

Chapter 2

Study Methodology

This chapter outlines EPA's approach for completing Phase I of the study. This chapter describes the development of the study, the information collection and review process that EPA used, and the internal and external review process for the report.

2.1 Overview of the Study Methods

EPA developed the Phase I study methodology to assess the potential for contamination of USDWs due to the injection of hydraulic fracturing fluids into coalbed methane wells, and to determine, based on these findings, whether further study is warranted.

On July 25, 2000, EPA published a *Federal Register* notice (65 FR 45774 (USEPA, 2000)) requesting comment on a conceptual study design in order to receive stakeholder input on how an EPA study should be structured. On August 24, 2000, EPA held a public meeting to obtain additional stakeholder input on the proposed study design. EPA received more than 80 sets of comments from industry, state oil and gas agencies, environmental groups, and individual citizens in response to the *Federal Register* notice and public meeting. A summary of these comments can be viewed on EPA's Web site at www.epa.gov/safewater/uic/cbmstudy.

EPA revised its study approach in response to the comments it received on the conceptual study design. The final study design, "Study Design for Evaluating the Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs", was released in April 2001 and is available on the website referenced above.

One significant change in the final study design was EPA's decision to complete the study in a phased approach to efficiently address the stated project objectives. This phased approach, similar in design to that used in other complex studies, would allow EPA to use information gained in one phase to focus on the need for, and direction of, subsequent phases.

Phase I of the study was intended as a limited-scope assessment that would enable the Agency to determine if hydraulic fracturing of coalbed methane wells clearly poses little or no threat to USDWs, or if the practice may pose a threat. In Phase I, EPA:

- Gathered existing information to review hydraulic fracturing processes, practices and settings;
- Requested public comment to identify incidents that had not been reported to EPA; and
- Reviewed reported incidents of groundwater contamination and any follow-up

actions or investigations by other parties (state or local agencies, industry, academia, etc.).

In addition, as recommended by commenters, EPA decided to compile accounts of personal experiences with coalbed methane impacts on drinking water wells. These experiences are summarized in Chapter 6.

In its final study design, EPA indicated that the Agency would make a determination regarding whether further investigation was needed after analyzing the Phase I information. Specifically, EPA determined that it would not continue into Phase II of the study if the investigation found that no hazardous constituents were used in fracturing fluids, hydraulic fracturing did not increase the hydraulic connection between previously isolated formations, *and* reported incidents of water quality degradation could be attributed to other, more plausible causes.

EPA identified two possible mechanisms by which hydraulic fracturing fluid injection into coalbed methane wells could potentially affect the quality of USDWs:

1. Direct injection of fracturing fluids into a USDW in which the coal is located, or injection of fracturing fluids into a coal seam that is already in hydraulic communication with a USDW (e.g., through a natural fracture system).
2. Creation of a hydraulic connection between the coalbed formation and an adjacent USDW.

To determine if contamination might occur through either mechanism, EPA collected information on:

1. Hydraulic fracturing practices.
2. Hydraulic fracturing fluids and additives to determine whether these substances contain hazardous constituents.
3. The hydrogeology of the coalbed methane basins, including the identification of coal seams that are located in USDWs.
4. Water quality incidents potentially associated with hydraulic fracturing.

EPA anticipated that sufficient information would be available to evaluate the impacts of direct injection into USDWs because the main considerations are the location of the coal formations relative to USDWs and the chemical constituents in hydraulic fracturing fluids. The Agency further anticipated that documenting USDW impacts via the creation of a hydraulic connection between the coalbed formation and adjacent USDW(s) would be more difficult. This is because more detailed, site-specific, geological information or

data for specific fracturing events needed to definitively document such a hydraulic communication are not readily available. Site-specific data include:

- Water quantity and quality conditions in a USDW (or a well) both before and after a fracturing event;
- Location, dimensions, and conductivity of fractures created during the coalbed stimulation event;
- Measured changes in groundwater flow between the USDW and coalbeds or other aquifers; and
- Impacts of other, unrelated, hydrologic and water quality processes that could also be affecting the USDW.

2.2 Information Sources

EPA obtained available literature and information through:

- Literature reviews.
- Coordination with DOE.
- Interviews with companies that perform hydraulic fracturing and interviews with citizens, local and state authorities, the Bureau of Land Management and EPA Region 8 personnel.
- Field visits.
- Responses to EPA's *Federal Register* request (66 FR 39396 (U.S. EPA, 2001)) for information on incidents of groundwater contamination believed to be associated with hydraulic fracturing of coalbed methane wells.

EPA researched more than 200 peer-reviewed publications, interviewed approximately 50 employees from industry and state or local government agencies, and communicated with approximately 40 citizens and groups who are concerned that CBM production affected their drinking water wells.

The procedure that EPA used to obtain information from each of these sources is discussed in more detail below. A copy of the quality assurance protocol that EPA employed to verify all the sources of data used to write this report is provided as Appendix B.

2.2.1 Literature Reviews

EPA conducted a review of existing literature and information on hydraulic fracturing for coalbed methane production. The focus of the literature review was to obtain information on topics 1 through 3 listed in Section 2.1, above.

The degree to which information was available for each of the 11 coalbed basins in the report was variable. The amount of information available depended on the extent of exploration and production in each basin.

EPA conducted an extensive literature search, using the Engineering Index and GeoRef on-line reference databases, for abstracts from technical articles, books, and proceedings. EPA also conducted Internet-based searches to locate additional information using relevant Web sites located using various search engines, including Google™, Yahoo®, and Alta Vista®. EPA used specialized search engines, such as those provided on state geological survey Web sites and by the Gas Technology Institute (GTI) for specific queries. All relevant Web sites were logged in project books and referenced in this report when cited.

EPA conducted these literature searches by subject topics and using the following key words, either separately or in combination: coal basin, coalbed methane, cross-linked gel, fracturing fluid additives, fracturing fluid technology, fracturing fluid performance, fracturing fluids, ground water, hydraulic fracturing, hydraulic fracture dimension, hydraulic fracture growth, hydrology, linear gel, methane gas production, nitrogen foam, underground sources of drinking water, and USDWs. EPA printed, catalogued, and surveyed all results of searches for pertinent journal articles, books, and conference proceedings containing information that might meet the specific data needs of this report.

EPA acquired most of the pertinent articles, which were identified from the Engineering Index and GeoRef on-line reference databases, from the University of Texas Library in Austin because this library's holdings include an extensive collection of publications related to oil and gas production. EPA researched references from the University of Texas documents and acquired those documents that were relevant to the study. Only a small fraction of the pertinent articles, specifically proprietary articles and articles published for overseas conferences were unavailable. EPA also acquired articles from GTI. EPA has archived, by topic, all papers collected for the study.

To verify key information extracted from the literature, EPA contacted by phone relevant organizations such as state regulatory agencies, state geological surveys, natural gas companies, GTI, and service companies. The Agency used telephone logs to document all communications. Personal conversations with the employees of the various organizations yielded additional information in the form of reports, figures, and maps, as well as statements based on best professional judgment and experience. These were collected, documented, and referenced in conjunction with the literature identified in the literature searches. The majority of the literature pertaining to coalbed methane basins

and hydraulic fracturing was written in the early to mid 1990s. According to the Texas Bureau of Economic Geology (TBEG) (personal communication, TBEG Staff, 2000), this period of intense activity was a result of the emphasis placed on gas exploration by the Section 29 Tax Credit of the Crude Oil Windfall Profit Tax Act of 1980 and research grants to industry, academia, and government agencies. The Section 29 credit does not, however, apply to coal gas wells drilled after December 31, 1992.

2.2.2 Department of Energy

EPA reviewed information from DOE's "White Paper" on hydraulic fracturing practices. This paper addresses the following topics:

- Objectives of hydraulic fracturing.
- How candidate wells are selected for hydraulic fracturing.
- How fracture treatments are designed.
- Field operation considerations.
- Physics of fracture formation in coalbeds.
- Fracturing fluids.
- Stimulation techniques used for developing coalbeds.
- Instrumentation/methods for tracking fractures.

The complete DOE paper is included as Appendix A, and excerpts from this paper are included in Chapter 3, Characteristics of Coalbed Methane Production and Associated Hydraulic Fracturing Practices.

2.2.3 Interviews

EPA contacted hydraulic fracturing service companies including BJ Services Company, Halliburton Energy Services, Inc., and Schlumberger Technology Corporation, as well as a fracturing fluids producer, Hercules, Inc., to obtain information regarding the content of hydraulic fracturing fluids and additives they use or manufacture. Two companies, Halliburton and Schlumberger, provided EPA with material safety data sheets (MSDSs) for several hydraulic fracturing fluids and additives. The MSDSs were reviewed to determine the nature of the constituents in fracturing fluids used to stimulate coalbed methane production. These topics are discussed in Chapter 4, Hydraulic Fracturing Fluids.

EPA also evaluated reports from individuals and organizations that are concerned that their drinking water supplies were affected by hydraulic fracturing. These reported personal experiences came from Colorado, New Mexico, Wyoming, Alabama, and Virginia. In response to these reports, EPA conducted telephone interviews with citizens, local and state authorities, the Bureau of Land Management and EPA Region 8 personnel. EPA also evaluated state agency responses to any complaints received by EPA or state agencies. The Agency also evaluated the available data to determine whether

there is sufficient information to reveal the source of the alleged water quality contamination.

2.2.4 Field Visits

EPA conducted field visits in Colorado, Kansas, and Virginia to better understand how local coalbed methane production activities may vary from basin to basin. In addition, during the field visits, EPA was able to meet with concerned local citizens and state agencies to discuss coalbed methane production issues. A summary of these field visits is outlined below.

In August 2000, EPA met with a group of concerned citizens, officials from the Colorado Oil and Gas Conservation Commission, and representatives of the La Plata County government. EPA witnessed a fracturing event, reviewed records including temperature logs of past fracturing events conducted on coalbed methane wells, and performed a reconnaissance of the area allegedly affected by coalbed methane production.

In August 2001, EPA met with the Virginia Department of Mines, Minerals and Energy, the agency that regulates the coalbed methane production industry in Virginia. The Department provided information about the state's investigation of water quality incidents potentially associated with coalbed methane production in the Central Appalachian Valley. The Department also submitted water quality incident reports for review by EPA. During this visit, EPA met with concerned citizens in Virginia. Citizens groups from Buchanan and surrounding counties were invited to meet with EPA and DOE staff to discuss water quality issues believed to be related to local hydraulic fracturing of coalbed methane wells. Notes from the meeting are referenced in Chapter 6.

EPA also organized a field visit with Consol Energy, Inc. and Halliburton to witness a hydraulic fracturing event. Halliburton performed a hydraulic fracture job on a coalbed methane well in western Virginia using equipment, fracturing fluids, and techniques, which are typical of those described in the literature. EPA was able to observe the fracturing process and collect information, including MSDSs from the service company and gas company engineers. The information from this field visit was used to supplement the data on hydraulic fracturing fluids in Chapter 4.

In November 2001, EPA witnessed a fracturing event in Wilson County, Kansas, to gain a better understanding of the regional geology and hydraulic fracturing practices in the area. In attendance were Colt Energy (the well operator); Consolidated Industrial Services, Inc. (the service company conducting the fracture job); and two state agencies, the Kansas Corporation Commission, and the Missouri Department of Natural Resources. MSDSs for fracturing fluids typically used in the area were also provided to EPA by the Kansas Corporation Commission.

2.2.5 Federal Register Notice to Identify Reported Incidents

EPA provided an opportunity for the public to submit information on any impacts to groundwater believed to be associated with hydraulic fracturing through a request for public comment (66 FR 39396 (USEPA, 2001)). EPA also sent copies of the *Federal Register* notice with a cover letter to county-level public health and/or environmental officials in counties that may be producing coalbed methane. In addition, letters were sent to stakeholders informing them that the *Federal Register* notice had been published. Responses to the *Federal Register* notice are available at EPA's water docket (docket number W-01-09; Water Docket (MC 4101); Rm EB 57; U.S. Environmental Protection Agency; 1200 Pennsylvania Avenue, NW; Washington, DC 20460; phone number: (202) 566-2426). A summary of the comments is provided in Chapter 6.

2.3 Review Process

This report has benefited from a series of internal and external technical reviews. EPA verified information through telephone interviews with state and local officials, as well as through the Agency's internal quality assurance process. EPA conducted a quality assurance review of the data collection procedures as well as a review of the individual literature sources cited in the report. In addition, more than nine EPA offices reviewed and commented on the draft report. Other federal agencies that reviewed the draft report included DOE and the U.S. Geological Survey (USGS).

In 2001, EPA also submitted the draft report to a scientific peer-review panel consisting of experts from industry, academia, and government agencies. The panel's task was to review the draft report and provide comments on the descriptions and conclusions developed by EPA. The panel also provided information about additional data sources to supplement those used in the report. Following receipt of comments on the draft report, EPA made the appropriate changes to the document prior to its publication and release.

EPA made the report available for public comment by an announcement in the *Federal Register* on August 28, 2002 (67 FR 55249 (USEPA, 2002)). The 60-day public comment period officially ended on October 28, 2002. The Agency received and reviewed comments from 105 commenters and incorporated many of these comments into this final Phase I report. A summary of the public comments and EPA's responses is provided in, "Public Comment and Response Summary for the Study on the Potential Impacts of Hydraulic Fracturing of Coalbed Methane Wells on Underground Sources of Drinking Water" (EPA 816-R-04-004), available on EPA's electronic docket.