RCSP Water Working Group

Monitoring, Verification, and Accounting Plans for Protection of Water Resources During the Geologic Storage of Carbon Dioxide

Introduction

Geologic storage (GS) is an evolving strategy being investigated for the long-term management of carbon dioxide (CO_2) emissions. A key component of CO_2 GS is the presence of cost-effective and efficient CO_2 monitoring, verification, and accounting (MVA) programs designed to demonstrate that each GS site is performing as anticipated, CO_2 is being sequestered, and water resources are being protected (Figure 1). The U.S. Department of Energy's (DOE's) Carbon Storage Program is researching, developing, and demonstrating a wide variety of the technologies for GS, including those needed for MVA. This fact sheet, developed by DOE's Water Working Group, focuses on the monitoring aspects of the MVA framework and provides an overview of the monitoring technologies that are being investigated for the protection of water resources.

Figure 1. Water sampling at a CO_2 GS demonstration site.

MVA Monitoring Framework for GS Projects

An MVA monitoring framework has evolved that captures both the physical and temporal aspects of a typical GS project. This monitoring framework focuses on three distinct vertical zones: atmospheric, near surface, and subsurface, during four distinct periods of operation: preoperation (or baseline), operation, closure, and postclosure (U.S. Department of Energy, 2009) (Figure 2). The framework comprises appropriate monitoring technologies needed to validate GS storage performance and to meet applicable EPA permit requirements. For the protection of water resources, i.e., underground sources of drinking water (USDW) and surface water bodies, these potential pathways include 1) natural leakage from the reservoir through cap rock seals, 2) leakage from the reservoir through cap rock faults and fractures, and 3) leakage from reservoirs through wellbores. Diligent site characterization activities are the first line of defense for addressing these migration pathways, with the goal of screening out those sites where they pose a measureable risk. However, the potential existence of these pathways should still be addressed on a site-by-site basis along with other potential pathways that may be unique to individual sites.

An MVA plan contains a mixture of monitoring techniques designed to detect the presence or absence of migration along each of these pathways and to provide assurance that storage site integrity is maintained. Should migration along a potential leakage pathway be detected, the MVA plan provides the basis for implementing mitigation strategies (e.g., halting CO_2 injection or implementing pump and treat scenarios), if required, to prevent and/or reduce the impacts of this migration to water resources.

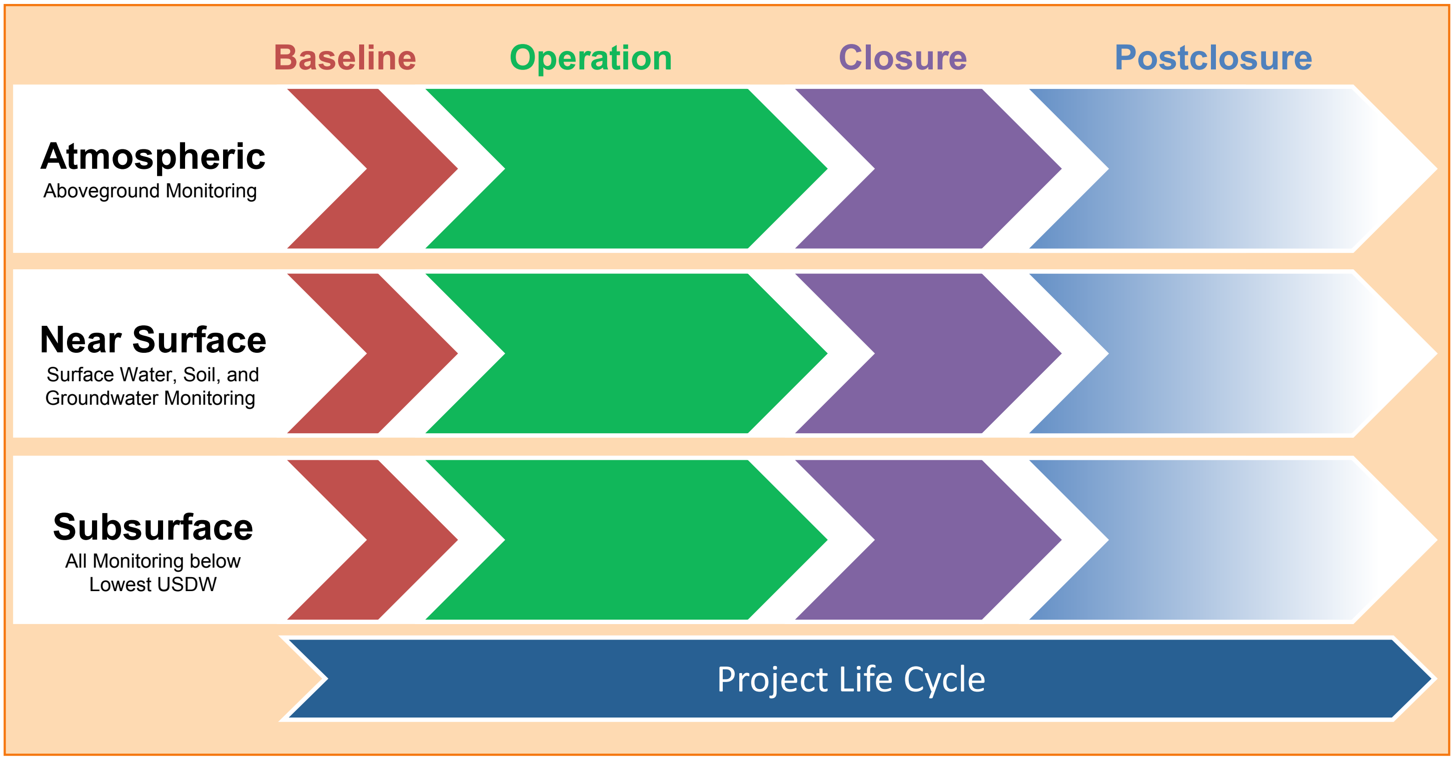

Figure 2. Monitoring occurs in all periods of GS project operation (baseline, operation, closure, and postclosure) in three distinct vertical zones (atmospheric, near surface, and subsurface).

Baseline data are critical in establishing variability of monitored parameters before injection begins. In some cases, a year or more of baseline data may be needed to adequately establish preinjection conditions. After baseline has been established, it may be qualitatively and quantitatively compared to data from other phases of the project to assess the potential leakage pathways and to verify that impacts have not occurred to the environment.

Candidate Monitoring Technologies

Table 1 presents a subset of the potential monitoring technologies that are available for use in MVA plans at GS projects (U.S. Department of Energy, 2009). These monitoring technologies have been grouped based on the three previously identified vertical monitoring zones with the understanding that several of these monitoring techniques can be used in more than one monitoring zone and will have different benefits and challenges in different zones.

The monitoring technologies in Table 1 are further classified as primary and secondary MVA technologies. Primary technologies are considered fully capable of both meeting and exceeding the U.S. Environmental Protection Agency's (EPA's) underground injection control (UIC) Class VI monitoring requirements (Federal Register, 2010) and meeting DOE's MVA goals of achieving 99% storage of injected CO_2. Secondary technologies are typically routine, often low-cost measurements that have been applied to other applications such as oil field monitoring or environmental remediation. There is also a third category of MVA technologies, designated as potential additional MVA technologies, which are promising tools being developed to better understand the long-term behavior of CO_2 in the broad portfolio of potential GS sites. These technologies, which are undergoing additional research, are not listed in Table 1 but can be found in Table 5 of U.S. DOE (2009).

Many of the monitoring techniques in Table 1 focus on determining the presence and movement of CO_2. This information can be used to anticipate contact with subsurface and surface water resources, providing early warning of these potential impacts. Other techniques such as groundwater and surface water monitoring provide direct measurements of the characteristics of the water resources. These monitoring results are effective in determining the presence or absence of impacts to water resources. All of these monitoring efforts will help establish public confidence in the integrity of CO_2 GS.

All of the technologies in Table 1 were identified as candidates for investigation as part of the Phase III demonstration tests of DOE's Regional Carbon Sequestration Partnerships (RCSPs). These demonstration tests were initiated in 2007 and will operate through 2017. In addition, several of the technologies have been the subject of investigations in other large-scale GS demonstrations conducted by other research organizations throughout the world (U.S. Department of Energy, 2012).

MVA at Large-Scale GS Demonstration Projects

The Petroleum Technology Research Centre (PTRC) recently released its best management practices (BMP) for the Weyburn–

Table 1. Candidate MVA Monitoring Technologies

Atmospheric	Near Surface	Subsurface
Objectives		
• Ambient CO_2 Concentration • CO_2 Surface Flux	• Groundwater monitoring • Fluid chemistry • Soil gas monitoring • Crustal deformation • Leak detection • Vegetative stress monitoring • Vadose zone characterization	• Groundwater monitoring • Soil gas monitoring • Leak detection • Subsurface and reservoir characterization • Plume tracking • Well integrity testing
Primary and Secondary MVA Technologies		
• CO_2 Detectors** • Laser Systems and Lidar**	• Groundwater monitoring* • Flux accumulation chamber** • Soil and vadose zone monitoring** • Ecosystem stress monitoring** • Shallow 2-D seismic**	• Annulus pressure monitoring* • Cement bond log (ultrasonic well logging)* • Crosswell seismic survey** • Density logging (RHOB log)* • Gamma ray logging* • Pulsed-neutron logging* • Sonic (acoustic) logging* • 2-D seismic survey** • Optical logging** • Aqueous geochemistry** • Multicomponent 3-D surface seismic time-lapse survey** • Vertical seismic profile (VSP)**

* Primary technology.
** Secondary technology.

Midale enhanced oil recovery/GS project in Canada. This BMP provides detailed descriptions of MVA approaches for the protection of water resources (Petroleum Technology Research Centre, 2012; International Journal of Greenhouse Gas Control, 2013). In addition, DOE recently updated its earlier document regarding BMP for MVA of GS projects (U.S. Department of Energy, 2012). As part of this effort, insights gained from the use of monitoring technologies by the RCSPs, as well as other large-scale demonstration tests, are presented. In summary, the waters that were targeted for analysis at these demonstration test sites and the nature of the analyses that were performed are as follows:

- Surface water, shallow groundwater wells (140 to ~1000 feet, both public and private) and upper- and lowermost USDWs:
  - Major cations, anions, pH, and other water quality measurements
  - Common trace constituents of concern
  - Isotopic analysis

- Formation water and brines (at point of CO_2 injection and monitoring wells at injection depth)
  - pH, iron, and manganese, among other water quality parameters
  - Geochemical and tracer analyses
  - Ion chromatography (e.g., mobilization of metals), isotopic analyses, salinity, major ions, and HCO_3^{1-}, CO_3^{2-}, and CO_2

Each field example presented in the DOE (2012) update contains an overview of the geologic setting and the objectives of the field test, the relationship between site-specific risk analysis and monitoring plans, monitoring requirements, site injection operations, and the lessons learned from deploying monitoring tools in each setting. Collectively, these projects are investigating the best practices for MVA of CO_2 GS in various geologic settings.

MVA Plan Requirements

EPA's rulemaking entitled Federal Requirements under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells [40 CFR 146.81 et seq.], referred to as the Class VI Rule, includes testing and monitoring requirements for GS projects. In addition, EPA released a guidance document to describe the technologies, tools, and methods available to owners and operators of Class VI wells to fulfill the Class VI Rule requirements related to developing and implementing site- and project-specific strategies for testing and monitoring (U.S. Environmental Protection Agency, 2013). These rules apply only to wells designed solely for GS operations, not to other injection activities such as EOR.

The goal of the various testing and monitoring activities required by the Class VI Rule is to identify any risks to, and endangerment of, USDWs during the various phases of a GS project. The owner or operator is expected to work in consultation with the UIC Program Director to develop a risk-based approach for Class VI well testing and monitoring that uses appropriate technologies and techniques, based on site-specific information, to ensure protection of and to minimize risk to USDWs. For example, while it is required that groundwater quality and geochemical changes above the confining zone(s) be conducted at a site-specific frequency and spatial distribution, surface air and soil gas monitoring are only necessary if required by the UIC Program Director.

Owners or operators must submit, as part of the permit application, a testing and monitoring plan that describes how they will meet the requirements of the Class VI Rule and establishes a detailed site- and project-specific testing and monitoring strategy. Additional details on the testing and monitoring plan are provided in the testing and monitoring guidance document referenced above as well as in other guidance documents such as the UIC Program Class VI Well Project Plan Development Guidance available on EPA's Web site (http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm).

[MVA programs are site-specific in both design and implementation.]

Summary

The RCSP MVA programs are focused primarily on the collection of data from the near surface and subsurface to demonstrate the safety and effectiveness of CO_2 GS. To date, no direct impacts to USDWs have been measured in any of these programs. The focus of these water-related efforts is on the characterization of the concentration of key water quality parameters, although pressure monitoring also plays an important role in understanding fluid movement in the subsurface.

The existing monitoring framework allows an assessment of the potential leakage pathways and determinations of whether impacts to water resources have occurred. In addition, large-scale demonstration projects are assessing the technologies that may provide for early detection of CO_2 and brine movement in the subsurface to prevent contact with USDWs and other water resources of interest.

Additional Information

Federal Register, 2010, Federal requirements under the underground injection control (UIC) program for carbon dioxide (CO_2) geologic sequestration wells: Final Rule, v. 75, no. 237, p. 77230–77303.

Federal Register, 2009, Part 98 mandatory greenhouse gas reporting: v. 74, no. 209.

International Journal of Greenhouse Gas Control, 2013, The IEAGHG Weyburn–Midale CO_2 monitoring and storage project: v. 16.

Petroleum Technology Research Centre, 2012, Best practices for validating CO_2 geological storage—observations and guidance from the IEAGHG Weyburn–Midale CO_2 monitoring and storage project: Geoscience Publishing.

U.S. Department of Energy, 2012, Best practices for monitoring, verification, and accounting of CO_2 stored in deep geologic formations—2012 update (2d ed.): U.S. Department of Energy National Energy Technology Laboratory.

U.S. Department of Energy, 2009, Best practices for monitoring, verification, and accounting of CO_2 stored in deep geologic formations (1st ed.): U.S. Department of Energy National Energy Technology Laboratory, www.netl.doe.gov/technologies/carbon_seq/refshelf/MVA_document.pdf (accessed 2013).

U.S. Environmental Protection Agency, 2013, Geologic sequestration of carbon dioxide—underground injection control (UIC) program Class VI well testing and monitoring guidance: EPA 816-R-13-001, March.

The Water Working Group (WWG) consists of members from all of the RCSPs who serve as a team of experts representing government, academia, and industry. The goal of the WWG is to address stakeholder concerns regarding emerging carbon capture and storage technology and its potential interactions with local and regional water resources. The WWG is organized by the PCOR Partnership, which is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of storing CO_2 emissions from stationary sources in the central interior of North America. The PCOR Partnership is led by the Energy & Environmental Research Center at the University of North Dakota and is one of seven regional partnerships under DOE's National Energy Technology Laboratory RCSP Initiative. To learn more, contact:

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Visit the PCOR Partnership Web site at www.undeerc.org/PCOR. New members are welcome.

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