stress, alter habitat selection, disrupt nesting, and reduce survival and reproduction (Knick and others, 2003). Songbird community structure (abundance, diversity), as well as nesting productivity and survival, will be evaluated across gradients in development intensity as characterized by four well pad density categories: 0, 1–6, 6–15 and greater than 15 well pads/$km^2$. The structure and condition of the songbird community will be characterized by conducting point counts with distance sampling. Nests of a suite of key indicator songbirds also will be located and monitored for nesting productivity and survival, variation in clutch size, hatching success, and abandonment rates. Morphological measurements of nestlings at a sub-set of nests will provide an index of offspring quality and likelihood of post-fledging survival. Analyses will focus on the three sagebrush-obligate species: sage thrasher, sage sparrow, and Brewer's sparrow, although nests of all species located will be monitored. Relevant habitat characteristics (for example, shrub cover, height and density, understory composition) at each point and nest location will be measured to examine possible habitat-disturbance interactions.

### *Additional Progress and Findings Information*

Abundance and diversity data from point count surveys conducted in 2008 have been analyzed. Observers located 128 Brewer's sparrow, 57 sage sparrow, and 43 sage thrasher nests. Non-focal species nests located included five greater sage-grouse, five vesper sparrow, two mourning dove, and five horned lark. Measurements were obtained from 106 Brewer's sparrow, 51 sage sparrow, and 67 sage thrasher nestlings.

## Mule Deer

### *Additional Background and Methods Information*

The vast majority of ungulate populations that occupy western Wyoming are migratory, often traveling 30–100 miles between seasonal ranges (Sawyer and others, 2005). Sustaining these populations will require that migration routes remain functional, concurrent with large-scale energy development across large portions of western Wyoming. There is a need to identify and prioritize migration routes such that they can be considered in land-use plans and targeted for conservation. USGS is conducting a collaborative study with agencies and industry to develop a quantitative framework that will enable managers to identify and prioritize ungulate migration routes. Initially, the framework and methodologies are being developed on a mule deer data set from the Atlantic Rim Project Area, but will be applied later to other species and regions in the WLCI region.

### *Additional Progress and Findings Information*

Existing GPS data from Atlantic Rim were used probabilistically to identify population-level migration routes (Horne and others, 2007) for mule deer that occupy two major wintering complexes (Sawyer and Kauffman, 2008). Additionally, a methodology has been developed to distinguish between migratory segments that are used as foraging/resting habitat versus those used primarily as movement corridors. Of particular importance, a methodology has been developed to prioritize migration routes based upon the relative amounts of use they receive, such that migratory segments with the highest conservation value can be readily identified. This work has provided common ground for the BLM, WGFD, industry, and non-governmental organizations to assess the potential impact to migrating mule deer. Recognizing that complete protection of migration route networks is unlikely, these stakeholders now have a means by which to prioritize routes for conservation and identify areas appropriate for seasonal timing restrictions and other mitigation measures (for example, habitat improvements, fence modifications, and conservation easements).

## Data and Information Management

### Data Management Framework and Clearinghouse

#### *Additional Background and Methods Information*

In collaboration with partners and sister USGS disciplines, the USGS Geospatial Information Office (GIO) will build the geospatial and project management framework for accessing and sharing information between science partners, land managers, landowners, industry, and the interested general public. Specific goals are to (1) identify the existing state of knowledge applicable to this project, (2) establish protocols for assembling data originating from monitoring and scientific fact-finding efforts for the WLCI Data Clearinghouse, and (3) build and maintain a Data Clearinghouse.

This effort will generate a robust, sustainable resource of scientific information, knowledge, and tools to ensure that future decisions regarding land and natural resource use, management practices, and energy development are based on up-to-date knowledge of the relationships of biological, geological, hydrological, and geographical processes to physical changes across the WLCI region.

In addition to the Data Clearinghouse, the WLCI teams identified need for an information management space in which ancillary information associated with the effort could be organized and maintained for convenient access by the WLCI community. Accessible information includes document artifacts produced by various efforts (for example, draft reports, collaborative agreements, and so on) and archival materials, such as meeting minutes, agendas, and notes. To accommodate the management of supporting information, the GIO will provide an online collaborative community within the myUSGS Web-based system that will be accessible to all WLCI partners (via authorized login).

#### *Additional Progress and Findings Information*

Central to the WLCI data and information management strategy is the production of a clearinghouse of data acquired from scientific and resource management partners. Providing a common "portal" for pertinent data enables WLCI partners to access and understand information upon which to build scientific investigation and decision support capabilities. The WLCI Data Clearinghouse is a component of the evolving USGS Comprehensive Science Catalog (CSC), a centralized data repository for use by the scientific community. The WLCI Data Clearinghouse is one of many projects within the CSC that contributes and shares resources with other projects.

The WLCI Data Clearinghouse provides access to both data resources hosted by the USGS on behalf of the WLCI and points to a variety of data resources maintained online by WLCI partners. These include resources that have been warehoused or hosted by the University of

Wyoming's Geographic Information Science Center. A goal of the WLCI Data Clearinghouse is not only to provide information about important datasets but also to facilitate direct access to those data through downloading or advanced streaming-type services.

The WLCI Interagency Web portal is a myUSGS community that has been supporting WLCI activities since 2007. The WLCI STAC named the community and it has been used primarily by the WLCI CT. Outreach efforts and education explaining the capabilities of the myUSGS space are broadening its use by other WLCI teams.

- As of August 8, 2008, the WLCI Data Clearinghouse had incorporated 238 current data resources.
- Of the 238 data resources in the Data Clearinghouse, 114 are of acceptable quality with adequate metadata, and are ready for limited access and use. Twenty-five of the data resources have been identified for public release. Additional records will be made available for public access. Other records are proprietary and preliminary and are, therefore, made available only to the WLCI community. In December 2008, the WLCI DIMT launched a review period for these data and assigned individual data record ownership.
- On August 27, 2008, the Data Clearinghouse was presented for review to the WLCI CT and the DIMT.
- On November 10 and 14, 2008, the first iteration of the WLCI Data Clearinghouse "explorer" view was demonstrated to the WLCI CT and EC. The WLCI Data Clearinghouse was released late 2008.

## Science and Conservation Projects Database

### *Additional Background and Methods Information*

One of the central goals expressed by WLCI partners and stakeholders during the 2007 Science Partner Workshop was to (1) identify "on-the-ground" conservation projects managed through the WLCI CT, and (2) track science projects being conducted by USGS and other science agency partners. The goal of the Project Database Map is to display project locations on a map with descriptive (attribute) information. Currently, project data are not consistent with respect to format, which makes them difficult to display by a given mapping application. One of the goals associated with the Project Database Map effort has been to develop more comprehensive and robust methods for capturing project information during the proposal period to produce a functional long-term dataset.

USGS Fort Collins Science Center personnel developed a Project Tracking System for the Jonah Interagency Office (JIO) and the mitigation projects it manages. This effort has identified several important data sources that will be made accessible to the WLCI and will produce a suite of project tracking technologies that will prove useful to the WLCI.

### *Additional Progress and Findings Information*

A team from the USGS Fort Collins Science Center and the GIO is working with the WLCI CT to centralize project information acquired since 2007. Geospatial footprinting (identifying geographic project locations) is often incomplete and requires correction. These amended data will be produced as a new dataset hosted by the WLCI Data Clearinghouse and used to create a live map for the WLCI Website (*www.wlci.gov*).

The WLCI DIMT and CT will develop a proposal process for new projects and establish a method of capturing geospatial footprints and attribute information to create a more robust application for the Project Database Map System.

### Outreach and Graphic Products

#### *Additional Background and Methods Information*

The WLCI Web site (*http://www.wlci.gov*) was the first endeavor completed by the USGS for the WLCI community. This public Web site provides information about WLCI goals and activities. The WLCI CT and Communication Team are jointly responsible for maintaining site content and, until late 2008, provided updated information to the USGS Web Services Team, which serviced the Web site. Since late 2008, the CT and Communication Team are able to directly update Web site content. The USGS Web Services Team continues to support the Web site and provide technical assistance.

#### *Additional Progress and Findings Information*

During 2008, in conjunction with other projects, the GIO developed a Web content-management application known as the Simple Content Item Manager (SCIM). The SCIM application allows authorized WLCI community members, with no Web site development experience, to directly manage content for the WLCI Web site including immediate posting of news items, event listings, new documents, and other dynamic content. The SCIM system enables members of the WLCI CT and Communication Team to login and access areas of the Web site where they can edit and post new content items.

## Integration and Coordination

### Wyoming Landscape Conservation Initiative Interagency Coordination

#### *Additional Background and Methods Information*

The science conducted by USGS as part of the overall WLCI effort entails a three-stage process founded on the most pressing management needs identified by WLCI partners: (1) conducting a baseline synthesis to acquire, synthesize, evaluate, and centralize existing and new information; (2) conducting targeted monitoring and research to address the priorities identified by WLCI partners and through the baseline synthesis; and (3) integrating and coordinating USGS science with overall WLCI objectives and efforts. Approaches for integrating and coordinating WLCI programs in general, and for integrating USGS science with WLCI goals in particular, include establishing various groups, teams, and liaisons to serve as communication and integration bridges between WLCI partners, scientists, decisions-makers, natural resources managers, and the public.

WLCI operations are being implemented by six groups or teams: (1) the WLCI EC, (2) WLCI CT, (3) WLCI STAC, (4) the DIMT, (5) the Monitoring Team, and (6) the Communication Team. The EC provides leadership, direction, and oversight for the CT, STAC, and DIMT, and consists of the WLCI member agency heads (or their representatives) identified in the WLCI MOU. The CT implements and manages the activities necessary for meeting WLCI objectives, in accordance with criteria outlined in the original WLCI MOU. The STAC advises the CT and EC on scientific and technical issues affecting southwest Wyoming and implements the Science and

Management Implementation Plan. This plan describes strategies and provides procedures and recommendations necessary for integrating science and management decisions. In addition, the CT developed the overall WLCI Strategic Plan and WLCI Operation Plan. The WLCI Strategic Plan describes the strategic direction and approach needed to successfully accomplish a science-based landscape-level initiative. The Operation Plan describes the steps and processes necessary to implement conservation priorities and actions. The DIMT is building and maintaining the WLCI data catalog and Web site and establishing the data management network necessary to ensure continued maintenance of the data catalog.

In addition to WLCI members, there are several organizations that cooperate with the WLCI and provide support on an as-required basis:

- National Park Service, Intermountain Region;
- Natural Resources Conservation Service, Wyoming;
- U.S. Bureau of Reclamation, Upper Colorado Region;
- Wyoming Department of Environmental Quality;
- Wyoming State Land Board;
- one duly elected county commissioner from each of the WLCI region counties (Sweetwater, Sublette, Lincoln, Uinta, Carbon, and Fremont); and
- Jonah Interagency Mitigation and Reclamation Office.

The overall objective of this task is to ensure that the interdisciplinary knowledge, expertise, and work of USGS scientists will be coordinated and integrated with the WLCI's overall objectives of evaluating and mitigating environmental impacts of changes in land-use, climate, and other phenomena potentially affecting ecosystems and people as energy and other development proceeds in southwest Wyoming. More specifically, the USGS aims to coordinate and integrate the science required for addressing critical management needs, assessing the health of wildlife species and their habitats, and monitoring ecosystem conditions to ensure the long-term viability and sustainability of natural resources in energy-development areas. The resulting scientific information and tools will be crucial for informing policy developers and resource managers regarding land/resource use, management practices, and energy and other development.

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