

## **Chapter 1**

### **Introduction**

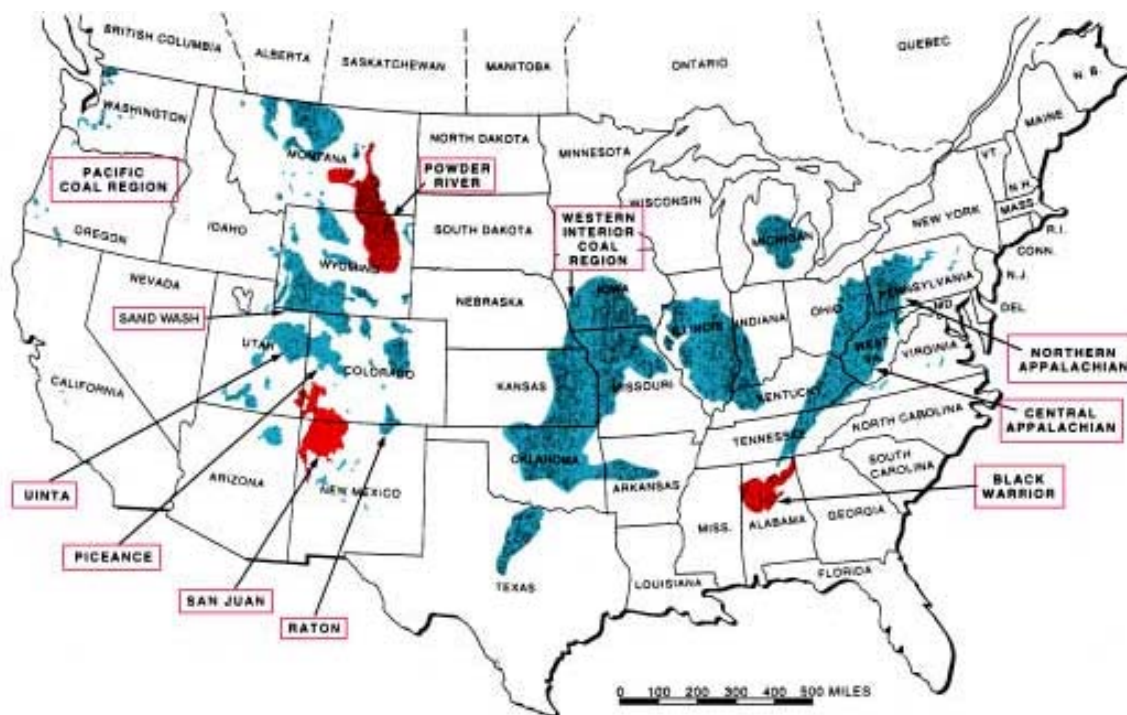
Section 1421 of SDWA tasks EPA with protecting USDWs for all current and future drinking water supplies across the country (see section 1.3 for the complete definition of a USDW). EPA's UIC Program is responsible for ensuring that fluids injected into the ground (for purposes including waste disposal, oil field brine disposal, enhanced recovery of oil and gas, mining, and emplacement of other fluids) do not endanger USDWs.

EPA, through its UIC Program, conducted a fact-finding effort based primarily on existing literature. The goal of this study was 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. For the purposes of this study, EPA assessed USDW impacts by the presence or absence of documented drinking water well contamination cases caused by coalbed methane hydraulic fracturing, clear and immediate contamination threats to drinking water wells from coalbed methane hydraulic fracturing, and the potential for coalbed methane hydraulic fracturing to result in USDW contamination based on two possible mechanisms as follows:

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.

EPA obtained information for this study from literature searches, field visits, a review of reported groundwater contamination incidents in areas where coalbed methane is produced, and solicitation of information from the public on any impacts to groundwater believed to be associated with hydraulic fracturing.

EPA also reviewed 11 major coal basins throughout the United States to determine if coalbeds are co-located with USDWs and to understand the coalbed methane activity in the area (Figure 1-1). The basins shown in red have the highest coalbed methane production volumes. They are the Powder River Basin in Wyoming and Montana, the San Juan Basin in Colorado and New Mexico, and the Black Warrior Basin in Alabama. Hydraulic fracturing is or has been used to stimulate coalbed methane wells in all basins, although it has not frequently been used in the Powder River, Sand Wash, or Pacific Coal Basins.

**Figure 1-1. Locus Map of Major United States Coal Basins**

### 1.1 EPA's Rationale for Conducting This Study

Although coalbed methane has many environmental advantages over traditional energy sources, concerns have been raised regarding the environmental impacts of coalbed methane production. Coalbed methane production in certain areas has led to groundwater depletion and production water discharge issues (i.e., issues that are not associated with the quality of USDWs). Citizens, state agencies, producers, and the regional EPA offices in those areas are working in concert to better understand and mitigate these potential problems.

This study examines the potential for hydraulic fracturing fluid injection into coalbed methane wells to contaminate USDWs. EPA conducted this study in response to allegations that hydraulic fracturing of coalbed methane wells has affected the quality of groundwater (i.e., issues that are associated with the mandates of the UIC Program). State oil and gas agencies receiving such complaints have indicated that, based on their investigations, hydraulic fracturing of coalbed methane wells has not contributed to water quality degradation in USDWs.

In response to an Eleventh Circuit Court of Appeals (hereafter, "the Court") decision [*LEAF v. EPA*, 118F.3d 1467 (11<sup>th</sup> Cir, 1997)], the State of Alabama recently

supplemented its rules governing the hydraulic fracturing of wells to include additional requirements to protect USDWs during the hydraulic fracturing of coalbeds for methane production. Prior to the Court's decision, EPA had not considered hydraulic fracturing as an underground injection activity, because the Agency did not consider production well stimulation as an activity subject to UIC regulations. Nevertheless, the Court held that the injection of fluids for the purpose of hydraulic fracturing constitutes underground injection as defined under SDWA, that all underground injection must be regulated, and that hydraulic fracturing of coalbed methane wells in Alabama must be regulated under Alabama's UIC program.

In the wake of the Eleventh Circuit Court decision, EPA decided to assess the potential for hydraulic fracturing fluid injection into coalbed methane wells to contaminate USDWs. EPA's decision to conduct this study was also based on concerns voiced by individuals who may be affected by coalbed methane development, Congressional interest, and the need for additional information before EPA could make any further regulatory or policy decisions regarding hydraulic fracturing.

## **1.2 Overview of Hydraulic Fracturing**

Hydraulic fracturing is a technique used by the oil and gas industry to improve the production efficiency of oil and coalbed methane wells. The hydraulic fracturing process uses high hydraulic pressures to initiate a fracture. A hydraulically induced fracture acts as a conduit in the rock or coal formation that allows the oil or coalbed methane to travel more freely from the rock pores to the production well that can bring it to the surface.

In the case of coalbed methane gas production, the gas is not structurally "trapped" under pressure. Rather, most of the coalbed methane is adsorbed within small pores in the "micro-porous matrix" of the coal (Koenig, 1989; Winston, 1990; Close, 1993). When coalbed methane production begins, water is first pumped out (or "produced" in the industry terminology) from the fractures, joints, and cleats (i.e., tiny, disconnected clusters of fractures) in the coal until the pressure declines to the point that methane begins to desorb from the coal matrix itself (Gray, 1987).

To extract the coalbed methane, a production well is drilled through rock layers to intersect the coal seam that contains the coalbed methane. Next, a fracture is created or enlarged in the coal seam to connect the well bore to the coalbed joint/cleat system. To create such a fracture, a thick, water-based fluid is pumped into the coal seam at a gradually increasing rate. At a certain point, the coal seam will not be able to accommodate the fracturing fluid as quickly as it is being injected. When this occurs, the pressure is high enough that the coal gives way, and a fracture is created or an existing fracture is enlarged. To hold the fracture open, a propping agent, usually sand (commonly known as "proppant"), is pumped into the fracture so that when the pumping pressure is released, the fracture does not close completely because the proppant is "propping" it open. The resulting fracture filled with proppant becomes a conduit

through which water can flow to the production well, thus depressurizing the coal matrix, allowing for the desorption of methane and its flow towards the production well.

The extent of the fracture in a coalbed is controlled by the characteristics of the geologic formation (including the presence of natural fractures), the fracturing fluid used, the pumping pressure, and the depth at which the fracturing is performed. Whether the fracture grows taller or longer is determined by the properties of the surrounding rock. A hydraulically created fracture will always take the path of least resistance through the coal seam and surrounding formations.

A more comprehensive discussion of the fracturing process and the fracturing fluids/additives used in hydraulic fracturing of coalbed methane wells is presented in Chapters 3 and 4, respectively.

### **1.3 EPA's Authority to Protect Underground Sources of Drinking Water**

SDWA requires EPA and EPA-authorized states to have effective programs to prevent underground injection of fluids from endangering USDWs (42 U.S.C. 300h et seq.). Underground injection is the subsurface emplacement of fluids through a well bore (42 U.S.C. 300h(d)(1)). Underground injection endangers drinking water sources if it may result in the presence of any contaminant in underground water which supplies or can reasonably be expected to supply any public water system, and if the presence of such contaminant may result in such system's noncompliance with any national primary drinking water regulation (i.e., maximum contaminant levels) or may otherwise adversely affect the health of persons (42 U.S.C. 300h(d)(2)). SDWA's regulatory authority extends to underground injection practices; SDWA does not provide a general grant of authority for EPA to regulate oil and gas production.

A USDW is defined in the UIC regulations at 40 CFR 144.3 as an aquifer or a portion of an aquifer that:

- "A.
  - 1. Supplies any public water system; or
  - 2. Contains sufficient quantity of groundwater to supply a public water system; and
    - i. currently supplies drinking water for human consumption; or
    - ii. contains fewer than 10,000 milligrams per liter (mg/L) total dissolved solids (TDS); and
- B. Is not an exempted aquifer."

The water quality standard for USDWs is more stringent than EPA's National Secondary Drinking Water Standards for potable water, which cover aesthetic concerns such as taste and odor. These secondary standards recommend a TDS limit of 500 mg/L (40 CFR 143.3).

An accurate understanding of the definition of USDW requires understanding of two other terms: public water system and aquifer exemption.

A public water system is defined at 40 CFR 141.2 as:

“A system for the provision to the public of water for human consumption through pipes or, after August 5, 1998, other constructed conveyances, if such a system has at least 15 service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year.”

To better quantify the definition of USDW, EPA determined that any aquifer yielding more than 1 gallon per minute can be expected to provide sufficient quantity of water to serve a public water system and therefore falls under the definition of a USDW (U.S. EPA Memorandum, 1993). EPA also assumes that all aquifers contain sufficient quantity of groundwater to supply a public water system, unless proven otherwise through empirical data.

An aquifer exemption may be granted under certain circumstances. According to 40 CFR 144.3, an exempted aquifer meets the definition of a USDW, but has been exempted according to the procedures in 40 CFR 144.7. An aquifer, or portion thereof, can be designated as an exempted aquifer, if it meets the following criteria (40 CFR 146.4):

1. It does not currently serve as a source of drinking water; and,
2. It cannot now and will not in the future serve as a source of drinking water because it is:
  - Mineral, hydrocarbon, or geothermal energy producing, or can be demonstrated to be commercially producible; or
  - Situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical; or
  - So contaminated that it would be economically or technologically impractical to render that water fit for human consumption; or
  - Located over a Class III well mining area subject to subsidence or catastrophic collapse; or,
3. The TDS content of the groundwater is more than 3,000 and less than 10,000 mg/L and, it is not reasonably expected to supply a public water system.

All requests for aquifer exemptions must be approved by the EPA Administrator or an authorized representative. A list of exempted aquifers, for states where such exemptions exist, is maintained by the state agency managing the UIC program or the regional EPA office. A comprehensive list or map identifying all USDWs in every state does not exist.

Identification of USDWs is an ongoing effort, as is EPA's consideration of aquifer exemptions. For example, coalbed methane production wells using hydraulic fracturing to stimulate production may be located in areas that coincide with existing aquifer exemptions.

Currently, injection associated with hydraulic fracturing of coalbed methane production wells is regulated only in Alabama under the state UIC program, and that injection activity falls under the category of Class II wells (Alabama Oil and Gas Board, Administrative Code, Oil and Gas Report 1, 400-3). Class II wells include the injection of brines and other fluids that are associated with oil and gas production.

#### **1.4 Potential Effects of Hydraulic Fracturing of Coalbed Methane Wells on USDWs**

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

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

Fracturing fluids can be directly or indirectly injected into a USDW, depending on the location of the coalbed relative to a USDW. In many coalbed methane-producing regions, the target coalbeds occur *within* USDWs, and the fracturing process injects stimulation fluids directly into the USDWs (Figure 1-2 at the end of the chapter). In other production regions, target coalbeds are adjacent to the USDWs, which are either higher or lower in the geologic section. EPA investigated the potential for fractures to extend through stratigraphic layers that separate coalbeds and USDWs and the potential for stimulation fluids to indirectly enter a USDW during the fracturing process (Figure 1-3 at the end of the chapter).

Local geologic conditions may interfere with the complete recovery of fracturing fluids injected into a formation. As a result, some of the fracturing fluids may be "stranded" in the USDW (Figures 1-2 and 1-3). Any hazardous constituents in the stimulation fluids could potentially contaminate groundwater in a USDW and any drinking water supplies that rely on the USDW.

## 1.5 Study Approach

Given the enormous variation in geology among and within coalbed basins in the United States, any initial evaluation of potential impacts by hydraulic fracturing of coalbeds on USDWs at a national level would necessarily be broadly focused. Based on public input, EPA decided to carry out this study in discrete phases to better define its scope and to determine if additional study is needed after assessing the results of the preliminary phase(s). EPA designed the study to have three possible phases, changing the focus from general to more specific as findings warrant.

Phase I of the study is a fact-finding effort based primarily on existing literature to identify and assess the potential threat to USDWs posed by hydraulic fracturing fluid injection into coalbed methane wells. It is designed to determine if site-specific detailed studies, including collection of new data, are needed. An overview of the methodology used for Phase I is provided below; a detailed discussion of this methodology is provided in Chapter 2.

In Phase I, EPA:

- Conducted a literature review for information on hydraulic fracturing processes, hydraulic fracturing fluids and additives, the geologic settings of and the hydraulic fracturing practices used in the 11 major coal basins (Figure 1-1), and the identification of coal seams that are co-located with USDWs.
- Published a request in the *Federal Register* (66 FR 39396 (U.S. EPA, 2001)) for information from the public, as well as governmental and regulatory agencies, regarding incidents of groundwater contamination believed to be associated with hydraulic fracturing of coalbed methane wells.
- Reviewed reported incidents of groundwater contamination and any follow-up actions or investigations by other parties such as state or local agencies, industry, and academia.
- Conducted field visits in three states.

In addition, EPA collaborated with the Department of Energy (DOE) to produce a document that details the technical aspects of hydraulic fracturing in the oil and gas industry. This document is included as Appendix A to this report.

EPA also provided support for a site-specific study, which was conducted by the Geological Survey of Alabama (GSA). This study attempts to address a concern that is central to USDW contamination and drawdown issues: the degree to which flow is confined within coalbeds in coalbed methane fields. Information on the GSA study is available at <http://www.gsa.state.al.us/gsa/3DFracpage/3Dfracstudy.htm>.

## 1.6 Stakeholder Involvement

EPA took several steps to fully involve the public and all stakeholders during the study. These steps included:

- Publishing *Federal Register* notices:
  - requesting comments on the study plan (65 FR 45774 (USEPA, 2000));
  - requesting information from the public on any impacts to groundwater believed to be associated with hydraulic fracturing of coalbed methane wells (66 FR 39396 (USEPA, 2001));
  - Requesting comments on the August 2002 draft of the study (67 FR 55249 (USEPA, 2002)).
- Holding a public meeting to obtain additional stakeholder input on the proposed study plan published in the July 2000 *Federal Register* notice (65 FR 45774 (USEPA, 2000))
- Providing periodic updates for stakeholders in the form of written communication.
- Maintaining a Web site where stakeholders can view the project documents and provide information to EPA.

EPA also received and reviewed comments from 105 commenters submitted in response to the August 2002 *Federal Register* notice (67 FR 55249 (USEPA, 2002)), which announced the availability of the August 2002 version of this Phase I study report. EPA 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.

## 1.7 Information Contained within This Report

This Phase I report is composed of an executive summary, 7 chapters, 11 attachments, and 2 appendices. The main chapters address the following topics:

- Chapter 2, Study Methodology, discusses in detail EPA's method for collecting information under Phase I of the study.
- Chapter 3, Characteristics of Coalbed Methane Production and Associated Hydraulic Fracturing Practices, discusses the hydraulic fracturing process as it applies to coalbed methane production.



- Chapter 4, Hydraulic Fracturing Fluids, describes the use and nature of hydraulic fracturing fluids and their additives. It also discusses EPA's evaluation of the fate and transport of fracturing fluids that are injected into targeted coal layers during the hydraulic fracturing process.
- Chapter 5, Summary of Coalbed Methane Basin Descriptions, briefly describes each of the 11 major coal basins in the United States and discusses the potential for impacts to USDWs in these basins.
- Chapter 6, Water Quality Incidents, in response to stakeholders' recommendations, summarizes water quality and quantity complaints received from citizens pertaining to hydraulic fracturing, coalbed methane production, and well stimulation.
- Chapter 7, Summary of Findings, summarizes the major findings presented in Chapters 3 through 6.

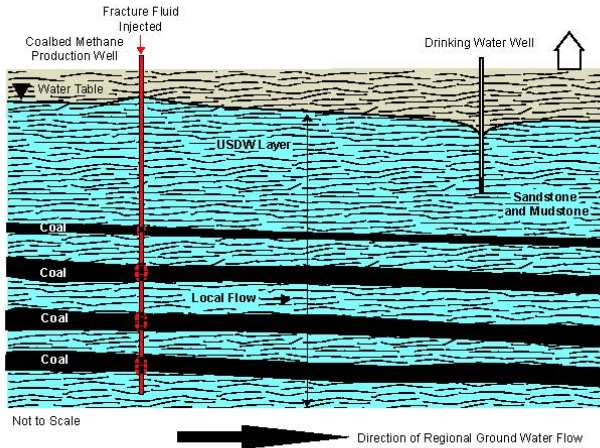
In addition, Chapters 3 through 6 contain numerous figures and tables to help readers visualize the hydraulic fracturing process and to help summarize some of the key information in the report.

The attachments to the report are a collection of in-depth hydrologic investigations of the 11 coal basins, focusing primarily on the coalbed methane production activities and the relationship between coalbed and USDW locations within these 11 basins. The attachments expand the discussions of Chapter 5 with greater details on the specific geology and gas production activities for the 11 basins.

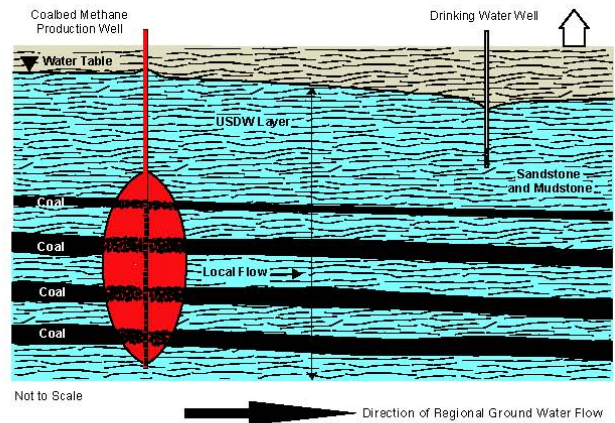
Appendix A, Hydraulic Fracturing, contains DOE's technical report on hydraulic fracturing. Appendix B, Quality Assurance Protocol, explains the quality assurance and quality control measures EPA used to conduct this study.

**Figure 1-2. Hypothetical Mechanism - Direct Fluid Injection Into a USDW (Coal within USDW)**

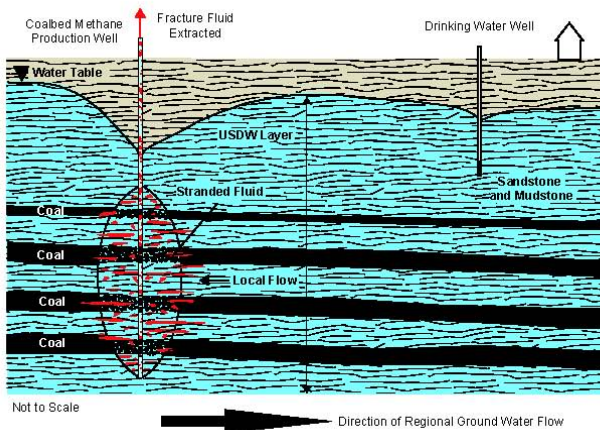
**Step 1:**  
Fracture Fluid is Injected into Coalbed Seams



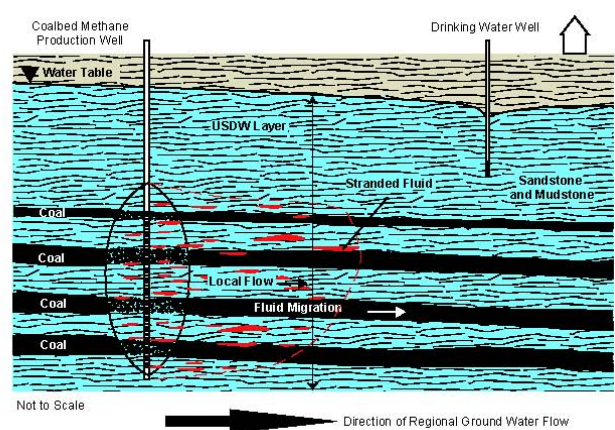
**Step 2:**  
Fracture Created

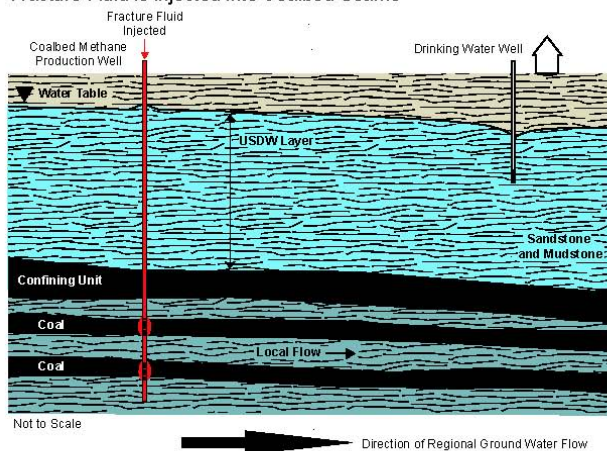
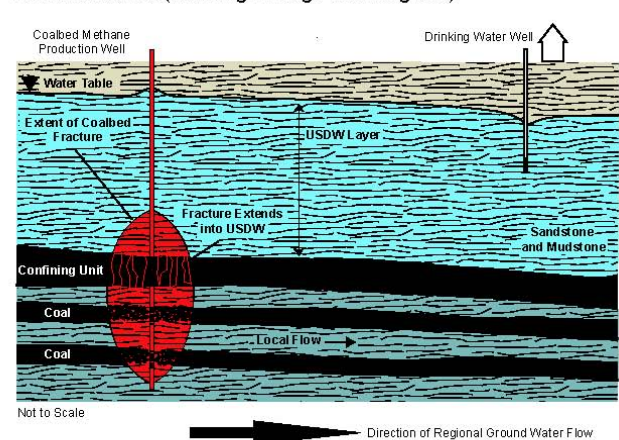
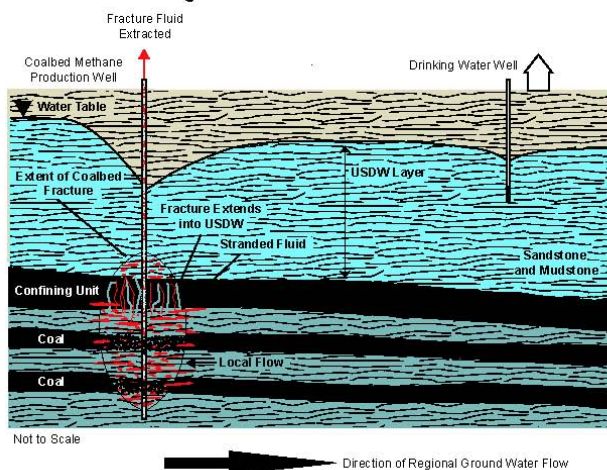


**Step 3:**  
Some Fluid Stranded During Production



**Step 4:**  
Stranded Fluid Migration Post-Production



**Figure 1-3. Hypothetical Mechanism - Fracture Creates Connection to USDW****Step 1:****Fracture Fluid is Injected into Coalbed Seams****Step 2:****Fracture Created (Breaking Through Confining Unit)****Step 3:****Fluid Stranded During Production****Step 4:****Stranded Fluid Migration in Coal Formation and USDW Post-Production**