Probabilistic Risk Based Decision Support for Oil and Gas Exploration and Production Facilities in Sensitive Ecosystems

Annual Management Progress Report

Reporting Period: October 1, 2007 through February 29, 2008

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Report Date: March 2008

Project Number: DE-FC26-06NT42930

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Acknowledgement

This research was sponsored by the U.S. Department of Energy through the National Energy Technology Laboratory (grant # DE-FC26-06NT42930).

Abstract

This report describes work performed during the first two quarters of the second year of the project "Probabilistic Risk Based Decision Support for Oil and Gas Exploration and Production Facilities in Sensitive Ecosystems." The specific region that is within the scope of this study is the Fayetteville Shale Play. This is an unconventional, tight formation, natural gas play that currently has approximately 2 million acres under lease, primarily to Southwestern Energy Incorporated and Chesapeake Energy Incorporated. The currently active play encompasses a region from approximately Fort Smith, AR east to Little Rock, AR approximately 50 miles wide (from North to South). The initial estimates for this field put it almost on par with the Barnett Shale play in Texas. It is anticipated that thousands of wells will be drilled during the next several years (approximately 1000 were drilled during 2007); this will entail installation of massive support infrastructure of roads and pipelines, as well as drilling fluid disposal pits and infrastructure to handle millions of gallons of fracturing fluids. This project focuses on gas production in Arkansas as the test bed for application of proactive risk management decision support system for natural gas exploration and production.

The activities reported on in this period include meetings with representative stakeholders, development of initial content and design for an educational web site, and development and preliminary testing of an interactive mapping utility designed to provide users with information that will allow avoidance of sensitive areas during the development of the Fayetteville Shale Play.

Executive Summary

Exploitation of a large natural gas reserve in central Arkansas, the Fayetteville Shale Play, will necessarily require development of significant infrastructure. Thousands of wells and hundreds of miles of roads will be constructed, as well as reserve pits and disposal options for fracture fluids. The project, "Probabilistic Risk Based Decision Support for Oil and Gas Exploration and Production Facilities in Sensitive Ecosystems," was proposed to develop modules for a web-based decision support tool that will be used by oil and gas exploration and production companies as well as environmental regulators and other stakeholders to proactively minimize adverse ecosystem impacts associated with the recovery of oil and gas reserves in sensitive areas in the Fayetteville Shale Play in central Arkansas. An additional goal of this project is to provide a mechanism that will help to streamline the process of acquiring the necessary permits for drilling in the play.

The first phase of the project resulted in identification of and contact with stakeholders involved in the Fayetteville Shale Play (FSP). The principal stakeholders and their affiliations have been presented in previous reports. Stakeholder discussions were positive and indicated a willingness of the industrial and regulatory parties to collaborate with each other and the project team. The major themes that emerged as areas offering the greatest benefit to the stakeholders were education and integration which led to development of the educational website presented in this report. We have also identified, through discussions with regulators and other governmental agencies, the principal roles of each agency which were discussed in detail in a previous management report. In addition we have also created a preliminary version of a web-based mapping decision support tool that will allow better planning for development in sensitive locations by providing a map of the intersection of proposed features such as drilling pads, roads or gathering lines with those of sensitive locations. An additional tool designed to help identify locations where sensitive species have higher probability of being found is under development.

Conclusions

Initial feedback from the stakeholders on our work product was very positive, and we are continuing to develop and refine these tools. Additional data layers that will provide further guidance on sensitive locations will be acquired, or created, and incorporated into the web based mapping utility. We are working with the Arkansas Natural Heritage Commission and the U.S. Fish and Wildlife Service to add data layers that they consider important for inclusion in decisions regarding environmentally friendly development.

Probabilistic Risk Based Decision Support for Oil and Gas Exploration and Production Facilities in Sensitive Ecosystems

INTRODUCTION

The Fayetteville Shale play is an unconventional natural gas play across central Arkansas. It is a tight formation and requires fracturing to produce economic quantities of gas. Initial estimates are that it may rival the Barnett Shale play in Texas. Currently there are about two million acres under lease in this play. It is anticipated that thousands of wells will be drilled during the next several years; this will entail installation of massive support infrastructure of roads and pipelines, as well as drilling fluid disposal pits and infrastructure to handle millions of gallons of fracturing fluids. This project is focused on gas production in Arkansas as the test bed for application of proactive risk management decision support system for natural gas exploration and production.

The project will develop a series of web-based application modules that will allow mid- and small-sized exploration and production companies to generate development plans for resource extraction in sensitive ecosystems in a manner that will meet regulatory requirements and proactively minimize risks to the ecosystem through implementation of best management or development practices implemented on a site specific basis. The program will be built from a database of existing technologies that can be implemented in ecosystem friendly ways. The principal objective of this project is development of tools that will allow industry to rapidly evaluate alternative leases through a GIS-based information support system so that location-specific environmental concerns can be identified early in the permitting process.

Exploring for oil and gas involves subsurface seismic mapping which can result in surface disturbance; it often involves small explosive charges placed in patterned grids. If potential oil or gas deposits are identified, exploratory drilling begins. This phase frequently requires constructing, operating, and maintaining a system of access roads, local pipelines to connect well sites to storage facilities and dispose of drilling wastes, and gravel pads for wells and to house equipment. In addition, the production phase normally requires storage tanks,

separating facilities, and gas compressors. Finally, gathering lines are needed to transport gas to cross country transmission pipelines and ultimately to users. Pipeline operation may require additional pumping stations and storage tanks.

Habitat fragmentation is one of the environmental concerns associated with the development of new oil and gas infrastructure. It can change the hydrology of the basin, potentially introducing toxic substances and sediment into surface waters. Fragmentation may exacerbate disturbances from human activities, may provide corridors for predators, and potentially helps spread invasive non-native plants.

Impacts in the drilling stage include disturbed land, which can be significant depending on the length of roads, size of equipment, and other factors. The movement of heavy vehicles and drilling can create continuous noise potentially disturbing wildlife behavior patterns. Emissions from diesel engines and turbines that power the drilling equipment can pollute the air with particulates and carbon monoxide.

This project will provide oil and gas planners, engineers, developers, cultural resource managers, and researchers with a geospatial decision support system able to present information and maps from a variety of geospatial data, for any proposed site or corridor location within the Fayetteville Shale Play. The system will be used in the planning process to quickly evaluate the potential of alternatives, to highlight sensitive areas and features, and to minimize adverse environmental impacts by allowing diversion of development projects away from sensitive areas. Implementation of the tools assembled for this project will lead to a streamlined permitting process for well placement and infrastructure development. As the Fayetteville Shale play develops, the number of drilling and reservoir pit permits will increase and may ultimately lead to a situation similar to that found in the Rocky Mountain region where the regulators are unable to keep up with permit processing with the result that environmental monitoring responsibilities are not effectively executed.

In this report we summarize the work performed during the first two quarters of the second project year, which has focused on the development of the specific tools identified through the stakeholder input during the first year: technology identification, identification of best

practices, creation of a prototype educational website, and a prototype geospatial decision support system.

PROJECT TASKS

Task 0: Identify and establish contact with stakeholders.
Task 1: Technology Evaluation
Subtask 1.1 Analysis of existing practices
Subtask 1.2: Identification of best practices
Task 2: Delineate regulatory and environmental concerns in the region and database development.
Task 3: Adapt fate and effects and ecosystem effects models
Task 4: Update and expand financial impact models.
Task 5: Integrate map products with risk analysis modules
Task 6: Web deployment
Task 7: Testing and technology transfer

Results

Several stakeholder meetings were held in 2006. A summary of participants and details of the outcomes has been reported in an earlier management report. Three areas were identified in which this project have a significant impact. These were education, integration, and data sharing. Overall the discussions were positive and indicated a strong willingness of the industrial and regulatory parties to collaborate with each other and the project team.

Education: Based on comments from stakeholders in October, 2007, we have restructured the mock-up website presented at that meeting and added additional, updated content. This has resulted in a beta-version of a website to serve as a central location where interested parties can access information about development in the Fayetteville Shale Play which we will be testing with stakeholders in the third quarter. An important aspect of this site will be to provide a forum where questions regarding the development of the Fayetteville Shale Play can be answered. Figure 1 presents the structure of the website. Screenshots from the website are provided in Appendix A.

Integration: Improving inter-agency communication during the permitting process would result in a more streamlined mechanism for the cooperation of the agencies involved in the

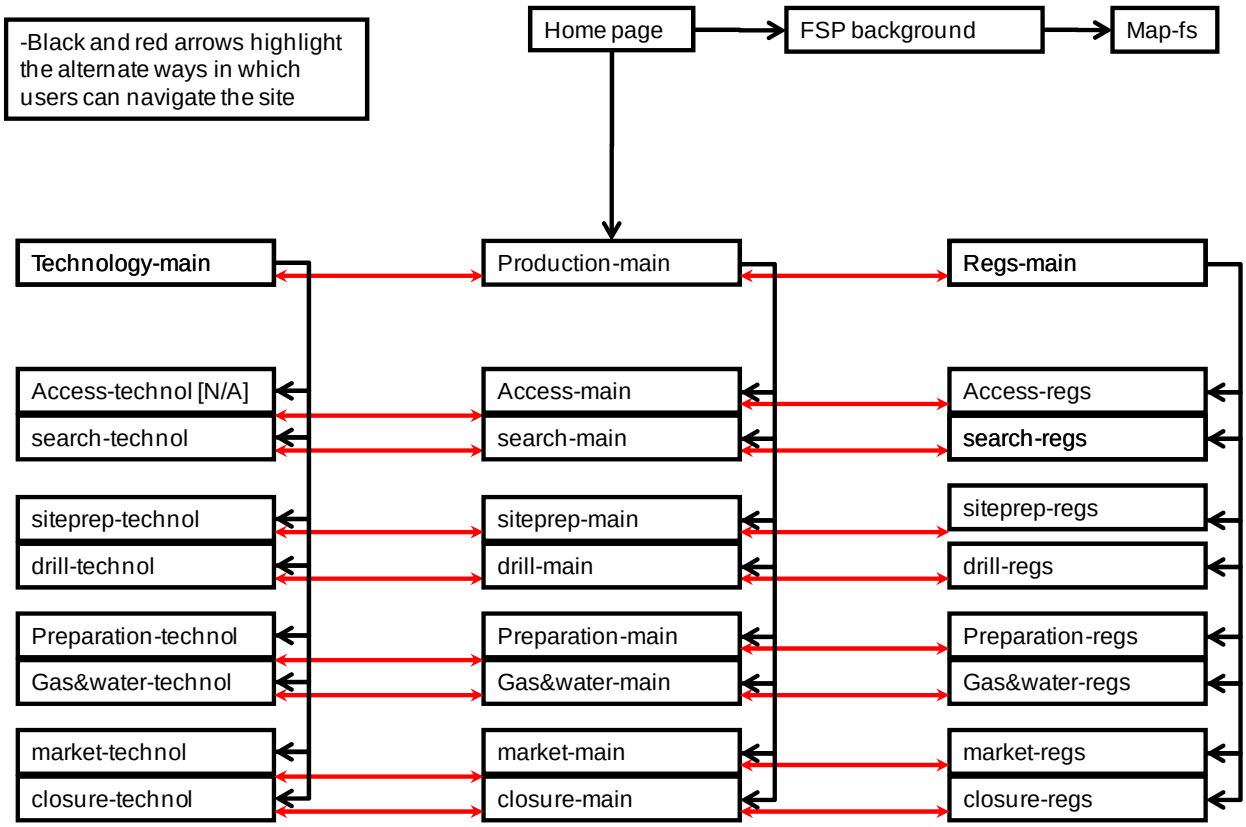

Figure 1. Schematic showing architecture of the educational web site

regulation of the FSP. We have been working with the Arkansas Oil &Gas Commission and the Arkansas Dept of Environmental Quality to establish protocols for mining their data sites for current information regarding permits that can be integrated to an interactive online mapping utility. The information can be screened for active or inactive status as well as the current well status at a particular location.

Data sharing: We have an agreement with the Arkansas Natural Heritage Foundation to provide information regarding the location of sensitive species in the Fayetteville Shale Play. The U.S. Fish and Wildlife Service has also indicated interest in providing data for this project that will allow users to identify sensitive areas prior to proceeding with any development. This information will be made available through an interactive web mapping service, which will allow users to determine the intersection of, for example, a drill pad with a sensitive location in the play area. We are currently working with the ANHC dataset in algorithm development. In addition, other work with the ANHC has focused on developing habitat maps in the play area.

New data layers have been created for this purpose. With habitat type maps, it will be possible to develop algorithms that can assign a likelihood that a certain location matches the known, preferred habitat of a sensitive species. This will provide an early warning to developers that additional effort is warranted in site selection in order to avoid adverse impacts. Appendix B contains a summary of the habitat mapping efforts completed to date.

Conclusions:

While there are two state agencies with regulatory authority (ADEQ and AOGC), and the BLM with regulatory authority over federal lands, several of the other agencies have the potential to become involved on a case by case basis. We have developed a prototype website to help explain the various roles of those involved with the development of the Fayetteville Shale Play. In addition, the website details the lease development process. A prototype model has been created that computes the intersection of proposed development features with sensitive landscape features , and beta testing will be initiated in the third quarter of this year. A habitat type map of the play area has been prepared in cooperation with the ANHC.

Progress on task completion:

Phase 1: Development of Environmentally Friendly Technologies Database

Task 0: Identify and establish contact with stakeholders.

This task is complete. Stakeholders and their roles are listed in an earlier Project Summary.

Task 1: Technology Evaluation

Subtask 1.1 Analysis of existing practices

This task is complete. In summer 2007 we visited both SEECO sites in Conway County and Chesapeake sites in White County. The trip reports from these two visits were included in the Annual Progress Report.

Subtask 1.2: Identification of best practices

The US Fish and Wildlife Service (USFWS) finalized a BMP document for the Fayetteville Shale Play in the spring of 2007. This USFWS document forms the basis for the work on this task. We have analyzed the USFWS BMP document and defined the GIS data layers that will be

necessary to include BMP information in the decision support tools; this was summarized in the Annual Progress Report, October 2007.

Task 2: Delineate regulatory and environmental concerns in the region and database development

The data collection activities associated with this part are complete. The results are briefly summarized below. This task is closely linked with the USFWS BMP document that has been prepared for the Fayetteville Shale Play. We have initiated discussions with regulatory and other data managers to implement data sharing that will allow site-specific 'flags' to be generated, so that industrial developers will have an early warning of particularly sensitive locales. One challenge associated with this effort is that the information regarding the locations of threatened or endangered species is not (and will not be made) publicly available. We currently have a 'low level' data sharing agreement in place with the Arkansas Natural Heritage Commission that will allow a "red flag" identification of sensitive locations. This level of warning will allow developers to avoid environmentally sensitive locations, or plan appropriate protective measures in advance of development.

A prototype of a Geospatial Decision Support System (GDSS) was presented to stakeholders during meetings held on October 10 and October 12, 2007 for governmental and industrial stakeholders respectively. More details of the GDSS are given below in "Phase 2".

We have had extensive discussions with regulatory agencies, and have a clear understanding of the regulatory concerns in the Fayetteville Shale Play. As indicated in the previous reports, Arkansas Oil &Gas Commission has primarily governing authority regarding the development of natural gas resources in the Fayetteville Shale Play, beginning with seismic exploration and ending with well closure. The Arkansas Dept of Environmental Quality has jurisdiction over construction, operation and closure of reserve pits. This authority derives from its responsibility for maintaining the quality of surface waters in the state of Arkansas. The other major regulatory activity in the Fayetteville Shale Play is associated with the U.S. Army Corps of Engineers enforcement of section 404 of the Clean Water Act. This is associated with the construction of small reservoirs for collection of surface water necessary for fracture

jobs, and for other infrastructure development that has the potential to generate sediment loading in streams.

Also through discussion with regulators and industry representatives, we have identified the major concerns that are raised associated with the development of the Fayetteville Shale Play. These include water supply and water quality both for surface waters and groundwater. Many residents in the area are concerned about potential impacts to drinking water wells; while others are concerned about adverse impacts to fishing streams. Another concern that has been identified is noise pollution associated with the large compressor stations necessary to deliver the natural gas from the field to the transmission lines. Of course, there are concerns about the impacts of development on rare species that are found within the Fayetteville Shale Play. This is particularly true for aquatic species that may be impacted by sediment runoff from the development of roads and drill pads.

Task 3: Adapt fate and effects and ecosystem effects models

Based on industrial stakeholder feedback during the first six months of the project, this task had been placed on hold. At present, we have not begun work on this task; however, at our last meeting with industry, some support was expressed for the development of these types of models under the presumption that they would be used not to make recommendations but primarily as a means of providing additional information that can be used for planning the location of specific developments. As indicated above, an environmental concern is sediment runoff, and models designed to predict levels of runoff could be useful in determining how the development should proceed. Other predictive models that were viewed as potentially very beneficial include habitat prediction models. Briefly, these models will use available information from known locations of sensitive species to develop a covariance matrix that can use to evaluate whether or not a specific development location has a high probability of containing that species. Of course, it is not possible to predict the location of sensitive species but it is possible to make recommendations that encourage cautious development. These warnings would have a “yellow flag” level. Manual collection of habitat distribution data throughout two million acres (approximately under lease) of the Fayetteville Shale Play would be cost prohibitive. Therefore, it is desirable to develop a modeling strategy which can predict

areas most likely to contain sensitive species. Development of a habitat distribution model would require following information:

1. Important habitat characteristic data, and
2. Spatial distribution of the characteristics on the study site

The important habitat characteristics may include all or some of the following factors: vegetation type, distance from water body, soil type, availability of nesting spots, topography, population density, etc. The characteristics of a field site in question can be compared with the characteristics of the habitats known to have target specie(s). Sites having strong covariance with the known habitat characteristics of target specie would be yellow flagged so that additional care can be taken to ascertain if a sensitive species is in fact present.

Task 4: Update and expand financial impact models.

This task has not been initiated because it is dependent on the approach taken for the Bayesian analysis, and the ultimate decision regarding fate and effects modeling (which provide the consequences of development actions for which the costs need to be estimated).

Phase 2: Preparation of decision support software tools

Phase 2 work is well underway with the development of the Geospatial Decision Support System (GDSS). This GDSS will provide regulators and gas producers, operating in the Fayetteville Shale Play, a platform to assess potential environmental impacts of proposed well pad, reserve pit, compressor station, gathering line and road placements. The system is web-based and will provide access to current geospatial data layers from a variety of sources. A screenshot of the current interface is shown in Figure2. A list of available data layers is provided in Table 1.

Approximately 1000 lines of code have been generated within the ARC server environment. A graphical user interface has been created in which standard map navigaion tools as well as special icons are available to activate a Feature Placement Tool.

This tool allows users to propose a location for well pad (with associated drill and reserve pit), gathering line or road using all available layers as a guide. After placement, the system will report potential environmental impacts. In addition the user will be able to see areas of potential environmental impact. As a simple example, all areas upslope and within a certain

distance from a perennial stream may be highlighted as a translucent layer over the aerial imagery. More complex "impact surfaces" will take into account soil type and land cover.

Two primary users are envisioned: 1) regulators at AOGC, ADEQ and ANRC who will have easy access to complex geospatial analysis to inform permitting decisions, and 2) producers who wish to vet infrastructure placement proposals and expedite permitting by efficiently communicating with regulators. After several meetings with both regulators and producers, it is clear that the data layers underlying the system must be recognized by both parties as

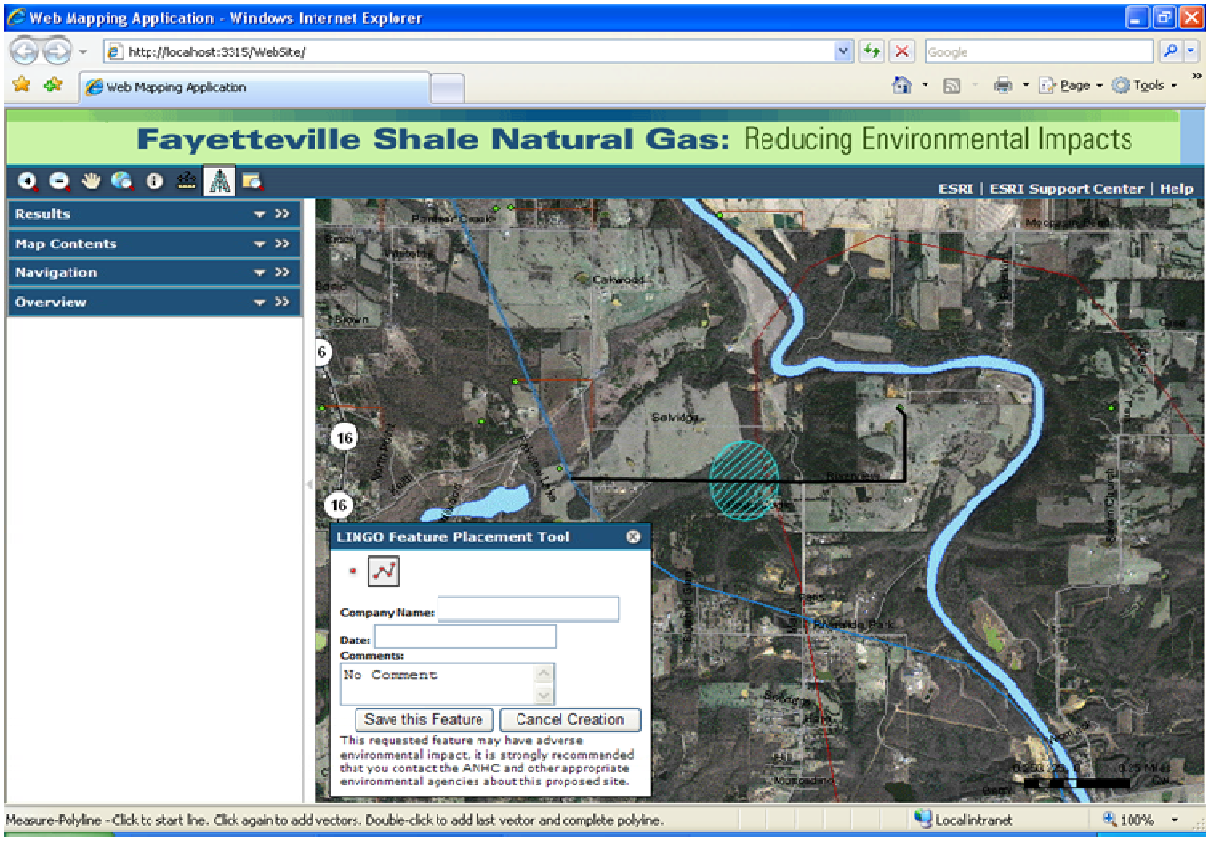

Figure 2. Fayetteville Shale Natural Gas GDSS. The Feature Placement Tool has been used to propose a gathering line, which crosses a (fictitious in this case) threatened and endangered "red flag" (shown as the cross-hached ellipse) area provided the Arkansas Natural Heritage Commission.

current and accurate. Therefore, we have placed a high priority and expended significant effort to develop technical relationships with AOGC, ADEQ, ANHC and ANRC to ensure the currency of geospatial layers available to the GDSS.

Table 1. Partial list of data layers available in the Fayetteville Shale Natural Gas GDSS.

Source	Layer
US Geological Survey	National Elevation Dataset (NED will serve as the basis for all terrain based decisions such as slope, aspect and flow)
US Geological Survey and US Environmental Protection Agency	National Hydrology Dataset (1:24,000 scale)
Arkansas Geographic Information Office	Arkansas Road Centerlines
Arkansas Geographic Information Office	Public Land Survey System (Township, Range and Section corners)
Arkansas Geographic Information Office	2006 Orthophoto Image Base (0.33 – 1.0 meter GSD)
Arkansas Geographic Information Office	Arkansas political boundaries (county, city)
Arkansas Natural Heritage Commission	Threatened and Endangered Species (Red Flag version)
Arkansas Natural Resources Commission	Location of known wetlands
Arkansas Natural Resources Commission	Watershed boundaries
US Forest Service	Public forest boundaries
US Census Bureau	TIGER Road Features
Bureau of Land Management	Public land boundaries
Arkansas Oil and Natural Gas Commission	Existing drill pad and well locations (permit status and production history)
Arkansas Oil and Natural Gas Commission	Locations of major gas transmission lines
Arkansas Department of Environmental Quality	Locations of reserve pit locations and permit status
Arkansas Natural Resources Commission	2006 Land Cover
Natural Resources Conservation Service (US Department of Agriculture)	State Soils Geographic Data (STATSGO) and Soil Survey Geographic Data (SSURGO)
US Fish and Wildlife Service	Threatened and endangered species sensitive areas

The Layers which are not developed by these agencies are recognized components of the Arkansas State and US Federal infrastructure and will be accompanied by Federal Geographic Data Committee (FGDC) metadata. The system will complement existing Fayetteville Shale Play informational websites, such as the Arkansas Oil and Gas Commission (AOGC) map service (http://www.geostor.arkansas.gov/apps/aogc/index.htm) which provides access to well permit and production status. It will complement the Arkansas Department of Environmental Quality

(ADEQ) site (http://www.adeq.state.ar.us/compsvs/webmaster/databases.htm) at which users can search for NPDES Permits by county, organization or permit number. ADEQ issues permits related to reserve pit construction and removal. Another component of the GDSS is an integrated view of the permit status of wells and reserve pits. .

In additional to providing a contextual view of proposed infrastructure placement, the systm will provide quantitative assessments including, but not limited to,

1. Proximity to threatened and endangered species habitats,
2. Delination of potential run-off areas based on local terrain, soil type and land cover,
3. Proximity to bodies of water and a traces from that body throughout the hydrologic system,
4. Required stream crossings, and
5. Infiltration potential.

Potential environmental impacts identified by the GDSS can be electronically forwarded to a variety of agencies or individuals for review. Impact information will include detailed reasons behind the assessment, an estimate of the likelihood of the impact and a URL which will direct the recipient to the same map view (including active layers) used to generate the report. Producers and regulatory officials with whom we have met all agree that this immediate electronic exchange of detailed information will increase the speed with which various permits can be submitted, reviewed and issued. Producers of natural gas in the Fayetteville Shale Play will be able to better plan drilling activities, reducing costs caused for example, by scheduling delays of scarce equipment. Regulators can likewise better manage environmental impacts by immediately having access to a sophisticated analysis of impacts within the scope of their regulatory authority.

Despite the scope and sophistication of the GDSS it is clearly designed to be a planning tool and is not intended to replace on-site surveys, which are required to establish applicable best management practices. As an example of the limits of the tool, consider proximity of a placement to a local water body. Proximity to down-slope surface water is a major limiting factor in road construction but existing hydrographic layers only locate streams to within 100 feet. Likewise, knowledge of local elevation is limited to heights at 30 meter intervals. Aerial imagery can, in some cases, be used to reduce error in relative distance measurement but only

an on-site survey can accurately establish proximity. In addition, terrain relief and soil type used to assess run-off can only be accurately surveyed on site. However, because the system will take into account imprecision and uncertainty (using “fuzzy” and/or “Bayesian” techniques) in the underlying geospatial data layers it will provide enough information to filter for (or perhaps rank order by) potential for environmental impact the full set of possible infrastructure locations and thus limit the number of required on-site surveys. The GIS layers listed in Table 1 also reflect information required to recommend a BMP based on the US Fish and Wildlife document mentioned as part of Tasks 1.2 and 2. Again, due to concerns about the accuracy of the available data, the uncertainty of these layers may included in “fuzzy” or “Bayesian” approach to analysis.

Finally, because many of the geospatial layers listed in Table 1 are from national datasets or layers readily available in most states, the GDSS can be exported to other regions of the country where the environment impact of drilling activities is a concern. The key to the success of this system in any play area is acceptance of an agreement between state and federal regulators on the one hand and producers on the other.

We are considering ways to address the industry concerns regarding the inherent uncertainty in GIS data and still provide an effective decision-support system. Our current focus is on assessing the feasibility of building a “fuzzy-logic” system that takes into account the uncertainty associated with the various GIS layers used as input. So, for example, if a BMP selection depended on the distance to body of water whose location was only known with 90% certainty to be within 75’ (this is typical of 1:100,000 scale map layers) of the reported location, the model would propagate this uncertainty into a probability that a particular BMP would be recommended. Only after an on-ground survey could a more precise BMP be chosen. However, providing a range of possible environmental impacts and subsequent BMP prescriptions would help industry and government stake-holders focus on potential drilling areas with the least likelihood of adverse environmental impact. This approach could take the form of a “risk” map showing the probability of a particular adverse impact across the shale.

Task 5: Integrate map products with risk analysis modules

The geospatial decision support system described above represents the current use of map products in the project. As indicated previously, we intend to include uncertainty analysis based at a minimum on buffer zones that are related to the inherent uncertainty of the data layers that are used in the decision making process. In the current context a traditional risk analysis is not necessary to provide adequate decision support. This arises from the fact that, for example, the likelihood of erosion associated with placement of a pad or access road is essentially certain. Therefore the risk can be directly correlated with the consequences. These in turn are directly related to the geospatial characteristics of the site being developed, and these data are represented by the GIS data layers available in the project. It is thus envisioned that the geospatial decision support system will satisfy the requirements of task five.

Task 6: Web deployment

This task is awaiting the development of both the Educational website and the Geospatial Decision Support System. Both of the web-based applications are currently being developed on internet servers not open to the public but can be easily transferred to a public site when they are complete.

Task 7: Testing and technology transfer

The preliminary testing of the geospatial decision support system is necessarily integrated with the development of this system. Beta testing of the system by representative stakeholders will not be initiated until later in the development cycle. This technology transfer aspect of task has not yet started. As the education and decision support components of the project progress we will hold demonstrations for the stakeholders. These updates are planned to occur in mid spring 2008, late summer 2008, and finally as a presentation/workshop at the International Petroleum Environmental Conference in the fall of 2008.

Conclusions

Overall the project is close to the proposed schedule. Some uncertainties in the regulatory climate and stakeholder concerns have resulted in parts of the project moving more slowly than originally planned, while other aspects of the project had been moved forward in the timeline. Specifically, the fate and effects modeling has been postponed to the second project year,

while certain aspects of the development of the geospatial decision support system have been moved forward into the first year.

Funding

This project was selected under DOE's Low Impact Natural Gas and Oil solicitation, February 2006.

Anticipated DOE Contribution: $499,582
Performer Contribution: $136,832 (30% of total)

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Appendix A:

Screen shots and initial content of the educational website.

Fayetteville Shale Natural Gas: Reducing Environmental Impacts

Search Go

- Home
- About Fayetteville Shale
- Drilling Locations and Status
- Natural Gas Production
- Minimizing Environmental Impacts
- Regulatory Requirements
- Documents

Announcements

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Fayetteville Shale:

Reducing the Environmental Impact of Natural Gas Development

A public information resource on natural gas development in Arkansas' Fayetteville Shale formation.

Welcome to the Fayetteville Shale Information Web site. In this site you will learn about the **natural gas resources** available in the **Fayetteville Shale** formation in Arkansas. The site explains the steps followed by natural gas development companies, from gaining access to the land through sending the gas to the marketplace. For each step in the process, the site provides information about the **state and federal regulatory requirements** that developers must follow. The site also describes some of the technologies that can be used to minimize the **environmental impacts** of natural gas development.

Follow the links below to learn about the Fayetteville Shale, explore map data related to natural gas development activities, the natural gas development process, regulations, and environmental technologies.

About the Fayetteville Shale
What is the Fayetteville Shale?

Fayetteville Shale Play Drilling Locations and Status
Maps and data showing current natural gas development activities in the Fayetteville Shale.

Natural Gas Production
How is natural gas produced from the Fayetteville Shale?

Minimizing Environmental Impacts
What technologies can be used to minimize environmental impacts during natural gas development?

Regulatory Requirements
What are the regulatory requirements governing natural gas development in the Fayetteville Shale region?

Documents
Reports, laws, regulations, notices, etc. concerning natural gas development in the Fayetteville Shale.

Drilling a Well in the Fayetteville Shale

Fayetteville | Drilling | Natural Gas Production | Regulatory Requirements
Minimizing Environmental Impacts | Documents

Announcements | Contact Us | About Us | Privacy/Security Statement

Fayetteville Shale Natural Gas: Reducing Environmental Impacts

Home
About Fayetteville Shale
Drilling Locations and Status
Natural Gas Production
Minimizing Environmental Impacts
Regulatory Requirements
Documents

Announcements

About the Fayetteville Shale?

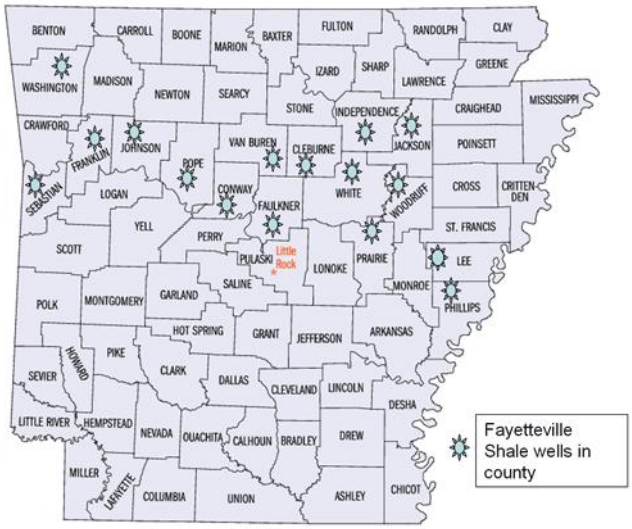
An introduction to the Fayetteville Shale including its location and geographic extent, economic importance, and physical characteristics.

The Fayetteville Shale is an unconventional natural gas reservoir located on the Arkansas side of the Arkoma Basin, ranging in thickness from 50 to 550 feet and ranging in depth from 1,500 to 6,500 feet. The shale is a Mississippian-age shale that is the geologic equivalent of the Caney Shale found on the Oklahoma side of the Arkoma Basin and the Barnett Shale found in north Texas.

Location

The Fayetteville Shale play stretches across Arkansas from approximately Fort Smith east to beyond Little Rock, Arkansas. It is approximately 50 miles wide from north to south. The figure shows those counties that have some wells drilled to the Fayetteville Shale formation.

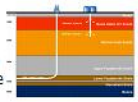
The most active area of natural gas development is from western Conway County through eastern White County. Development further to the east is anticipated to proceed very slowly because the shale is considerably deeper, making gas extraction less economical.



Economic Importance

The Fayetteville Shale is important to Arkansas because it holds large quantities of natural gas. Unlike more traditional oil and gas fields that contain hydrocarbons in porous rock formations, shale holds natural gas in a fine-grained rock matrix. Until recent years, most shale formations were not considered profitable areas for gas production. With new technology and elevated natural gas prices, companies have made the Barnett Shale play in north Texas one of the hottest production fields in the country. Encouraged by the success in the Barnett Shale formation, operators looked at other large shale formations, including the Fayetteville Shale.

Geologists describe the Fayetteville Shale formation as tight, which means it requires fracturing to produce economic quantities of gas. The most prolific gas production from the Fayetteville Shale is associated with horizontal wells that have been completed with multi-stage fracture jobs in the middle to lower portions of the formation. Click to enlarge the figure at right which shows the major stratigraphic layers surrounding the Fayetteville Shale layer. (Graphic courtesy of Chesapeake Energy, Inc.)



Click to enlarge

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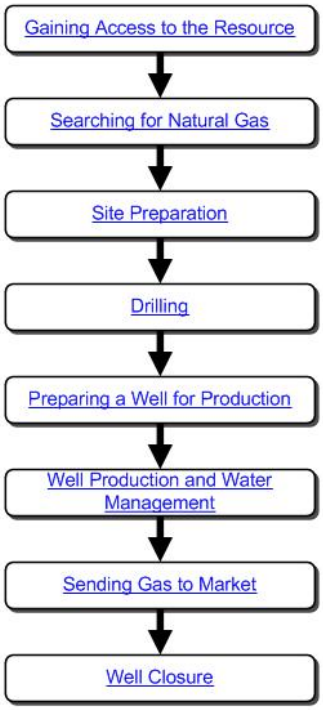
- Home
- About Fayetteville Shale
- Drilling Locations and Status
- Natural Gas Production
  - Gaining Access to the Resource
  - Searching for Natural Gas
  - Site Preparation
  - Drilling
  - Preparing a Well for Production
  - Well Production
  - Moving Natural Gas to Market
  - Well Closure
- Minimizing Environmental Impacts
- Regulatory Requirements
- Documents

Announcements

Producing Natural Gas from the Fayetteville Shale

Finding and producing natural gas from the Fayetteville Shale is a multi-step process.

The process of finding and producing natural gas from the Fayetteville Shale can be described as a series of discrete steps and processes. Each major step is shown below. Click on any of the boxes for additional information about that step.



Other information on this website regarding technologies and practices that can minimize environmental impacts and regulatory requirements follows the same process steps. Users can navigate and access information in two ways:

1. Start at the main technology/practices page or the main regulatory page. Each includes a flowchart of the steps shown above and enables links to technology/practices and regulatory requirements for each step.
2. Start at the main page for each step in the process, which in turn links to technology/practices and regulatory pages for each step.

Fayetteville | **Drilling** | **Natural Gas Production** | **Regulatory Requirements**
Minimizing Environmental Impacts | **Documents**

Announcements | Contact Us | About Us | Privacy/Security Statement

Fayetteville Shale Natural Gas: Reducing Environmental Impacts

Search Go

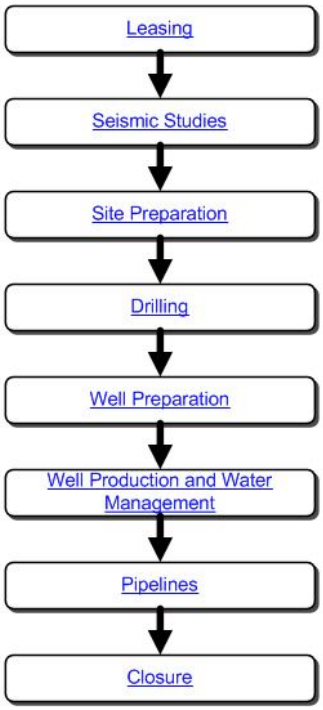
- Home
- About Fayetteville Shale
- Drilling Locations and Status
- Natural Gas Production
- Minimizing Environmental Impacts
- Regulatory Requirements
  - Leasing
  - Seismic Studies
  - Site Preparation
  - Drilling
  - Well Preparation
  - Well Production & Water Management
  - Pipelines
  - Closure
- Documents

Announcements

Overview of Regulatory Requirements Governing Natural Gas Development in the Fayetteville Shale Region

State and federal regulatory requirements govern each step in the process of finding and producing natural gas from the Fayetteville Shale.

The process of finding and producing natural gas from the Fayetteville Shale can be described as a series of discrete steps and processes. Each major step is shown below. Click on any of the boxes for additional information about the state and federal regulatory requirements that govern each step.



Several documents are applicable to multiple steps in the process. They are listed below.

State:

Arkansas Oil and Gas Commission (AOGC) Rules and Regulations.

Federal:

Bureau of Land Management Gold Book.

Onshore Order No. 1.

Home
About Fayetteville Shale
Drilling Locations and Status
Natural Gas Production
Minimizing Environmental Impacts
- Seismic Studies
- Site Preparation
- Drilling
- Well Preparation
- Well Production & Water Management
- Pipeline Construction
- Closure

Regulatory Requirements
Documents

Announcements

Minimizing Impacts of Drilling

Technologies that can minimize the environmental impacts of drilling

Directional Drilling

Most Fayetteville Shale wells are drilled directionally, with long extended-reach sections. Wellheads do not need to be located directly above the natural gas resources being produced. This allows much more flexibility in choosing an environmentally friendly location for the surface facilities.

Drilling Multiple Wells from the Same Well Pad

Another benefit of directional drilling is that multiple wells can be drilled from a single well pad. Therefore, the total number of drill pads in a field can be reduced. Drilling multiple wells from the same well pad also reduces the number of trips by heavy vehicles across unimproved county roads. Drilling rigs do not need to be moved as many times, and the large number of vehicles required for fracturing jobs can remain at the well site to fracture several wells at a time.

Use of Air Drilling Rigs for the Upper Sections of Wells

At most Fayetteville Shale wells, the upper sections of the wells are drilled using smaller drill rigs and air drilling technology. This minimizes the volume of drilling fluids needed for the full well and reduces the time that fluids are held in reserve pits.

Use of Environmentally Friendly Drilling Muds

Following completion of the upper hole sections by air drilling rigs, operators switch to more traditional drilling rigs using large volumes of drilling muds. When drilling conditions allow, operators should choose water-based muds (WBMs) or synthetic-based muds (SBMs) rather than oil-based muds (OBMs). WBMs and SBMs are more environmentally friendly than OBMs. Most Fayetteville Shale wells are drilled using WBMs. When WBMs are used for drilling, the drill cuttings are placed in the reserve pit. At the end of the drilling job, the cuttings are stabilized with fly ash and are then buried in place after all liquids have been removed. The used WBMs are disposed of using land application.

Closed-Loop Drilling Waste Systems

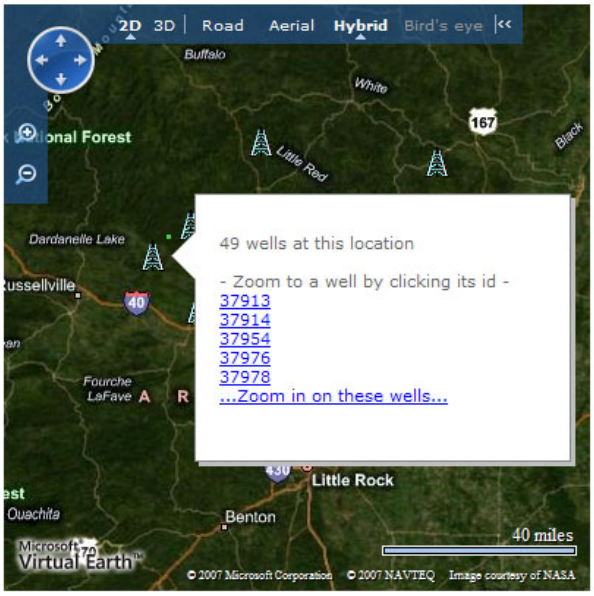
When operators choose to use oil-based muds (OBMs) for better drilling performance, they should provide a closed-loop drilling waste system (typically this includes a series of tanks) rather than using a reserve pit. At the end of the drilling job, the OBMs are typically recycled, and the cuttings should be hauled offsite for disposal.

Reserve Pits and Other Pits

Operators should construct reserve pits and other pits that are intended to store oily materials using suitable natural or synthetic liner material. During times when pits are actively holding drilling fluids, cuttings, and other oily substances, fencing should be placed around the pit perimeters to keep livestock and wildlife from entering the pits. At the end of the drilling job, the reserve pit should be closed by removing any accumulated fluids. The liner should be removed to the extent possible, and the pit solids should be covered with clean dirt, regarded to natural contours, and revegetated.

Operators should consider constructing other pits to collect non-oily stormwater runoff and other relatively clean water. Segregation of "clean" and "dirty" fluids helps to minimize waste volumes. Liners are not necessarily needed for the clean water pits.

The interactive Map below shows the location of currently operating wells. By pressing the Ctrl button and dragging the mouse on the map, you can zoom to various areas of the Fayetteville Shale. You can turn information on and off using the legend on the side of the map. You can display information about a particular feature by moving your mouse over it.



- [x] Wells
- [ ] Production Data
- [ ] Drilling Permits (1 week ago)
- [ ] Drilling Permits (2 weeks ago)
- [ ] Drilling Permits (3 weeks ago)
- [ ] Sections

Gas Well

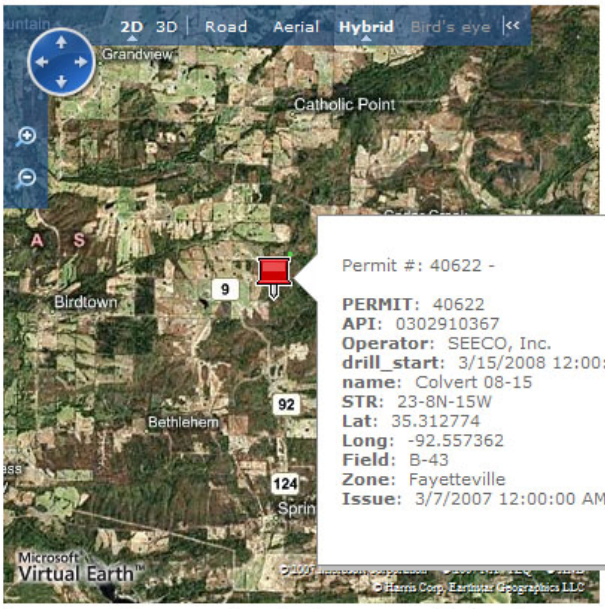
Drilling Permit

Production Data is listed as the MCF field when the information for a well is showing

Input your address or well section # to zoom to that location:

Go

The interactive Map below shows the location of currently operating wells. By pressing the Ctrl button and dragging the mouse on the map, you can zoom to various areas of the Fayetteville Shale. You can turn information on and off using the legend on the side of the map. You can display information about a particular feature by moving your mouse over it.



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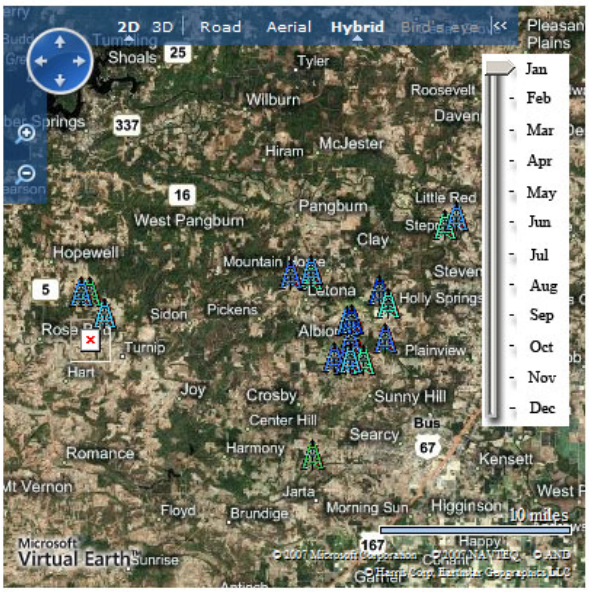
The interactive Map below shows the location of currently operating wells. By pressing the Ctrl button and dragging the mouse on the map, you can zoom to various areas of the Fayetteville Shale. You can turn information on and off using the legend on the side of the map. You can display information about a particular feature by moving your mouse over it.

Production Data Classified by MCF via Color



- ☐ Wells
- ☑ Production Data
- ☐ Drilling Permits (1 week ago)
- ☐ Drilling Permits (2 weeks ago)
- ☐ Drilling Permits (3 weeks ago)
- ☐ Sections

Gas Well

Drilling Permit

Production Data is listed as the MCF field when the information for a well is showing

Input your address or well section # to zoom to that location:

Go

The interactive Map below shows the location of currently operating wells. By pressing the Ctrl button and dragging the mouse on the map, you can zoom to various areas of the Fayetteville Shale. You can turn information on and off using the legend on the side of the map. You can display information about a particular feature by moving your mouse over it.

- ☑ Wells
- ☐ Production Data
- ☐ Drilling Permits (1 week ago)
- ☐ Drilling Permits (2 weeks ago)
- ☐ Drilling Permits (3 weeks ago)
- ☑ Sections

Permit #: 38338 -

OBJECTID: 15014
API: 03029101050000
WL_PERMIT: 38338
STATUS: Producing
STATUSSYM: Active
WL_TYPE: Natural Gas
S_T_R: 14 - 9N - 17W
LATITUDE: 35.43011
LONGITUDE: -92.76933
FIELD: B-43
ZONE:
DT_MOD: 8/14/2007 12:00:00 AM
PRODUCTION: 0
FAYSHALE: True

Input your address or well section # to zoom to that location

Go

Appendix B:

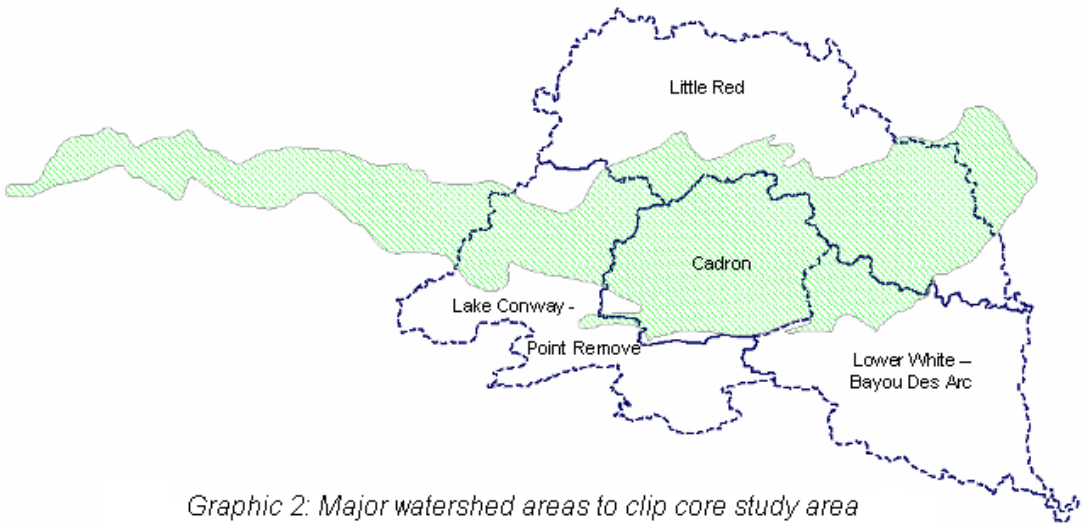
Terrestrial Habitat Mapping Project Report

Purpose: The purpose of this study is to create an up-to-date terrestrial habitat model for the core Fayetteville Shale area. Terrestrial habitat models organize landscapes into discrete categories based upon such things as geology, vegetative cover, terrain characteristics, land-use, etc. Habitat models are used for predicting the existence and location of animal species within the area modeled. The work proposed here focuses on terrestrial, non-aquatic, habitats.

Area of Interest: The western and central portions of the Fayetteville Shale region roughly coincide with the "Arkansas Valley Hills" ecoregion from the EPA Level IV Ecoregion map (shown in green hatching in graphic 1, below.) This ecoregion stretches west to east, north of the Arkansas River, from Ft. Smith to approximately 20 miles east of Searcy. (Graphic 1).

The area to be modeled is a subset of the "Arkansas Valley Hills" and forms the active core of the Fayetteville Shale region. This "active core" area covers approximately 180 square miles of north-central Arkansas. The exact extent of the core area boundary will be determined by four major watershed boundaries: Lower White Bayou Des Arc, Little Red, Lake Conway Point Remove, and Cadron. Only those areas of the Arkansas Valley Hills ecoregion that fall within these watersheds will be considered in this model. (Graphic 2).

Graphic 1: "Arkansas Valley Hills" (EPA Level 4 Ecoregions)



Graphic 2: Major watershed areas to clip core study area

The "core" area, shown in green in graphic 3, covers the most active exploration and extraction areas of the Fayetteville Shale region and takes in portions of Cleburne, Conway, Faulkner, Independence, Jackson, Pope, Van Buren, and White, counties in Arkansas. (Graphic3).

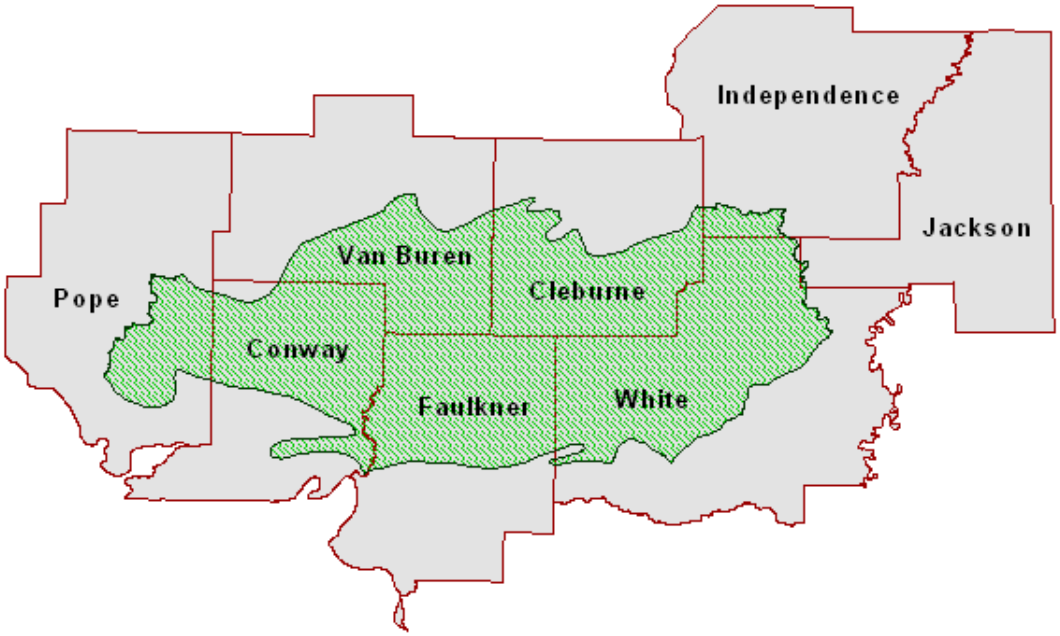
Project Component Status: All project components are on schedule and no delays are expected at this time. Components 1: (Pre-Fieldwork Planning) and 2: (Fieldwork) have been completed and component 3: (Data Preparation & Model Development) is underway. More specific information is given below in the "Project Component Status" section.

Component 1: Pre-Fieldwork Planning (Completed)

a) Category Definition: The terrestrial habitat model depends on a well defined, consistent set of habitat categories, and samples for each category type had to be collected in the field. The first step in our pre-fieldwork planning was to create a list of habitat types presently existing in the Arkansas Valley Hills region of Arkansas in cooperation with field scientists from the Arkansas Natural Heritage Commission, including state naturalist Thomas Foti. The list for the Arkansas Valley Hills region is a subset of the statewide "Terrestrial Habitats" list found in chapter four of the Arkansas Game and Fish Commissions Wildlife Action Plan http://www.wildlifearkansas.com/strategy.html. The study area Terrestrial Habitat list is as follows:

1) Cultivated Forest
2) Pasture Land
3) Central Interior Acid Cliff and Talus
4) Central Interior Highlands and Appalachian Sinkhole and Depression Pond
5) Central Interior Highlands Dry Acidic Glade and Barrens
6) Lower Mississippi Flatwoods Woodland and Forest
7) Ozark Ouachita Dry Oak Woodland
8) Ozark Ouachita Dry-Mesic Oak Forest
9) Ozark Ouachita Mesic Hardwood Forest
10) Ozark Ouachita Pine/Bluestem Woodland
11) Ozark Ouachita Pine-Oak Forest
12) Ozark Ouachita Pine-Oak Woodland
13) Ozark Ouachita Riparian

b) GPS equipment preparation and route planning: before going in the field for sample collection, several steps were taken to streamline the collection process. GPS data-logging units were prepared for fieldwork. Each GPS unit was installed with a "data dictionary" which enabled the rapid collection of our sample data points in the field. The data dictionary is a menu driven software package for GPS units that make it quick to collect both a map coordinate and associated attributes (from the category list above) for that coordinate in the field. Project personnel used GPS data loggers to collect sample points for each potential category. These attributed coordinate points will provide the TH model with real-world examples of each category for subsequent



Graphic 3: Core Study Area

classification (see component 3, below). Before going into the field, an optimal route was established to ensure that a good cross-section of sample types from all categories was collected.

Component 2: Fieldwork and Field Data Processing (Completed). Personnel from the University of Arkansas and the Arkansas Natural Heritage Commission (ANHC) have completed the fieldwork component of the project. ANHC personnel provided consultation on Arkansas' natural landscape and assisted in the collection of sample data points by guiding field workers to appropriate sample sites for each potential terrestrial category. Sample points were logged with GPS units in the field, and each point was attributed with its associated TH category. When necessary, notes were electronically attached to each point for subsequent referral. Upon completion of the field work, all sample points were post-processed (differentially corrected for improved spatial accuracy) and exported to the appropriate software format, i.e. ArcGIS shapefiles.

Component 3: Data Preparation & Model Development (In Progress). A number of new spatial data layers were prepared specifically for this project. As noted above, 5 meter spatial resolution terrain datasets (DEM, slope, and aspect maps) were prepared as inputs to the TH delineation model. Other datasets were also generated including a "distance to stream" map, and several map layers derived from the USDA SSURGO soils dataset. Finally, many pre-existing data layers are being processed: clipped, re-projected, converted to spatial, etc. for inclusion in the TH model. Project partners from the University of Arkansas and ANHC have met on two occasions to work out the details regarding data inputs to the delineation model.

Component 4: Model verification and data delivery (Not Begun).

Other Accomplishments: Three new, seamless data layers were developed for this project: a 5 meter spatial resolution digital elevation model (DEM), a 5 meter spatial resolution slope map (derived from the DEM), and a 5 meter spatial resolution aspect map (also derived from the DEM). These data layers mark a significant improvement in available terrain characterization data.

We are happy to announce that the terrestrial Habitat Mapping project has been enhanced through further cooperation with the Arkansas Natural Heritage Commission (ANHC). ANHC has

made significant in-kind contributions to this project, mostly through the consultation services of state naturalist Thomas Foti and his staff. They have also contributed to field work by covering their own transportation and per diem costs. ANHC has also funded an add-on project to map terrestrial habitats, using the procedures developed in this project, in the adjoining "Boston Mountain" ecoregion of Arkansas. This is welcome news, and bodes well for further habitat mapping, both in Arkansas, and around the region.