United States
Environmental Protection
Agency

# Geologic Sequestration of Carbon Dioxide

# Draft Underground Injection Control (UIC) Program Class VI Well Project Plan Development Guidance for Owners and Operators

March 2011

Office of Water (4606M)
EPA 816-D-10-012
March 2011
http://water.epa.gov/drink

# Disclaimer

The Class VI injection well classification was established by the *Federal Requirements under the Underground Injection Control Program for Carbon Dioxide Geologic Sequestration Wells* (75 FR 77230, December 10, 2010). No previous guidance exists for this class of injection wells.

The Safe Drinking Water Act (SDWA) provisions and EPA regulations cited in this document contain legally-binding requirements. In several chapters this guidance document makes suggestions and offers alternatives that go beyond the minimum requirements indicated by the rule. This is done to provide information and suggestions that may be helpful for implementation efforts. Such suggestions are prefaced by "may" or "should" and are to be considered advisory. They are not required elements of the rule. Therefore, this document does not substitute for those provisions or regulations, nor is it a regulation itself, so it does not impose legally-binding requirements on EPA, states, or the regulated community. The recommendations herein may not be applicable to each and every situation.

EPA and state decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Any decisions regarding a particular facility will be made based on the applicable statutes and regulations. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. EPA is taking an adaptive rulemaking approach to regulating Class VI injection wells, and the Agency will continue to evaluate ongoing research and demonstration projects and gather other relevant information as needed to refine the rule. Consequently, this guidance may change in the future without public notice.

While EPA has made every effort to ensure the accuracy of the discussion in this document, the obligations of the regulated community are determined by statutes, regulations or other legally binding requirements. In the event of a conflict between the discussion in this document and any statute or regulation, this document would not be controlling.

Note that this document only addresses issues covered by EPA's authorities under the SDWA. Other EPA authorities, such as Clean Air Act (CAA) requirements to report carbon dioxide injection activities under the Greenhouse Gas Mandatory Reporting Rule (GHG MRR) are not within the scope of this document.

# Executive Summary

EPA's *Federal Requirements Under the Underground Injection Control Program for Carbon Dioxide Geologic Sequestration Wells,* codified in the US Code of Federal Regulations (40 CFR §146.81 *et seq*.), known as the Geologic Sequestration (GS) Rule, establishes a new class of injection well (Class VI) and sets minimum federal technical criteria for Class VI injection wells for the purpose of protecting underground sources of drinking water (USDWs). This document is part of a series of technical guidance documents that EPA is developing to support owners or operators of Class VI wells and permitting authorities. The final GS Rule and all associated guidance documents are available at http://water.epa.gov/type/groundwater/uic/wells_sequestration.cfm.

The GS Rule requires owners or operators of Class VI wells to develop, gain approval for, and implement five (5) project-specific plans, including: an Area of Review (AoR) and Corrective Action Plan, a Testing and Monitoring Plan, an Injection Well Plugging Plan, a Post-Injection Site Care (PISC) and Site Closure Plan, and an Emergency and Remedial Response Plan.

This guidance describes, for Class VI injection well owners and operators, the required elements of each plan and the site-specific elements of each GS project that they might consider in developing the plan. This document also describes the process by which the UIC Program Director of the permitting authority will evaluate and approve each plan and how EPA recommends that each plan is to be reviewed and amended, if necessary, throughout the lifecycle of the project.

# Table of Contents

# List of Tables



# List of Exhibits

# List of Appendices

# Acronyms and Abbreviations

| | |
|---|---|
| AoR | Area of Review |
| CFR | Code of Federal Regulations |
| GS | Geologic Sequestration |
| MIT | Mechanical Integrity Test |
| NOI | Notice of Intent |
| PISC | Post-injection Site Care |
| pH | Potential for Hydrogen Ion Concentration |
| SC | Specific Conductivity |
| SDWA | Safe Drinking Water Act |
| TDS | Total Dissolved Solids |
| UIC | Underground Injection Control |
| USDW | Underground Source of Drinking Water |
| VOC | Volatile Organic Compound |

# Definitions

**Analyte**: A chemical species that is the subject of analysis for determination of concentration.

**Area of review**: The region surrounding the geologic sequestration project where USDWs may be endangered by the injection activity. The area of review is delineated using computational modeling that accounts for the physical and chemical properties of all phases of the injected carbon dioxide stream and displaced fluids, and is based on available site characterization, monitoring, and operational data as set forth in §146.84.

**Carbon dioxide plume**: The underground extent, in three dimensions, of an injected carbon dioxide stream.

**Carbon dioxide stream**: Carbon dioxide that has been captured from an emission source (e.g., a power plant), plus incidental associated substances derived from the source materials and the capture process, and any substances added to the stream to enable or improve the injection process. This does not apply to any carbon dioxide stream that meets the definition of a hazardous waste under 40 CFR Part 261.

**Class VI wells**: Wells that are not experimental in nature that are used for geologic sequestration of carbon dioxide beneath the lowermost formation containing a USDW; or, wells used for geologic sequestration of carbon dioxide that have been granted a waiver of the injection depth requirements pursuant to requirements at §146.95; or, wells used for geologic sequestration of carbon dioxide that have received an expansion to the areal extent of an existing Class II enhanced oil recovery or enhanced gas recovery aquifer exemption pursuant to 40 CFR §§ 146.4 and 144.7(d).

**Confining zone**: A geologic formation, group of formations, or part of a formation stratigraphically overlying the injection zone that acts as a barrier to fluid movement. For Class VI wells operating under an injection depth waiver, confining zone means a geologic formation, group of formations, or part of a formation stratigraphically overlying and underlying the injection zone.

**Corrective action**: UIC Program Director-approved methods to ensure that wells within the area of review do not serve as conduits for the movement of fluids into underground sources of drinking water.

**Geologic sequestration**: The long-term containment of a gaseous, liquid, or supercritical carbon dioxide stream in subsurface geologic formations. This term does not apply to carbon dioxide capture or transport.

**Geologic sequestration project**: An injection well or wells used to emplace a carbon dioxide stream beneath the lowermost formation containing a USDW; or, wells used for geologic sequestration of carbon dioxide that have been granted a waiver of the injection depth requirements pursuant to requirements at §146.95; or, wells used for geologic sequestration of carbon dioxide that have received an expansion to the areal extent of an existing Class II

enhanced oil recovery or enhanced gas recovery aquifer exemption pursuant to 40 CFR §§146.4 and 144.7(d). It includes the subsurface three-dimensional extent of the carbon dioxide plume, associated area of elevated pressure, and displaced fluids, as well as the surface area above that delineated region.

**Injection depth waivers**: Provisions at §146.95 that allow owners or operators to seek a waiver from the Class VI injection depth requirements for GS to allow injection into non-USDW formations while ensuring that USDWs are protected from endangerment.

**Mechanical integrity**: The absence of significant leakage within the injection tubing, casing, or packer (known as internal mechanical integrity), or outside of the casing (known as external mechanical integrity).

**Mechanical integrity test**: A test performed on a well to confirm that a well maintains internal and external mechanical integrity. MITs are a means of measuring the adequacy of the construction of an injection well and a way to detect problems within the well system before leaks occur.

**Multiphase flow parameters**: Model parameters that describe the rate of fluid flow and fluid saturation for multiple immiscible fluids within a porous medium.

**Phased corrective action**: A provision of the GS Rule [§146.84(b)(2)(iv)] afforded to Class VI well owners or operators to defer some needed corrective action needed within the AoR, but farther away from the injection well, until after injection has commenced, but prior to carbon dioxide plume and pressure front movement into that particular area.

**Post-injection site care**: Appropriate monitoring and other actions (including corrective action) needed following cessation of injection to ensure that USDWs are not endangered, as required under §146.93.

**Pressure front**: A zone of elevated pressure that is created by the injection of carbon dioxide into the subsurface. For the purposes of this subpart, the pressure front of a carbon dioxide plume refers to a zone where there is a pressure differential sufficient to cause the movement of injected fluids or formation fluids into a USDW.

**Site closure**: The point/time, as determined by the UIC Program Director following the requirements under §146.93, at which the owner or operator of a GS site is released from post-injection site care responsibilities.

**Stochastic estimate**: A type of modeling prediction that is based on a statistically generated representation of key model input parameters.

**Underground Injection Control Program**: The program EPA, or an approved state, is authorized to implement under the Safe Drinking Water Act (SDWA) responsible for regulating the underground injection of fluids by injection. This includes setting the minimum federal requirements for construction, operation, permitting, and closure of underground injection wells.

**Underground Injection Control Program UIC Program Director**: The person responsible for permitting, implementation, and compliance of the UIC program. For UIC Programs administered by EPA, the UIC Program Director is the EPA Regional Administrator or his/her delegate; for UIC Programs in Primacy states, the UIC Program Director is the person responsible for permitting, implementation, and compliance of the state, territorial, or tribal UIC Program.

**Underground source of drinking water**: An aquifer or portion of an aquifer that: supplies any public water system or that contains a sufficient quantity of ground water to supply a public water system; currently supplies drinking water for human consumption, or; that contains fewer than 10,000 mg/l total dissolved solids and is not an exempted aquifer.

# 1.0 Introduction

Owners or operators of Class VI carbon dioxide injection wells must develop, implement, periodically review and, if necessary, amend a series of project- and site-specific plans that guide the management of each GS project. The purpose of this Project Plan Development Guidance is to present recommendations for Class VI injection well owners or operators, in developing the project plans required in the *Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide Geologic Sequestration Wells* [40 CFR §146.81 et seq.], hereafter referred to as the GS Rule. This guidance focuses on preparing GS project plans that meet the requirements of the GS Rule, submitting them to the appropriate permitting authority's UIC Program UIC Program Director (UIC Program Director) for approval, and periodically reviewing and amending the plans.

## 1.1 Overview and Need for GS Project Plans

Owners or operators of Class VI wells must prepare five (5) project plans and submit them to the UIC Program Director for approval with their Class VI permit application. When the plans are approved, they become an enforceable part of the Class VI permit. The required project plans, which must be based on site-specific information, include the following:

- **Area of Review (AoR) and Corrective Action Plan.** This plan describes how an owner or operator intends to delineate the AoR for the Class VI injection well and ensure that all identified deficient artificial penetrations (i.e., wells that are improperly plugged or completed) will be addressed by corrective action techniques so that they will not become conduits for fluid movement into underground sources of drinking water (USDWs).
- **Testing and Monitoring Plan.** This plan describes how the owner or operator intends to perform all necessary testing and monitoring associated with a GS project, including injectate monitoring, performing mechanical integrity tests (MITs), corrosion monitoring, tracking the carbon dioxide plume and area of elevated pressure, monitoring geochemical changes above the confining zone, and, at the discretion of the UIC Program Director, surface air and soil gas monitoring for carbon dioxide fluctuations and any additional tests necessary to ensure USDW protection from endangerment.
- **Injection Well Plugging Plan.** This plan describes how, following the cessation of injection, the owner or operator intends to plug the Class VI injection well using the appropriate materials and methods to ensure that the well will not become a conduit for fluid movement into USDWs in the future.
- **Post-Injection Site Care (PISC) and Site Closure Plan**. This plan describes how the owner or operator intends to monitor the site after injection has ceased, in order to ensure that the carbon dioxide plume and pressure front are moving as predicted and USDWs are not endangered. PISC monitoring results from plugged Class VI injection wells must be reported until it can be demonstrated that the site poses no further endangerment to USDWs.
- **Emergency and Remedial Response Plan.** This plan describes the actions that the owner or operator intends to take in the event of movement of the injectate or formation fluids in a manner that may cause an endangerment to a USDW, including the appropriate people to contact.

These detailed site-specific GS project plans are necessary to ensure that management of the GS project is based on the most up-to-date site characterization, modeling, operational, and monitoring data to protect USDWs from endangerment. The plans also afford the flexibility needed to address the variety of types of geologic formations in which GS will occur, while also facilitating dialogue between the Class VI injection well owner or operator and the UIC Program Director.

Class VI well permits are issued for the operating life of the project (i.e., from authorization of injection through site closure, which may occur many decades later). Thus, unlike other injection well classes regulated under the UIC Program, there is no periodic reapplication for, or reissuance of, a Class VI permit. Instead, these five GS project plans, which are reviewed as part of the Class VI permit application review and approval process and incorporated into the Class VI permit, must be amended periodically, as specified in the GS Rule. The iterative process of developing and executing the GS project plans described in this guidance is tailored to the unique aspects of GS and is intended to ensure that time and resources are committed to the most critical aspects of managing Class VI injection well operations (see Exhibit 1 below).

## 1.2 Interaction of GS Project Plans

Development, approval, and implementation of the project-specific plans involve an iterative process. Exhibit 1 presents a general overview of the process of gathering data for, developing, approving, and periodically reviewing and amending the plans throughout the life of a GS project. The sections below describe this process in greater detail.

*Pre-Operations Development of the GS Project Plans*

Before a Class VI permit may be issued, the owner or operator must develop and obtain the UIC Program Director's approval of each of the five project plans. The initial plans are to be based on the extensive site-specific data collected during site characterization (e.g., geologic and geochemical data on subsurface formations and hydrologic data on aquifers), preliminary predictions of plume movement and pressure perturbations, and planned operational conditions. See the *Draft UIC Program Class VI Well Site Characterization Guidance for Owners and Operators* posted on the EPA website at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm for additional information on the types and collection of required site-specific data.

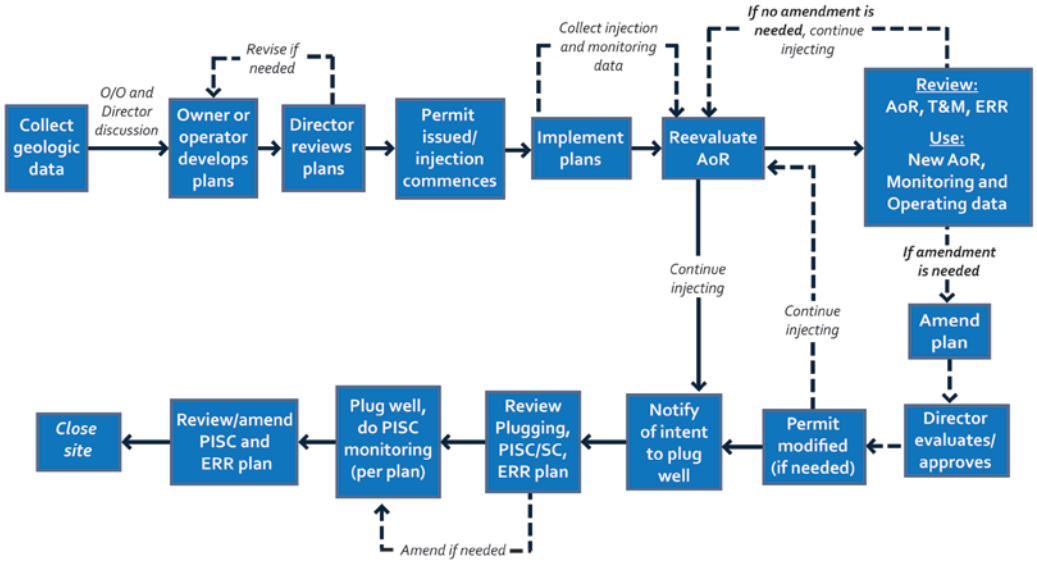
Owners or operators must submit the five proposed GS project plans with their Class VI permit application. The UIC Program Director will evaluate the proposed plans in the context of other geologic and operational data submitted with the Class VI permit application. The owner or operator and the UIC Program Director are encouraged to discuss the plans as they are written and evaluated (especially while site-specific data are being collected). This coordination can improve the likelihood that the proposed plans will be approved and help both the owner or operator and the UIC Program Director anticipate any issues related to the operation of a GS project that may be of concern to the public.

EPA recommends that owners or operators consider revising or adjusting portions of the project plans as additional data become available during the site characterization process. All five of the

project plans must be submitted with the Class VI permit application (i.e., prior to operation of the injection well or drilling of any test wells). Therefore, the owner or operator will need to develop the plans prior to the formal modeling of the AoR. While certain preliminary information would be available at that time, e.g., the estimated extent of the AoR based on initial geologic data and planned injection volumes, EPA recommends that the owner or operator revisit and revise the operational-phase plans (e.g., the AoR and Corrective Action Plan, Testing and Monitoring Plan, and Emergency and Remedial Response Plan) as necessary once the AoR modeling has been completed. This would for example, help ensure that the AoR and Corrective Action Plan addresses all improperly abandoned artificial penetrations throughout the delineated AoR, that planned testing and monitoring is thorough, or that the Emergency and Remedial Response Plan addresses all potential resources and infrastructure that may be impacted by the project.

In their discussion of the plans, EPA recommends that the owner or operator and UIC Program Director consider the advantages of tailoring activities to project conditions, and not necessarily performing only the minimum activities required by the GS Rule. For example, increasing the number of monitoring locations or the frequency of AoR reevaluations may help ensure that future reviews of the project plans will not necessitate amendments or permit modifications. This type of proactive planning early in the process may help ensure that the owner or operator and the UIC Program Director have considered both the current and possible future conditions at the proposed Class VI injection well site based on all available site-specific information.

## Exhibit 1: Process for Developing, Approving, and Amending GS Project Plans



*Plan Reviews and Amendments*

Throughout the operational (injection) phase of a GS project, owners or operators will collect operating data (e.g., injection pressures, volumes, rates) and monitoring data (e.g., the position of the carbon dioxide plume and pressure front, ground water quality data). In addition to verifying that the site is operating as planned/modeled, this data will inform reevaluations of the AoR [§146.84(e)] and any subsequent project plan revisions and amendments.

The AoR reevaluation involves the comparison of recently collected monitoring data to earlier model predictions, which must take place at least every five (5) years [40 CFR §146.84]. Based on these comparisons, the AoR delineation model may need to be modified or run again in order to incorporate additional monitoring, site characterization, or operational data. Within one (1) year of an AoR reevaluation, the owner or operator must review the Class VI AoR and Corrective Action Plan, Testing and Monitoring Plan and the Emergency and Remedial Response Plan, and determine if any amendments are necessary. Following this project plan review, the owner or operator must either submit amended project plans to the UIC Program UIC Program Director or submit information that demonstrates why no amendments to the project plans are needed. Amended project plans must be subsequently approved by the UIC Program Director. (Periodic amendments of the Injection Well Plugging Plan and the PISC and Site Closure Plan are not required throughout the operational phase of the project because these plans would not be implemented until the cessation of injection operations.)

The amended plans would then be incorporated into the Class VI operating permit, which would constitute a modification of the permit. Unless the modification to the permit is a minor modification (as defined at §144.41), a draft permit must be prepared and the procedures specified in 40 CFR Part 124 (public participation) must be followed. For additional information regarding the procedures that need to be followed for a Class VI permit modification, see 40 CFR §144.39, as well as the forthcoming *UIC Class VI Program Interim Final Primacy Application and Implementation Manual for State UIC Program Directors*, to be available on EPA's website in the future at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm.

The five GS project plans are inter-related. Changes to (or information acquired through the implementation of) one plan may necessitate a review of, or possibly a change to, some or all of the other plans. For example, data collected pursuant to the approved Testing and Monitoring Plan will inform the AoR reevaluation, which may, in turn, indicate that, a revision of the Emergency and Remedial Response plan is needed. Plan reviews and amendments may also be triggered if there are indications based on monitoring data (collected per the approved Testing and Monitoring Plan) that the site is not performing as predicted. Table 1 presents examples of how, in the course of implementing one plan, changes may be identified that trigger the need for review of—and possible amendments to—the other project plans associated with a GS project. Note that the list presented in Table 1 is not intended to be exhaustive.

A detailed and thorough periodic reevaluation of the AoR, and the review and applicable revisions of the project plans throughout the life of the project are key components of the GS Rule. EPA recommends that the plans be reviewed simultaneously to promote a holistic

approach that considers all available information and ensures that the site is managed in a manner that protects USDWs from endangerment. This iterative plan review and revision process is unique in the UIC Program for Class VI wells, and it is required in place of the periodic permit renewals conducted for other injection well classes regulated under the UIC Program. Linking GS project plan reviews to the AoR reevaluation frequency will ensure that these reviews are conducted on a defined schedule (i.e., no less than every five (5) years). This adds little burden on the Class VI injection well owner or operator if the AoR reevaluation confirms that the project plans are appropriate and can continue to be implemented as written.

**Table 1. Interaction of Class VI Injection Well Project Plans**

| Plan | Changes identified in implementing the plan | Potential impacts on other plans |
|---|---|---|
| AoR and Corrective Action Plan | Revised modeling delineates a larger/differently shaped AoR | • Amend the AoR and Corrective Action Plan to address newly identified deficient wells<br>• Add monitoring locations to the Testing and Monitoring Plan<br>• Revise the Emergency and Remedial Response Plan if new resources/ infrastructure are identified in the AoR |
| Testing and Monitoring Plan | Ground water monitoring indicates leaching/mobilization of toxic metals or organics | • Adjust corrective action methods to address water quality changes<br>• Adjust injection well plugging methods<br>• Modify operational and post-injection ground water monitoring |
| | Monitoring detects impairment of a USDW | • Implement the Emergency and Remedial Response Plan<br>• Modify operational and post-injection ground water monitoring |
| | Monitoring indicates the carbon dioxide plume is moving faster than predicted, or in a different direction | • Adjust corrective action schedule; conduct more frequent AoR reevaluations<br>• Expand ground water monitoring/pressure monitoring network |
| | Pressures within the injection zone vary from modeled predictions | • Adjust post-injection pressure monitoring<br>• Reevaluate AoR, considering current pressure data; Revise AoR and Corrective Action Plan |
| PISC and Site Closure Plan | Monitoring detects ground water contamination or plume excursions | • Implement emergency and remedial response plan<br>• Modify post-injection monitoring regime |
| Emergency and Remedial Response Plan | An adverse event required implementation of emergency and remedial response plan | • Revisit all plans to identify lessons learned |

## 1.3 Other Relevant Guidance

Other detailed Draft UIC Program Class VI guidance documents prepared by EPA on specific technical aspects of GS projects can provide additional detail on the activities to be included in

the five GS project plans. The Draft UIC Program Class VI guidance documents can be found on EPA's website at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm:

- **Draft UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance:** This draft guidance document describes recommended approaches to apply computational modeling to delineate the AoR, perform corrective action at GS sites, and periodically reevaluate the AoR. It contains information that will support the development of the AoR and Corrective Action Plan for a proposed GS project.

- The forthcoming **Draft UIC Program Class VI Well Testing and Monitoring Guidance:** This draft guidance document will describe the available technologies for implementing a Testing and Monitoring Plan for a Class VI injection well site, including well testing such as MITs and corrosion monitoring, groundwater quality monitoring, carbon dioxide plume and pressure front tracking, and soil gas and surface air monitoring (which may be required by the UIC Program Director). It contains information that will support the development of the required Testing and Monitoring Plan for a proposed GS project.

- The forthcoming **Draft UIC Program Class VI Well Plugging, Post Injection Site Care (PISC) and Site Closure Guidance:** This draft guidance document will describe how EPA recommends that owners or operators plug injection and monitoring wells, and perform post-injection monitoring, non-endangerment demonstrations and site closure activities. It will contain information that will support the development of the required Injection Well Plugging Plan and the PISC and Site Closure Plan.

Additionally, three other draft Agency guidance documents address topics related to the development or submittal of the GS project plans:

- The **Draft UIC Program Class VI Financial Responsibility Guidance** explains the requirements related to demonstrating and maintaining financial responsibility for corrective action on wells in the AoR, injection well plugging, PISC and site closure, and emergency and remedial response at §146.85. Since many of these activities will be performed pursuant to UIC Program Director-approved GS project plans, the coordination of activities associated with demonstrating financial responsibility and developing the project plans is crucial so that cost estimates for financial responsibility demonstrations accurately address all the covered injection well operation, monitoring, and post-injection activities. EPA recommends that financial responsibility demonstration requirements be considered throughout the development, implementation, and future amendments to the GS project plans.

- The forthcoming **Interim Final Class VI Primacy Application and Implementation Manual** will describe how the UIC Program Director will consider various types of information about the site when evaluating and approving the project plans, including areas on which the UIC Program Director is afforded discretion in setting permit criteria or reviewing the project plans.

- The forthcoming **Draft UIC Program Class VI Well Recordkeeping, Reporting, and Data Management Guidance** will provide detailed information for owners or operators on

how to submit all required data for a permitted Class VI injection well, including how to submit the five project plans and any necessary amendments.

Other EPA-developed guidance documents available to assist owners or operators of Class VI wells will address: the site characterization process, well construction, injection depth waivers for Class VI wells, transitioning from Class II to Class VI, and options for Class V experimental technology well owners and operators.

## 1.4 Reporting Requirements for the Information Collected

Each initial GS project plan must contain the required content described in the GS Rule and outlined in Sections 2 through 6 of this guidance document. Owners or operators must submit the proposed project plans, along with their Class VI permit applications, to EPA's electronic reporting system. EPA recommends that each GS project plan be submitted as a PDF document.

Amendments to the plans must be submitted to EPA's electronic reporting system [§146.91(e)] as follows:

- Class VI AoR and Corrective Action, Testing and Monitoring, and Emergency and Remedial Response Plan amendments must be submitted within one (1) year of an AoR reevaluation [§§146.84(e), 146.90(j), and 146.94(d)].
- Any amendments to the Injection Well Plugging Plan must be submitted at least sixty (60) days prior to plugging the injection well [§146.92(c)].
- An amendment to the PISC and Site Closure Plan, if needed, must be submitted at the cessation of injection [§146.92(a)(3)]. EPA also recommends that further amendments to the plan be submitted periodically throughout the entire PISC phase, as described in the approved plan.

For more information on reporting formats and the EPA electronic reporting system, see the *Draft UIC Program Class VI Well Recordkeeping, Reporting, and Data Management Guidance for Owners and Operators* to be posted when available at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm.

## 1.5 Organization of this Document

The next five Sections of this guidance describe each of the five GS project-specific plans as follows:

Section 2 – AoR and Corrective Action Plan
Section 3 – Testing and Monitoring Plan
Section 4 – Injection Well Plugging Plan
Section 5 – Post-Injection Site Care and Site Closure Plan
Section 6 – Emergency and Remedial Response Plan

For each of the required plans, the following is described:

- Developing the plan (Sections 2.1, 3.1, 4.1, 5.1, and 6.1): these sections describe the required content of the plan as specified in the GS Rule, recommended approaches for developing plans that meet EPA's requirements, and the site-specific considerations that EPA recommends owners or operators make in developing each plan.
- UIC Program Director's evaluation of the plan (Sections 2.2, 3.2, 4.2, 5.2, and 6.2): these sections describe—for the benefit of the owner or operator—what the UIC Program Director will consider and evaluate as he/she reviews the proposed plan, including any areas of UIC Program Director's discretion regarding the GS Rule requirements.
- Amending the plan (Sections 2.3, 3.3, 4.3, 5.3, and 6.3): these sections describe the recommended scope of the periodic review of each plan and information that EPA recommends to be considered in the course of the review, the timing of the review, and what must be reported to the UIC Program Director [§§146.84(e), 146.90(j), 146.92(c), 146.93(a)(3), and 146.94(d)].

Appendices A through E contain sample templates for each of the required project plans.

Note that there is some repetition from section to section in this guidance. Each section provides a thorough discussion of the process for development, evaluation, and review/amendment of each of the required plans so there is some repetition when the processes are the same for the different plans. Each section of this Plan Development guidance is intended to serve as a "how to" manual for each individual plan.

## 2.0 Area of Review and Corrective Action Plan

Owners or operators of Class VI injection wells must submit a Class VI Area of Review (AoR) and Corrective Action Plan that describes how they intend to delineate the AoR (using appropriate models and assumptions), address all deficient artificial penetrations within the AoR, and update the AoR modeling periodically throughout the life of the project. This comprehensive planning is necessary to ensure that an appropriate site-specific strategy is in place to predict the extent of the carbon dioxide plume and pressure front (i.e., to delineate the AoR) and ensure that all deficient artificial penetrations within the AoR that could serve as conduits for fluid movement into USDWs are addressed through appropriate and timely corrective action methods.

Implementation of the AoR and Corrective Action Plan also supports the development of effective monitoring strategies by identifying the locations where ground water quality or pressure monitoring should be performed. Additionally, data gathered by implementing the AoR and Corrective Action Plan will help direct emergency response planning by identifying potential vulnerable areas (e.g., public water supplies) within the AoR that could require consideration when implementing an emergency response. AoR and Corrective Action Plans will also guide the ongoing process of periodic AoR reevaluations, which are essential to informed site management and monitoring over the lifecycle of the injection project.

## 2.1 Developing the AoR and Corrective Action Plan

The GS Rule, at §146.84(b), presents the required content of an AoR and Corrective Action Plan for a GS project. In the proposed AoR and Corrective Action Plan, the owner or operator must demonstrate to the satisfaction of the UIC Program Director that the modeled AoR will be based on the detailed site-specific geologic data collected during the site characterization process and that all necessary corrective action within the modeled AoR will be performed in a timely manner to protect USDWs.

Guidance and recommended approaches on performing the activities to be carried out under the approved plan (e.g., performing AoR delineation modeling and addressing wells that require corrective action) are presented in the *Draft UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance for Owners and Operators*, available on EPA's website at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm. Exhibit 2 presents the highlights of the information presented in that guidance.

### Exhibit 2: Draft UIC Program Class VI Well AoR and Corrective Action Guidance Highlights

The *Draft UIC Program Class VI Well Area of Review and Corrective Action Guidance* provides EPA recommendations regarding modeling to delineate the AoR for a GS project, under what circumstances the AoR is reevaluated, and performing AoR reevaluations. In addition, the Guidance covers recommended approaches to identify, evaluate, and perform corrective action on any artificial penetrations identified within the delineated AoR, and needing remediation.

The introductory section reviews the definition of the AoR for Class VI projects and Class VI regulations pertaining to AoR and corrective action. Remaining sections of the guidance address the following topics:

- The data to be considered in running a model for the initial AoR delineation;
- The computational modeling needed to delineate the AoR;
- The identification and evaluation of, and performing corrective action on, artificial penetrations located within the delineated AoR; and
- AoR reevaluations.

For each section, the Guidance:

- Explains how to perform activities necessary to comply with the GS Rule AoR and corrective action requirements (e.g., performing computational modeling). Illustrative examples are provided in several cases.
- Provides references to other, more comprehensive documents and published scientific literature for further information.
- Explains how and when to report to the UIC Program UIC Program Director the results of activities related to AoR and corrective action.

The AoR and Corrective Action Plan must be submitted with the Class VI permit application for approval by the UIC Program Director [§146.82(a)(13)], and must include a description of how the owner or operator will meet the Class VI AoR and corrective action requirements [§146.84]. The sections below provide a description of the required content of the AoR and Corrective

Action Plan, how EPA recommends the content be described in the plan to demonstrate that the plan is sufficient and approvable, and other topics that Class VI injection well owners or operators might consider as they develop their plan. Appendix A of this guidance document presents a sample template of an AoR and Corrective Action Plan.

### *2.1.1 The method for delineating the AoR*

The GS Rule requires Class VI injection well owners or operators to describe in their AoR and Corrective Action Plan how they will delineate the AoR. Specifically, the plan must describe the computational model that will be used for the AoR delineation process, the assumptions that will be made, and the site characterization data on which the model will be based [§146.84(b)(1)].

Several computational codes are available that are appropriate for modeling to delineate the AoR for Class VI wells. EPA recommends that the model be appropriate to the site-specific geologic conditions (i.e., be able to accurately predict movement of the plume and pressure front, given the particular geologic conditions at the site) and the model must meet the requirements specified in the GS Rule [§146.84(c)(1)]. See Section 3 of the *Draft UIC Program Class VI Well AoR and Corrective Action Guidance* for additional information on the required AoR modeling for a Class VI injection well.

A detailed geologic site characterization is essential to evaluating the presence and adequacy of the geologic formations in a proposed area to both receive and confine the injected carbon dioxide. The AoR and Corrective Action Plan must describe the site characterization data on which the model will be based, (e.g., porosity, permeability, geochemistry, artificial penetrations, or stratigraphy). See the *Draft UIC Program Class VI Well Site Characterization Guidance* for details on collecting this data, and the *Draft UIC Program Class VI Well AoR and Corrective Action Guidance* for EPA-recommended approaches for incorporating this data into AoR delineation modeling.

Additionally, prior to authorizing injection, the UIC Program Director will evaluate the delineated AoR along with all information submitted regarding the model and its assumptions. This evaluation is necessary to ensure that the delineated AoR encompasses a sufficient area in which corrective action will be performed so that no improperly constructed, plugged, or abandoned wells are present that could serve as conduits for fluid movement into USDWs. An AoR and Corrective Action Plan that includes a detailed and complete description of the model and its planned inputs will be helpful for the UIC Program Director and facilitate and expedite the review of the plan.

EPA recommends that the owner or operator convey in the plan to the UIC Program Director how the model's code, input, and assumptions will be considered, or accounted for and that the model will appropriately address local conditions and delineate an accurate AoR. Owners or operators might use the following types of information when selecting a computational modeling code for the AoR delineation and developing input parameters and assumptions:

*Site Geology and Hydrogeology Information*

- The **type and number of subsurface formations** from the surface to the injection zone, as determined by borehole sampling and logging, geophysical, and other tests or methods to characterize the site geology;
- For each formation, initial **fluid pressures**, horizontal and vertical gradients, and **groundwater flow directions and velocity**;
- The presence and characterization of **faults or fractures**;
- The presence of **wells and mines**;
- **Baseline geochemistry** and the compatibility of the carbon dioxide stream with fluids in the injection zone and minerals in the subsurface formations;
- **Multiphase flow parameters**, and relevant permeability-saturation relationships and equations of state; and
- The measures of **porosity and permeability** (and/or geostatistical or stochastic estimates of these parameters).

*Proposed Operating Data and Information*

- Proposed injection **rates**, **pressures**, and **well depths**;
- The presence, or planned presence, of **other injection (or production) wells**, including Class VI injection wells operated as part of separate projects, within the injection zone or other pertinent zones; and
- If an **injection depth waiver** is sought, **all USDWs above and below** the injection zone must be included in the model.

### *2.1.2 The minimum fixed frequency to reevaluate the AoR*

The GS Rule requires owners or operators to periodically reevaluate the AoR to incorporate monitoring and operational data. In the plan, owners or operators must describe the minimum frequency at which this reevaluation would occur [§146.84(b)(2)(i)]. In no case can this reevaluation happen less frequently than every five (5) years. However, it may be appropriate to reevaluate the AoR more frequently based on site-specific information, as described below. This may be particularly important for the first reevaluation to verify, once injection commences, that the carbon dioxide plume is behaving in the subsurface as predicted.

Below are some factors to consider when determining the minimum AoR reevaluation frequency, including whether a reevaluation more frequently than every five (5) years would be appropriate. EPA recommends that the AoR and Corrective Action Plan describe how these factors were considered in determining the AoR reevaluation frequency.

- The presence of **multiple injection wells** or **planned additional injections**: a reevaluation may be warranted once all of the injection wells come on-line, or after a threshold volume of carbon dioxide has been injected;

- The pace of **population growth** and **development or land use changes** in the region: rapid growth may indicate that additional public and private wells have been drilled or that ground water supplies within the AoR are being developed for use;
- **Planned phased corrective action** (see Section 2.1.5): an AoR reevaluation may be warranted following commencement of injection and after a significant number of wells are plugged;
- **Confidence in the modeling assumptions** or the **amount and quality of site characterization data** that will be used for AoR delineation or the **general modeling approach**: significant uncertainties in site characterization data and the AoR delineation modeling may be addressed by more frequent reevaluation and comparison to monitoring data, particularly early in the project;
- **Injection volumes and rates**: UIC Program Directors may consider that higher volume projects warrant more frequent reviews, particularly early in the injection phase;
- **Planned changes in operation**: these changes may include the addition of injection wells, changes to injection or production rates (e.g., associated with enhanced oil recovery operations or dewatering/depressurization), or a change in the source of the carbon dioxide; and
- **Public acceptance**: if the public expresses concerns about the project (e.g., about safety or environmental justice considerations) or if the public opposes the proposed siting of a Class VI injection well, the publication of GS project monitoring results and an early AoR reevaluation may help allay some of these concerns.

### *2.1.3 Conditions that would warrant an early AoR reevaluation*

It may be necessary, based on site-specific circumstances or events, to reevaluate the AoR before the next scheduled reevaluation (see Section 2.1.2 of this guidance document, above). The owner or operator must describe in the AoR and Corrective Action Plan what monitoring or operational conditions may warrant a reevaluation of the AoR prior to the next scheduled reevaluation [§146.84(b)(2)(ii)]. EPA recommends that the owner or operator convey in the plan how the following monitoring data and operating conditions would be considered in determining the need for an unscheduled AoR reevaluation:

- If monitoring data reveal an **unexpected change** in the rate or direction of carbon dioxide plume movement, the areal extent of the plume, or formation pressures;
- **Changes in operation**, including the addition of injection wells, changes to injection rates or volumes injected, a change in production rates from the injection zone (e.g., associated with enhanced oil recovery operations or dewatering/depressurization), or changing the source of the carbon dioxide;
- Following **any seismic event**, whether related to the GS project or not (the area over which seismic events might be considered would be site-specific);
- Following an **exceedance of any Class VI operating permit condition** (e.g., exceeding the permitted volumes of carbon dioxide injected); or
- **Newly available site characterization data** that may impact model predictions.

### *2.1.4 How monitoring and operational data will inform AoR reevaluations*

The GS Rule requires that the AoR delineation and reevaluations account for all available operating, site characterization, and monitoring data. Owners or operators must describe in the AoR and Corrective Action Plan how these data will be incorporated into the AoR reevaluation; e.g., how the data would be collected and compared to model predictions, and if necessary, incorporated into future modeling runs [§146.84(b)(2)(iii)].

An AoR reevaluation may not necessarily need to result in additional modeling or changes to the site computational model. If, based on a comparison of the site monitoring data, project information, and the current AoR model predictions, the owner or operator determines that no changes to the model are necessary, than the owner or operator would only need to demonstrate to the UIC Program Director that no model revision is necessary. EPA recommends that the plan discuss how monitoring and modeling data will be compared, and how this demonstration of no model revision will be made, if that demonstration is appropriate.

In the event that the owner or operator determines that revisions to the model are necessary, the plan must discuss how the newly available data will be used to revise the model and AoR delineation. EPA recommends that these discussions tie closely to how operating data will be collected and how the Class VI Testing and Monitoring Plan will be implemented (see Section 3 of this guidance document). Owners or operators may consider factors similar to those used to incorporate the site characterization data into the original model. EPA recommends that the revised AoR and Corrective Action Plan discuss how the owner or operator intends to consider the following:

- How specific types of **monitoring data** (e.g., ground water quality or plume tracking results) will be **quantitatively compared to modeling results**: EPA recommends that the plan outline under what conditions deviations between monitoring data and model results will be deemed "significant" and trigger a revision of the site computational model and AoR delineation;
- How **model parameters will be adjusted** to reflect monitoring data (i.e., model calibration process) if a model revision is necessary;
- How **operational parameters** (injection rate, injection pressure, and the total volume injected) will be **compared to the original model inputs**: EPA recommends that the plan outline when (and the threshold magnitude for which) deviations between model inputs and actual operational conditions warrant a revision of the computational model and AoR delineation;
- How **newly available site characterization data** will be compared to existing data used as model input parameters, and under what conditions newly available site characterization data will trigger a revision of the computational model and AoR delineation; and
- How the **impacts of other injection well owners or operators in the AoR** (or new owners or operators), including consideration of their operating procedures, may affect or require alterations to the modeling.

### *2.1.5 How corrective action will be conducted*

Owners or operators of all classes of injection wells, including Class VI injection wells, must perform corrective action on all improperly plugged artificial penetrations identified within the delineated AoR in order to ensure that they will not serve as conduits for fluid movement into USDWs. All improperly plugged artificial penetrations within the AoR must be plugged using materials that can withstand the potentially corrosive environment that results when carbon dioxide mixes with water [§146.84(d)]. Additionally, at §146.84(b)(2)(iv), the GS Rule affords owners or operators the option (if approved by the UIC Program Director) of phased corrective action, (i.e., deferring corrective action for those wells that are not expected, based on modeling and site-specific information, to be impacted by the carbon dioxide plume or pressure front for several years).

The Class VI AoR and Corrective Action Plan must describe how the corrective action will be performed, including the corrective action methods to be used, the schedule for completing all corrective action, and what corrective action will be phased [§146.84(b)(2)(iv)]. The plan must address all wells in the AoR that are determined to need corrective action. It may be appropriate to include in the plan a table that lists all identified and located wells that need corrective action, the scheduled date for performing corrective action (both pre-injection and during injection operations), and the planned corrective action method(s). Specific information on determining the appropriate corrective action methods and schedule for completion is presented below.

*Corrective Action Methods*

The GS Rule requires that all improperly plugged artificial penetrations located within the AoR be addressed, but it does not specify the corrective action methods to be used. Instead, the GS Rule affords flexibility in order to ensure that all corrective action methods employed are appropriate to the specific artificial penetration needing plugging, the characteristics of the injectate, and any other site-specific conditions that may be warranted (e.g., the formation geochemistry).

The AoR and Corrective Action Plan must describe the specific corrective action activities that will be taken for each type of improperly plugged artificial penetration located within the AoR (e.g., depth and type of plugs; cement to be used). Well schematics may be appropriate.

Section 4 of the *Draft UIC Program Class VI Well AoR and Corrective Action Guidance* describes how to identify improperly plugged artificial penetrations within the AoR, assess their integrity, and perform corrective action when necessary. EPA recommends that the AoR and Corrective Action Plan convey how the following factors about the site and the artificial penetrations within the AoR will be considered in determining the appropriate corrective action methods:

- The **age of each improperly plugged well**, the **condition of the cement**, and the overall **maintenance of the improperly plugged well** (including maintenance records or the lack thereof);

- **Well depth**, which would affect the number of plugs and the types and amount of cement needed;
- The **composition of the carbon dioxide stream**, which can affect the appropriate cement needed to plug the well;
- **Formation fluid geochemistry** and the presence of other **corrosive native fluids** (e.g., hydrogen sulfide), which can impact the potential formation of carbonic acid that could react with or degrade well materials or cements;
- The **presence of all USDWs** and the **characteristics of the formations penetrated** by the well, which may affect the number of plugs and the amount and types of cement required; and
- What **remedial techniques** will be used to address improperly plugged wells within the AoR.

*Corrective Action Schedule*

The AoR and Corrective Action Plan must include a schedule for completing corrective action on all improperly plugged wells located within the AoR. The GS Rule allows for phased corrective action, so that improperly plugged wells that are not anticipated to be intersected by the carbon dioxide plume and pressure front for several years may not need to be addressed prior to commencing injection. However, for improperly plugged wells that will need corrective action prior to injection, and whenever otherwise practical, EPA recommends that the AoR and Corrective Action Plan include specific dates for performing corrective action, in order to give the UIC Program Director an opportunity to witness the corrective plugging activities.

The Class VI AoR and Corrective Action Plan must describe the following [§146.84(b)(2)(iv)]:

- *What corrective action will be performed prior to the start of injection:* The plan must demonstrate that all improperly plugged wells located within the AoR that are determined to need corrective action, and are likely to be intersected by the carbon dioxide plume and pressure front early on, will receive corrective action in a timely manner. This determination would be tied to modeled predictions of the rate of plume movement. If phased corrective action is approved, pre-injection corrective action would only be necessary in areas with a high certainty of carbon dioxide exposure during the first several years of injection as informed by site characterization data and modeling. Conversely, if modeling indicates that the injected carbon dioxide plume and pressure front will expand throughout the AoR in a short time, all corrective action should be completed prior to the initiation of carbon dioxide injection operations.

- *What corrective action will be phased:* If phased corrective action is planned, the AoR and Corrective Action Plan must describe which portions of the AoR will have corrective action performed on a phased basis. The plan must also describe how the phasing was determined; i.e., it must justify why corrective action on certain improperly plugged wells can be deferred until a later date, based on modeled predictions.

EPA recommends that the plan include a schedule for performing corrective action on all improperly plugged wells located within the AoR that are determined to need corrective action (i.e., a schedule of which wells will be plugged in year 1, year 2, etc).

It is important to note that phased corrective action must be approved by the UIC Program Director. If an owner or operator seeks to phase corrective action, consultation with the UIC Program Director is encouraged in order to identify whether phased corrective action is appropriate based on information about a proposed Class VI injection well site and to avoid unnecessary delays in injection operations.

To ensure that corrective action activities on all improperly plugged wells will be possible, the owner or operator must also describe in the plan how surface access to all wells needing corrective action will be guaranteed. The owner or operator will need to obtain the right of access to improperly plugged wells in order to perform the necessary corrective action and demonstrate in their submitted AoR and Corrective Action Plan that these access rights have been granted. This demonstration may include information regarding how the owner or operator will maintain current information on land ownership changes or enter into necessary agreements with current land owners to be able to access and address the improperly plugged wells. If surface access rights cannot be guaranteed, or if additional development of the land area around the improperly plugged well is anticipated, it may be beneficial to complete all corrective action activities prior to commencing injection activities or prior to the additional land development.

- *How the corrective action schedule will be adjusted if there are changes in the AoR:* The plan must also describe how any changes to the delineated AoR will be addressed (i.e., if the reevaluation determines that the carbon dioxide plume is moving differently than modeled/expected). For example, EPA recommends that the plan describe how additional improperly plugged wells will be identified and corrected expeditiously in advance of being intersected by the carbon dioxide plume or pressure front.

Owners or operators might consider the following factors in determining which improperly abandoned wells located within the AoR need to be corrected prior to initiating injection and in developing the corrective action schedule to be submitted with the plan. EPA recommends that the owner or operator convey in the plan how these factors will be considered in complying with the GS Rule corrective action requirements:

- Any predictions of **plume or pressure front migration rates** that may be available during the preparation of the plan;
- The **historical use of wells** and the **location and density of artificial penetrations** in the AoR of the well. For GS projects in saline reservoirs, there may be few, if any, existing wellbores. However, older/well-developed oil and gas fields may have a significant number of wells.
- The **number of deficient wells**. If there are many improperly plugged wells to correct, then the corrective action implementation schedule may need to account for a larger effort; and

- The **pace of development** or **land use changes** in the region, which may increase the chance that additional wells, including other Class VI injection wells will be drilled (or abandoned) between AoR evaluations.

## 2.2 UIC Program Director's Evaluation of the AoR and Corrective Action Plan

The UIC Program Director will evaluate the proposed Class VI AoR and Corrective Action Plan in connection with the geologic and proposed operating data submitted with the Class VI permit application in order to determine whether to approve the plan. Therefore, the owner or operator needs to demonstrate in the proposed plan, to the UIC Program UIC Program Director's satisfaction, that implementing the plan will result in: an appropriately modeled AoR, a thorough identification of the improperly plugged wells located within the AoR, and a justifiable schedule for correcting all deficient wells located within the AoR.

The UIC Program Director will evaluate the proposed AoR and Corrective Action Plan to verify that all of the required elements, as described in §146.84(b), are present and that the plan accounts for all of the site-specific conditions that need to be addressed in order to ensure that USDWs will be protected from endangerment. Examples of possible considerations by the UIC Program Director are given below:

*Examples of Considerations Related to the AoR Delineation:*

- Is the code that will be used to develop the AoR delineation model sufficient to accurately predict movement of the carbon dioxide plume and pressure front; and does it have the capability to incorporate multiphase flow, the relative buoyancy of carbon dioxide, and three-dimensional geologic heterogeneity?
- Does the proposed model incorporate all relevant site geology, data on subsurface pressures and fluid movement, and proposed operating data submitted with the Class VI permit application?
- Is sufficient information submitted regarding modeling assumptions, including relative permeability/saturation relationships and equations of state?
- Is the proposed AoR reevaluation schedule appropriate based on the operational conditions or anticipated monitoring data?
- Have the geologic factors and operational conditions that could warrant a change in the reevaluation schedule been included in the plan?

*Examples of Considerations Related to Corrective Action:*

- Has a reasonable effort been made to locate all improperly plugged wells located within the AoR, has the condition of each improperly plugged well been established, and based on this information, is the plan sufficient to ensure that no wells in the AoR will serve as conduits for fluid movement into USDWs?
- Are the remediation techniques proposed to be used appropriate to the number and condition of all the improperly abandoned wells located within the AoR?

The UIC Program Director has discretion to allow for phased corrective action activities. In determining whether to exercise this discretion, the UIC Program Director may consider:

- The proposed **carbon dioxide injection rate**, total **injection volumes**, and the **duration of the project**;
- The **composition of the carbon dioxide stream** and potential impacts on **native/formation fluids and the rock matrix**;
- The **density of artificial penetrations** in the vicinity of the injection project;
- The **anticipated number of wells that will need corrective action**, and possible "work load" issues in addressing all of the deficient wells in a large or densely penetrated AoR;
- Whether there is a **guarantee that all wells can be accessed** and remediated at the appropriate time; and
- The AoR delineation **modeling uncertainty** and the resulting impact on the size and shape of the AoR.

The submittal, evaluation, and approval of the AoR and Corrective Action Plan may be an iterative process, involving multiple drafts, until all the information required is submitted at the appropriate level of detail, as determined by the UIC Program Director. If the UIC Program Director has reason to believe (e.g., based on site-specific conditions) that additional data are needed to sufficiently address the anticipated risk associated with the proposed injection (e.g., through adjustments to the model or corrective action methods), it is within his/her authority to request that additional site-specific information be collected, or additional activities be included and described in the AoR and Corrective Action Plan.

EPA recommends that owners or operators consider revising portions of the AoR and Corrective Action Plan as site characterization data become available and modeling is performed. For instance, if AoR modeling indicates that the carbon dioxide plume and pressure front will move faster than initially anticipated based on preliminary geologic data (especially if abandoned wells are to be intersected by the carbon dioxide plume/pressure front), EPA recommends that the owner or operator consider whether the originally planned corrective action schedule is appropriate. Likewise, it may not be possible to prepare a final tabulation of all the improperly abandoned wells in the AoR that require corrective action until the AoR delineation modeling is complete.

The owner or operator and the UIC Program Director are encouraged to discuss the AoR and Corrective Action Plan prior to final submittal, e.g., to discuss the advantages and disadvantages of various modeling approaches, whether to phase corrective action, etc. Such discussions prior to developing and submitting the proposed AoR and Corrective Action Plan can increase the chance that the plan will be approved and avoid any need to revise and resubmit the plan. This background preparation may also limit the need for future amendments to the AoR and Corrective Action Plan. The approved AoR and Corrective Action Plan (including all approved activities and schedules) is enforceable, whether or not the plan is a condition of the permit, because the plan itself and the UIC Program Director's approval are required by the GS Rule [§146.84(b)].

Appendix F presents a checklist of questions and considerations that UIC Program Directors may use when evaluating the proposed AoR and Corrective Action Plan. For additional information on how the UIC Program Director will evaluate the plan, including exercising discretion regarding phased corrective action, see the forthcoming *UIC Class VI Program Interim Final Primacy Application and Implementation Manual*, available in the future on EPA's website, at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm.

## 2.3 Amending the AoR and Corrective Action Plan

The GS Rule requires that the AoR and Corrective Action Plan be reviewed and, if necessary, amended following each reevaluation of the AoR [§146.84(e)]. The purpose of this review is to ensure that the management of the GS project is based on the most up-to-date information available in order to protect USDWs from endangerment. This review of the AoR and Corrective Action Plan follows the required AoR reevaluation, which must occur at least once every five (5) years (see the *Draft UIC Program Class VI Well AoR and Corrective Action Guidance* for additional information on performing AoR reevaluations).

The owner or operator must submit the amended AoR and Corrective Action Plan to the UIC Program Director for approval following an AoR reevaluation or any other event that triggers an AoR and Corrective Action Plan Review [§146.84(e)]. EPA recommends that owners or operators submit the revised AoR and Corrective Action Plan along with revisions to the Testing and Monitoring Plan and the Emergency and Remedial Response Plan, both of which are due within (1) year of an AoR reevaluation, or within one (1) year of any other event that triggers an AoR reevaluation.

To assess the need for amending the AoR and Corrective Action Plan, EPA recommends that owners or operators use the results of the AoR reevaluation, along with monitoring data (e.g., carbon dioxide plume and pressure front tracking and ground water monitoring) and operational data (e.g., injection rates and volumes) collected since the last reevaluation. It is recommended that the owner or operator also undertake a review of the AoR and Corrective Action Plan if there are significant changes to the facility, such as the permitting of an additional injection well, or if any adverse events occur that require the implementation of an emergency response.

EPA recommends that, as part of their ongoing dialogue, the owner or operator and the UIC Program Director discuss the most recent AoR delineation or reevaluation, along with monitoring and operational data collected, and any other pertinent information about the carbon dioxide injection operation during this plan review. This communication and coordination are an important part of the process to ensure that the GS project is (and continues to be) managed appropriately to protect USDWs, and that injection operations remain in compliance with permit conditions. These discussions can also help the owner or operator understand the UIC Program Director's expectations, including whether an amended plan might be needed so that the UIC Program Director receives all the required information up front in order to facilitate the review process. The sections below describe a recommended process by which the owner or operator may review and amend the AoR and Corrective Action Plan:

***Step 1: Review the results of the AoR reevaluation,*** along with the most recent monitoring and operational data. The purpose of this review is to identify whether an amendment to the AoR and Corrective Action Plan is needed. Questions that may be considered in the review include:

- Did the most recent AoR reevaluation identify a need to revise the AoR computational model? If so, the AoR and corrective action plan may need to be amended to reflect any changes to the modeling approach or the modeled AoR.
- Do the most recent AoR modeling results closely match monitoring results? If not, it may be necessary to revise the model, adjust the modeling assumptions, and/or review or supplement input data.
- Is the plume or pressure front moving faster or in a different direction than previously predicted? This may indicate that more frequent AoR reevaluation is appropriate.
- Do additional wells need corrective action, or do some wells previously identified for corrective action need to be addressed earlier than planned, based on modeling results or monitoring data? Either of these situations may necessitate revisions and amendments to the corrective action plan.
- Have land use changes potentially affected the owner or operator's ability to secure rights to access wells identified as needing corrective action? These land use changes may necessitate revisions to the corrective action schedule, e.g., to implement corrective action on some improperly abandoned artificial penetrations before the planned changes to land ownership take place.

***Step 2: Discuss the results with the UIC Program Director.*** EPA recommends that the owner or operator and the UIC Program Director discuss whether an amendment to the AoR and Corrective Action Plan is needed, based on the considerations in Step 1. The final decision regarding the need for an amended plan will be made by the UIC Program Director.

If this review indicates that an amendment to the AoR and Corrective Action Plan is needed, it is important that the owner or operator begin revising the plan as soon as possible, so that the one (1) year deadline for amending this plan (along with any necessary amendments to the other related project plans) can be met. Regardless of whether a conversation with the UIC Program Director takes place, it is recommended that the owner or operator use the site-specific monitoring and operational data to prepare and present a recommendation for action on an amended AoR and Corrective Action Plan.

***Step 3: Amend the AoR and Corrective Action Plan if needed.*** EPA recommends that the amended AoR and Corrective Action Plan include the same categories of information that were included in the original plan that was developed before injection commenced (see Section 2.1 of this guidance document for a description of the required plan elements). After injection has begun, and as new operational and monitoring data become available, the following changes may necessitate an amendment to the plan:

- Based on a comparison of previous modeling results and monitoring data, revisions may be required for the AoR modeling approach and can include justified modifications to the code used, parameterization process, assumptions (e.g., relative permeability/saturation relationship), or the representation of site-specific geologic conditions in the model;

- If the predicted extent of the AoR changes, additional improperly plugged wells may be located within the newly defined AoR boundary. Likewise, if the plume and pressure front are moving at a faster rate than originally predicted (as evidenced through monitoring data or modeling), revisions to the phasing schedule for corrective action activities may be needed; or
- Information about when the next AoR reevaluation will be performed, or confirmation that the next scheduled reevaluation is appropriate, vs. identifying the conditions that would warrant an AoR reevaluation ahead of schedule.

***Step 4: Submit the amended plan***. The GS Rule requires that the owner or operator submit the amended AoR and Corrective Action Plan to the UIC Program Director for approval following an AoR reevaluation or any other event that triggers an AoR and Corrective Action Plan Review [§146.84(e)]. EPA recommends that owners or operators submit the revised AoR and Corrective Action Plan along with revisions to the Testing and Monitoring Plan and the Emergency and Remedial Response Plan, both of which are due within (1) year of an AoR reevaluation, or within one (1) year of any other event that triggers an AoR reevaluation.

The amended plan must be approved by the UIC Program Director and would then be incorporated into the operating permit for that Class VI injection well [§146.84(e)(4)]. If significant changes to the AoR and Corrective Action Plan are needed, the UIC Program Director may need to modify the Class VI permit. A permit modification under §144.39 (e.g., to incorporate a much larger AoR or a significantly larger number of wells needing corrective action) would require notification to the public and an opportunity for public participation and comment. See 40 CFR Part 124 for the details of the process. Minor changes to the plan as defined under §144.41 (e.g., to provide clarification, correct typographical errors, or other minor changes), do not require a permit modification or a public process under 40 CFR Part 124. See the forthcoming *UIC Class VI Program Interim Final Primacy Application and Implementation Manual*, available on EPA's website in the future, for additional information about the procedures for modifying Class VI permits and the related plan amendments.

## 3.0 Testing and Monitoring Plan

Testing and monitoring are important components of managing a GS project to ensure that USDWs are not endangered. Information generated through a rigorous testing and monitoring regime can provide information about site performance when compared to the baseline site characterization information submitted pre-injection or to any previously collected monitoring results.

Monitoring data can also be used to demonstrate that the project is performing as predicted, or provide warning that unexpected fluid movement has occurred and that USDWs may be endangered. For example, monitoring data can demonstrate that the carbon dioxide is confined in the injection zone as predicted; identify the potential corrosion of well construction materials and signal needed construction/mechanical integrity fixes; or identify changes in formation fluid geochemistry (e.g., pH decreases that could cause metals to leach into the ground water). Appropriate monitoring of a GS site can also provide data to maintain the efficiency of the

storage operation, minimize costs, provide input data for AoR reevaluation modeling, or target future corrective action.

## 3.1 Developing the Testing and Monitoring Plan

The GS Rule, at §146.90, describes the required elements of a Class VI Testing and Monitoring Plan, including: injectate analysis, monitoring the injection operation, corrosion monitoring, monitoring of geochemical changes in the subsurface, mechanical integrity tests (MITs), pressure fall-off testing, tracking the carbon dioxide plume and area of elevated pressure, surface air and soil gas monitoring for carbon dioxide fluctuations (at the discretion of the UIC Program Director), and any additional tests determined by the UIC Program Director to be necessary to ensure protection of USDWs from endangerment.

Guidance presenting recommended approaches to performing the activities under the approved Testing and Monitoring Plan (e.g., how to select appropriate testing equipment, monitoring techniques, locations, and frequencies) can be found in the forthcoming *Draft UIC Program Class VI Well Testing and Monitoring Guidance* posted on EPA's website, when available for the public, at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm. Exhibit 3 presents highlights of the information presented in that guidance.

The Testing and Monitoring Plan must be submitted with the Class VI permit application for approval by the UIC Program Director [§146.82(a)(15)]. It must include a description of how the owner or operator will meet the requirements of §146.90, including quality assurance and surveillance measures, and obtaining necessary access to sites for all testing and monitoring during the life of the GS project.

The sections below present the required elements of the Testing and Monitoring Plan, how they may be described to demonstrate, to the UIC Program Director's satisfaction, that the plan is sufficient and can be approved, and the issues that owners or operators may consider as they develop their plan. Some of the elements of the Testing and Monitoring Plan are highly site-specific (e.g., monitoring well placement) and will require detailed descriptions of how these specific factors were identified and considered in developing the plan. Other elements of the Testing and Monitoring Plan, (e.g., where testing frequency is set in the rule), may require less site-specific consideration and description. Appendix B of this guidance document presents a sample template of a Class VI Testing and Monitoring Plan.

**Exhibit 3: Draft UIC Program Class VI Well Testing and Monitoring Guidance Highlights**

The *Draft UIC Program Class VI Well Testing and Monitoring Guidance* presents recommended approaches for performing the monitoring and testing activities required of Class VI well owners or operators during the lifetime of a GS project.

The introductory section reviews the Class VI regulations related to testing and monitoring. Remaining sections of the guidance address the following topics:

- Logging, sampling, and testing of injection wells prior to operation;
- Performance of internal and external mechanical integrity tests during operation;
- Conducting additional injection well tests during operation;
- Ground water monitoring around the injection site;
- Tracking of the carbon dioxide plume and pressure front; and
- Monitoring of soil gas and surface air around the injection site.

For each section, the Guidance:

- Presents recommended ways to perform activities necessary to comply with GS Rule testing and monitoring requirements (e.g., ground water monitoring, MITs). Illustrative examples are provided in several cases.
- Provides references to other, more comprehensive, reference documents and published scientific literature for further information.
- Explains how and when to report to the UIC Program UIC Program Director the results of activities related to testing and monitoring.

### *3.1.1 Analysis of the carbon dioxide stream*

The GS Rule requires owners or operators to analyze the carbon dioxide stream with "sufficient frequency to yield data representative of its chemical and physical characteristics" [§146.90(a)]. Chemical characteristics include the fluid composition (e.g., the concentration of impurities in the carbon dioxide). Physical characteristics may include temperature and pressure. The forthcoming *Draft UIC Program Class VI Well Testing and Monitoring Guidance* provides detailed information and recommended approaches on performing analyses of various physical and chemical parameters of carbon dioxide streams.

EPA recommends that the Class VI Testing and Monitoring Plan describes parameters and frequencies at which they are to be tested, and that the Plan specifies, for each analyte/parameter, sampling methods; the analytical technique to be used; whether the testing will be done in-house or at a laboratory; and quality assurance and surveillance measures. To demonstrate that the proposed analysis will be performed at an appropriate frequency, the schedule may include testing dates as appropriate (e.g., the first day of each quarter or month), and describe how the test results are to be recorded and reported to the UIC Program Director.

The necessary type and frequency of injectate analysis will be project-specific and will depend on the carbon dioxide source and the likelihood of variability in injectate composition. EPA

recommends that the owner or operator consider and include the following in developing the Testing and Monitoring Plan:

- The **source of the carbon dioxide**: it is important that the suite of parameters tested reflect the potential for impurities, based on the process generating the carbon dioxide and the capture technologies. Note: if the presence or concentrations of impurities render the carbon dioxide a hazardous waste, the injection well would need to be permitted as a Class I hazardous waste injection well.
- **Whether the source of the carbon dioxide will vary** over the life of the well: for example, a carbon dioxide-capture process from a coal-fired power plant with a consistent coal source and operating parameters is likely to produce a carbon dioxide stream with a fairly consistent composition. Frequent changes in the carbon dioxide source, or multiple carbon dioxide sources, may necessitate more frequent or varied analysis that aligns to changes in the source facility or may necessitate testing and monitoring for additional parameters.
- The potential for **changes in the composition of the stream** based on contamination during transport (i.e., within a pipeline), including any mixing with water.

### *3.1.2 Installation and use of continuous recording devices*

Owners or operators of Class VI wells must install and use continuous recording devices to monitor: injection pressure, injection rate, and volume of fluid injected; the pressure on the annulus between the tubing and the long-string casing; and the annulus fluid volume added [§146.90(b)]. Continuously monitoring these parameters (required in lieu of internal MITs) helps to verify that the well has internal mechanical integrity and ensure that the injection facility is operating within permitted limits so as to not fracture the confining zone. These data can also serve as inputs for modeling to support AoR reevaluations. See the forthcoming *Draft UIC Program Class VI Testing and Monitoring Guidance*, available in the future at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm, for descriptions of the types of gauges and meters available for use when monitoring these types of parameters.

In the Class VI Testing and Monitoring Plan, EPA recommends that owners or operators describe the recording devices to be used for continuous monitoring, as well as the associated quality assurance and surveillance measures, the frequency at which the information will be recorded (e.g., every 20 seconds), and how the data will be retained and reported.

### *3.1.3 Corrosion monitoring*

The GS Rule requires owners or operators to monitor the injection well materials for signs of corrosion; including loss of mass, thickness, cracking, pitting and other signs of corrosion [§146.90(c)]. This corrosion monitoring must be performed on a quarterly basis. Corrosion monitoring is necessary to verify that the well components meet the minimum standards for material strength and performance and to identify well maintenance needs. Corrosion of well construction materials is a particular concern for Class VI wells given that carbon dioxide in the presence of water becomes acidic, potentially accelerating the corrosion of construction materials. The carbon dioxide stream for a GS project may also contain small volumes of impurities (e.g., sulfur dioxide) that could contribute to corrosion.

Class VI well operators can meet the GS Rule corrosion monitoring requirement by analyzing coupons of the well construction materials that are placed in contact with the carbon dioxide stream or by routing the carbon dioxide stream through a loop constructed of the material used in the well and inspecting the materials in the loop. Owners or operators may also use an alternative method, if it is approved by the UIC Program Director. See the *Draft UIC Program Class VI Well Testing and Monitoring Guidance* for additional information on corrosion testing methods.

EPA recommends that the Testing and Monitoring Plan describe the corrosion monitoring program, including the monitoring method to be used and any associated quality assurance and surveillance measures. If the owner or operator seeks to use an alternative corrosion testing method, the Testing and Monitoring Plan should describe the method to be used and why it is appropriate for the project, e.g., to the specific carbon dioxide injectate or the well characteristics. It is important that the owner or operator discuss with the UIC Program Director the appropriateness of alternative methods as the plan is developed. EPA recommends that the Testing and Monitoring Plan also include a schedule for performing the quarterly tests (e.g., anticipated testing dates) and how the data will be reported.

### *3.1.4 Ground water quality monitoring*

Owners or operators must perform periodic monitoring of ground water quality and geochemical changes above the confining zone(s) [§146.90(d)]. This monitoring is important for identifying any geochemical changes that may be a result of fluid movement through the confining zone, including whether formation fluids have acidified and might have leached (or may leach in the future) metals into the ground water.

Site characterization data (particularly baseline geochemical data) should be considered in selecting ground water monitoring parameters, and ground water monitoring data should be compared to the initial data collected during site characterization. See the *Draft UIC Program Class VI Well Site Characterization Guidance* for details about what information must be generated as part of the baseline data collection required under §146.82(a). The location and number of monitoring wells must be based on specific information about the GS project, including site-specific geology and baseline geochemistry, the presence of artificial penetrations, and planned operations (carbon dioxide injection rates and volumes).

Where injection depth waivers are sought, the plan must also describe the ground water quality monitoring that will be done below the lower confining zone. See the forthcoming *Draft UIC Program Class VI Well Injection Depth Waiver Application Guidance,* currently under development and to be posted on EPA's website when available, for additional monitoring considerations for wells operating under injection depth waivers. See the *Draft UIC Program Class VI Well Testing and Monitoring Guidance*, when available, for additional information on ground water monitoring, including analytical methods and monitoring well design.

It is recommended that the Testing and Monitoring Plan describe the number and placement of monitoring wells, the parameters to be monitored, and the frequency at which sampling and analysis will be performed. EPA also recommends that the plan include maps that identify the injection well, the AoR, and the placement of all planned monitoring wells. Ground water quality

monitoring is site-specific and depends on many factors; considerations for each of these aspects of the Testing and Monitoring Plan are described below.

*Monitoring Well Placement*

Planning of monitoring well placement should include the number of wells; their distribution and density within the AoR; and their depth, the subsurface formations to be sampled, and the screened interval(s). The Testing and Monitoring Plan should identify (e.g., with the use of maps and cross sections) the location and depth of each monitoring well. The owner or operator must also indicate in the plan that they will be able to access (e.g., have rights to drill and sample the ground water) all planned monitoring well locations.

EPA recommends that owners or operators consider the installation and operation of more than a minimally acceptable number of monitoring wells. For example, owners or operators may consider and discuss with the UIC Program Director what monitoring may be needed—not only in the near term, but also during the period of active injection operations (i.e., as the injected carbon dioxide is moving away from the well). More extensive and frequent monitoring from the outset of the injection operation may eliminate the need for future amendments to the Class VI Testing and Monitoring Plan or to the permit. This more extensive and frequent monitoring throughout the injection phase may also support more dependable non-endangerment demonstrations during the post injection site care (PISC) phase of a GS project (see Section 5 of this guidance document, below).

EPA recommends that owners or operators consider the tradeoff between a monitoring program with a large number of monitoring wells vs. a minimum number of wells, based on site-specific geologic conditions and the subsurface impacts of drilling monitoring wells. An extensive monitoring program involving many monitoring wells could better characterize changes in subsurface geochemistry and more closely track the carbon dioxide plume; however, with a larger number of wells, there is an increased chance that one or more wells could serve as a conduit for fluid movement into USDWs. Where possible, owners or operators may consider using monitoring wells for multiple purposes, such as ground water monitoring above the confining zone and pressure monitoring in the injection zone, to satisfy the requirements at §146.90(g); see Section 3.1.7 of this guidance document, below. While wells with multiple screenings (i.e., in the injection and confining zones) may be more expensive to construct, this multiple usage of a single monitoring well may ultimately reduce costs.

Existing wells in the AoR may be considered for use as monitoring wells. Enhanced oil or gas recovery fields, for example, might contain existing production or monitoring wells that could be adapted for use as monitoring wells instead of being plugged.

It is important that monitoring wells be properly designed and constructed in order to reduce their potential to serve as conduits for fluid movement into USDWs. This is particularly important where the monitoring wells perforate the confining zone (e.g., to allow pressure monitoring in the injection zone or to sample ground water below the lower confining zone for wells operating under injection depth waivers). EPA recommends that the Testing and Monitoring Plan include schematics of the planned monitoring wells, including the sampling

equipment the owner or operator plans to use. The forthcoming *Draft UIC Program Class VI Well Testing and Monitoring Guidance* provides additional information on monitoring well construction.

The location, number, and depth of monitoring wells must be based on site-specific information about the project [§146.90(d)(1)]. See the *Draft UIC Program Class VI Well Testing and Monitoring Guidance* for additional information on proper well spacing. The Testing and Monitoring Plan must describe how the following information has been considered in determining appropriate monitoring well placement:

- The **depth, thickness, and permeability** of the injection and confining zones, USDWs, and any relevant additional zones;
- The **size and shape of the AoR**, based on the current delineation;
- The presence of **artificial penetrations**; and
- The planned **injection rates and volumes**.

Other site-specific considerations the owner or operator may consider in planning monitoring well placement include:

- **Land use changes** in the region and the pace of development, including the presence of sensitive populations including children, and environmental justice concerns, which may warrant additional monitoring to address public concerns. EPA recommends that owners and operators work with the UIC Program UIC Program Director on any issues pertaining to environmental justice concerns and sensitive populations, as the Program UIC Program Director may have additional tools and resources to assist in this process;
- **Proximity to USDWs**, public water supplies, or private wells, which may necessitate additional monitoring, particularly if all residents in the vicinity of the well rely on one USDW for their drinking water supply;
- The **presence of other injection operations**, which may impact geochemical changes in formation fluids or subsurface fluid movement; and
- The **possibility of** conducting water quality monitoring in the injection zone **using wells needed for pressure monitoring** (i.e. monitoring for the presence or absence of elevated pressure) [§146.90(g)]. See Section 3.1.7 of this guidance document, below for more information.

*Monitoring Parameters*

Determining the ground water monitoring parameters to be analyzed is site-specific. EPA expects that ground water collected above the confining zone, or from any additional zones, would most likely be monitored for, at a minimum; total dissolved solids (TDS); specific conductivity (SC); temperature; potential for hydrogen ions (pH), i.e., a measure of water acidity; and carbon dioxide. In addition, based on the site-specific considerations, as discussed below, other ground water constituents owners or operators may monitor for include major anions and cations; trace metals (e.g., arsenic, mercury, or lead); carbon dioxide tracers; hydrocarbons; and volatile organic compounds (VOCs). EPA suggests that the choice of monitoring parameters be based on the baseline geochemical data collected during the initial site characterization, all previous monitoring data, and any available geochemical modeling information.

The Class VI Testing and Monitoring Plan must describe the specific parameters to be monitored and detail any additional factors that were considered in designing the list of monitoring parameters. In addition, EPA recommends that the planned sample collection, handling (i.e., chain of custody), and analytical procedures be provided; the plan should also describe the analytical methods, and the name of the certified laboratory that will perform the analysis. The forthcoming *Draft UIC Program Class VI Well Testing and Monitoring Guidance* describes examples of acceptable sampling procedures for ground water monitoring at GS sites.

EPA recommends that owners or operators consider and convey to the UIC Program Director the following in determining which geochemical parameters to include in the Testing and Monitoring Plan:

- If any **impurities** are present (or may be anticipated to be present) in the carbon dioxide stream (e.g., hydrogen sulfide), it is important that these be included in routine ground water monitoring;
- The type of **target formation**; for example EPA recommends that owners or operators of GS projects located in depleted (or depleting) oil and gas reservoirs monitor for residual hydrocarbons that may be in the formation and potentially mobilized into ground water as a result of carbon dioxide injection; and
- If site-specific data generated during the baseline geochemical survey indicate the presence of arsenic or other **metals that have the potential to be mobilized** by the injection activity, it may be appropriate to monitor for heavy metals, organic contaminants, and dissolved minerals.

*Monitoring Frequency*

EPA recommends that the Class VI Testing and Monitoring Plan describe, for each monitoring parameter, the proposed frequency of sampling and analysis. Testing for more typical parameters, such as TDS, aqueous and pure carbon dioxide, and pH will likely occur relatively frequently, while parameters less likely to occur in ground water may warrant less frequent analysis.

The GS Rule requires that the owner or operator consider baseline geochemical data and AoR modeling results in determining the monitoring frequency [§146.90(d)(2)]. Thus, the Testing and Monitoring Plan must describe how these factors were considered. EPA recommends that owners or operators also consider the schedule for planned AoR reevaluations, so that the ground water monitoring data would be available to serve as inputs for future modeling runs, if necessary.

### *3.1.5 A demonstration of external mechanical integrity*

Owners or operators of GS projects must perform external MITs to determine the absence of significant fluid movement into a USDW through potential channels adjacent to the injection well bore [§146.90(e)]. Regular MITs are an important protective measure that can indicate the need for well repairs in order to avoid potential contamination through the wellbore.

The GS Rule, at §146.89(c), specifies the approved MIT methods for Class VI wells: an approved tracer survey, such as an oxygen-activation log, or a temperature or noise log. Other MIT methods may be approved by the EPA Administrator. However, because a request for using alternative methods other than those currently approved by EPA requires an additional EPA approval process to become acceptable and the eventual publication of the alternative method approval in the *Federal Register*, EPA recommends that owners or operators discuss any such need for an alternative MIT method with the UIC Program Director as early as possible to determine what course of action may be preferred to avoid delays in approving the Class VI Testing and Monitoring Plan.

Note that periodic internal MITs are not required for Class VI injection wells. The continuous monitoring that is briefly described in Section 3.1.2 of this guidance document, above, is required to be performed in lieu of internal MITs during injection operations. However, internal MITs must still be performed before commencing injection and before plugging the well [§§146.82(c)(8) and 146.92(a)].

Selecting the specific MITs to be used at an injection well should be based on the well design and the planned use of automatic surface or down-hole shut off devices [§§146.88(e)(2) and 146.88(e)(3)]. See the forthcoming *Draft UIC Program Class VI Well Testing and Monitoring Guidance* for additional information on available MITs. See Section 2 of the *Draft UIC Program Class VI Well Construction Guidance* for some additional information on using surface and down-hole shut devices.

The UIC Program Director has the discretion to require the use of casing inspection logs to determine if there is any casing corrosion [§146.89(d)]. The frequency of this casing corrosion test is established based on site-specific and well-specific conditions, and EPA recommends that this information be incorporated into the Testing and Monitoring Plan.

External MITs must be performed at least once per year. However, the owner or operator may set the testing schedule to coincide with regularly scheduled well workovers or other routine well maintenance. EPA recommends that the plan describe the specific MITs to be employed, the associated quality assurance and surveillance measures, anticipated testing dates, and the owner or operator's plans to record and report the MIT results.

### *3.1.6 A pressure fall-off test*

Pressure fall-off tests are designed to verify that pressure declines agree with modeled projections of reservoir pressure changes. A pressure fall-off test must be performed every five (5) years, unless more frequent testing is required by the UIC Program Director [§146.90(f)]. However, the owner or operator may set the testing schedule to coincide with scheduled well workovers or other testing or maintenance. EPA recommends that the owner or operator and the UIC Program Director discuss what conditions may trigger the need for more frequent pressure fall-off testing. See the forthcoming *Draft UIC Program Class VI Well Testing and Monitoring Guidance* for additional information about performing pressure fall-off tests.

EPA recommends that the Class VI Testing and Monitoring Plan also describe the pressure fall-off tests to be employed, the associated quality assurance and surveillance measures, anticipated testing dates, and how the owner or operator plans to record and report the test results.

### *3.1.7 Carbon dioxide plume and pressure front tracking*

Owners or operators must perform testing and monitoring to track the extent of the carbon dioxide plume and the presence or absence of elevated pressure, i.e., the pressure front [§146.90(g)]. This monitoring provides information about the rate and direction of carbon dioxide plume and pressure front movement, demonstrates that formation pressures are stable, and verifies that the injectate is safely confined (or provides early warning that it is not).

The purpose of this requirement is to ensure that the owner or operator and the UIC Program Director know, and discuss, the position of the carbon dioxide plume and pressure front during the lifetime of the GS project. This is necessary to ensure that carbon dioxide and/or mobilized fluids are not endangering USDWs or migrating in a manner contrary to the initial estimates generated by the AoR delineation modeling. Ongoing monitoring data are also to be used to inform AoR reevaluations.

All owners or operators must use direct methods to monitor for the presence or absence of carbon dioxide and pressure changes in the injection zone. Owners or operators may find it useful to consider also performing pressure monitoring in ground water quality monitoring wells (i.e., in the first permeable formation above the confining zone). This could provide additional data to verify confinement without additional monitoring well construction. See Section 3.1.4 of this guidance document, above, for additional information on the use and benefits of multiple-purpose monitoring wells.

Class VI injection well owners or operators must also use indirect methods (e.g., seismic, electrical, gravity, or electromagnetic surveys and/or down-hole carbon dioxide detection tools) to track the plume and pressure front, unless the UIC Program Director determines, based on the site-specific geology, that such indirect methods are not feasible. If indirect geophysical techniques cannot be used, EPA recommends that additional pressure monitoring wells be used.

Various subsurface monitoring techniques are available to track the extent of a carbon dioxide plume, including seismic and electrical methods. EPA recommends that the owner or operator

discuss with the UIC Program Director the use and feasibility of indirect geophysical methods, including which methods are most appropriate based on site-specific geologic information. If the owner or operator believes that no indirect plume tracking methods are feasible, it is important that this be discussed with the UIC Program Director early in the planning process. The forthcoming *Draft UIC Program Class VI Well Testing and Monitoring Guidance* provides detailed information on carbon dioxide plume and pressure front tracking methods.

The Class VI Testing and Monitoring Plan must describe which direct and indirect tracking methods will be used. This might include pressure monitoring locations, the types of indirect surveys to be performed, their resolution, and the areal extent of geophysical surveys. The associated quality assurance and surveillance measures must also be included in the plan. It is important that the plan describe the testing frequency, how site access will be guaranteed, and how the owner or operator plans to record and report the results.

EPA recommends that owners or operators consider and include the following in developing the plan for carbon dioxide plume and pressure front tracking:

- The predicted **size and shape of the AoR**, which would affect the pressure monitoring locations and the areal extent of geophysical surveys;
- Any **site-specific geologic conditions** that inform what indirect geophysical techniques may be used, including the presence of any features that may impact the feasibility of geophysical methods;
- The presence of **multiple subsurface layers with USDWs**, which may affect the placement of pressure monitoring wells;
- Whether an **injection depth waiver** is sought. This would necessitate additional geochemical monitoring or pressure monitoring, both above the upper confining zone and below the lower confining zone;
- The **presence of other injection operations**, which may impact pressure changes in the subsurface; and
- The **presence, location, and construction of any additional wells** at the site, including monitoring wells, which may be used for plume and pressure-front tracking.

### *3.1.8 Surface air monitoring and/or soil gas monitoring (if required)*

The GS Rule provides the UIC Program Director discretion to require surface air monitoring and/or soil gas monitoring to detect movement of carbon dioxide that could endanger a USDW [§146.90(h)]. All surface air and/or soil gas monitoring must be based on potential risks to USDWs within the AoR.

The UIC Program Director's decision to require surface air/soil gas monitoring and the selection of monitoring methods will be site-specific (e.g., based on geology or injection depth). Therefore, it is important that the owner or operator and UIC Program Director discuss the proposed Testing and Monitoring Plan and the site characterization data collected as the plan is developed. This dialogue can support a UIC Program Director’s determination as to whether any soil or air monitoring is necessary to protect USDWs from endangerment. If so, the owner or

operator will need to consider what baseline soil or air monitoring data may need to be collected prior to the commencement of injection activities.

If the UIC Program Director requires the installation and use of surface air/soil gas monitoring technologies, Class VI well owners or operators may use the same technologies as they will employ to comply with the Carbon Dioxide Injection and GS Reporting rulemaking (subpart RR) under the Greenhouse Gas Reporting Program (40 CFR Part 98). Compliance with these Part 98 requirements is considered a condition of the Class VI permit [§146.90(h)(3)].

If soil or air monitoring is determined by the UIC Program Director to be necessary, then the owner or operator's Testing and Monitoring Plan must describe how the proposed monitoring will yield useful information for the AoR delineation and/or for compliance with standards that prevent movement of fluids to USDWs under §144.12 [§146.90(h)(2)]. The Class VI Testing and Monitoring Plan must also describe the carbon dioxide monitoring techniques and equipment, quality assurance and surveillance measures, monitoring locations (including how the owner or operator will access the monitoring sites), monitoring frequency (e.g., anticipated dates), and how the owner or operator plans to record and report the results. See the *Draft UIC Program Class VI Well Testing and Monitoring Guidance* for additional information on surface air monitoring and soil gas monitoring technologies. The owner or operator should also consider the requirements of 40 CFR Part 98 when developing this particular aspect of the Testing and Monitoring Plan.

EPA recommends that the owner or operator and the UIC Program Director discuss and consider the following in determining whether surface air and/or soil gas monitoring is needed or when developing the plan:

- The **presence or proximity of USDWs** that could be endangered, which will drive the need for this monitoring;
- **Baseline geologic information** regarding the existence and location of any fractures, faults, or other discontinuities that could serve as conduits for fluid movement;
- **Baseline geochemical data**;
- The pace of **development or land use changes** in the region, which would drive monitoring locations (e.g., the need to monitor near structures or populated areas); and
- **Public input and concerns**, including environmental justice considerations. A robust monitoring scheme that includes soil/air monitoring for carbon dioxide may be the key to local acceptance of the project.

### *3.1.9 Any additional monitoring required by the UIC Program Director*

The rule provides the UIC Program Director discretion to require the owner or operator to perform any additional monitoring necessary to support, upgrade, and improve computational modeling of the AoR, and to determine compliance with standards that prevent movement of fluids to USDWs [§146.90(i)].

One potential additional monitoring technique is the use of tracers. These may include stable isotopes of carbon and oxygen, perfluorocarbon, or radioactive tracers. Tracers can be useful

tools for monitoring, plume tracking, and verification at GS sites and may help improve public confidence in certain projects. However, tracer use is not appropriate in all situations. For this reason, they are not required at all GS sites, although the UIC Program Director has the discretion to require their use if he/she determines that using tracers could improve the monitoring of the site and enhance USDW protection.

EPA recommends that the owner or operator discuss the proposed Class VI Testing and Monitoring Plan, and the site characterization data collection process, with the UIC Program Director as he/she develops the plan in order to determine whether any additional monitoring would be necessary at the proposed Class VI injection well site. If the UIC Program Director requires additional testing and monitoring, the plan must describe the testing techniques, equipment to be used and the associated quality assurance and surveillance measures, testing frequency (e.g., anticipated test dates), and how the owner or operator plans to record and report the results [§146.90].

## 3.2 UIC Program Director's Evaluation of the Testing and Monitoring Plan

The UIC Program Director must evaluate the proposed Testing and Monitoring Plan in connection with the geologic and proposed operating data submitted with the Class VI permit application to determine whether to approve the plan. Therefore, the owner or operator must demonstrate, to the satisfaction of the UIC Program Director, that the proposed plan will be sufficient to meet the requirements of §146.90 and account for all site-specific conditions to ensure that USDWs are protected from endangerment. For example the UIC Program Director may consider:

- Is the planned testing and monitoring sufficiently robust (e.g., the proposed frequency, location, parameters) to provide early warning if USDWs are endangered?
- Does the proposed testing and monitoring plan address all potential risks identified in the site characterization process, e.g., all nearby USDWs or non-transmissive faults or fractures?
- Will the proposed plan provide the necessary data and model inputs on which to verify predictions of carbon dioxide plume movement and to reevaluate the AoR?
- Is monitoring appropriate to address the additional risk associated with injection into non-USDWs that are below/between USDWs if an injection depth waiver is sought?
- Are the planned monitoring wells located and constructed in a way to ensure they do not provide a conduit for fluid movement to USDWs?

The submittal, evaluation, and approval of the testing and monitoring plan are meant to be parts of an iterative process. This may involve multiple drafts of the plan until all required information is submitted in an appropriate format and level of detail. If the UIC Program Director has reason to believe, based on site-specific conditions, that additional monitoring is needed to sufficiently assess the behavior of the GS project or to protect USDWs from endangerment, it is within his/her authority to request that additional monitoring be included. This may include more frequent monitoring or the monitoring of additional parameters. The approved Testing and Monitoring Plan is enforceable, whether or not it is a condition of the permit, because the plan itself and the UIC Program Director's approval are required by the GS Rule [§146.90].

Interaction and conversation are encouraged to discuss the areas of UIC Program Director's discretion, such as more frequent monitoring or soil and air gas monitoring. Having such discussions prior to developing and submitting the plan may increase the chance that the proposed plan can be approved, and it may avoid the need for plan revision or future amendments.

Appendix F of this guidance document presents a checklist of questions and considerations that UIC Program Directors may use when evaluating the proposed Class VI Testing and Monitoring Plan. See the forthcoming *UIC Class VI Program Interim Final Primacy Application and Implementation Manual* for additional information on how the UIC Program Director may evaluate the plan, including exercising any discretion regarding requiring additional monitoring.

## 3.3 Amending the Testing and Monitoring Plan

The GS Rule requires that the Testing and Monitoring Plan be reviewed and, if necessary, amended following each reevaluation of the AoR [§146.90(j)]. The purpose of this review is to ensure that the management of the GS project and all of the project plans are based on the most up-to-date information available. This review of the plan follows the required AoR reevaluation timeframe, which must occur at least once every five (5) years. See Section 5 of the *Draft UIC Program Class VI Well AoR and Corrective Action Guidance* for additional information on performing AoR reevaluations. The amended Testing and Monitoring Plan (or a demonstration that no amendment is needed) is due no later than one year after the reevaluation [§146.90(j)(1)].

Owners or operators must use the results of the AoR reevaluation, along with monitoring data (e.g., the results of carbon dioxide plume and pressure front tracking and ground water monitoring); operational data (e.g., injection rates and volumes); and any newly collected site characterization data collected since the last AoR reevaluation, to assess the need for amending the Testing and Monitoring Plan. The owner or operator must also review the plan if there are significant changes to GS facility operations, such as the addition of a Class VI injection well, or if any adverse events requiring the implementation of an emergency response occur.

EPA recommends that the owner or operator and the UIC Program Director coordinate and discuss the most recent AoR evaluation, along with monitoring and operational data and other information about the facility during this plan review. EPA considers this dialogue to be an important part of the process to ensure that the GS project continues to be managed appropriately and that compliance with the Class VI permit is achieved. These discussions can also help the owner or operator to understand the UIC Program Director's expectations, including whether an amended plan is needed so that the UIC Program Director receives all the required information up front in order to facilitate the review process.

The sections below describe a recommended process by which the owner or operator may review and amend the Class VI Testing and Monitoring Plan.

***Step 1: Review the results of the AoR reevaluation,*** along with the most recent monitoring and operational data. The purpose of this review is to identify whether an amendment to the Testing and Monitoring Plan is needed. Topics that may be considered in the review include:

- Model revisions, because if the most recent AoR reevaluation necessitated a revision to the AoR computational model, EPA recommends that the plan be amended to reflect any changes to the prediction of plume and pressure front movement.
- Carbon dioxide plume and pressure front monitoring data, e.g., any changes in the size or shape of the AoR or indications that the plume is moving differently than predicted. These changes may indicate the need for additional monitoring locations, pressure monitoring in more locations, or more frequent/extensive geophysical surveys. Since some variability is expected, the owner or operator is advised to evaluate the significance of these changes and discuss with the UIC Program Director the need for any additional testing and monitoring.
- Evidence of leaching/mobilization of metals or organic constituents in the subsurface, which may indicate a need to modify ground water monitoring parameters or analytes. An analysis of the location of the subsurface reactions (i.e., in the injection zone) and the risks posed of fluid movement that would require additional monitoring.
- Well construction, mechanical integrity, and corrosion testing data, which may indicate the need to modify the well testing regime, e.g., by revising MITs or corrosion monitoring activities.
- If an expansion to the areal extent of an existing Class II EOR/EGR aquifer exemption was issued for the project, do testing and monitoring data confirm that the estimated extent of the exemption is adequate?

***Step 2: Discuss the results with the UIC Program Director.*** EPA recommends that the owner or operator and the UIC Program Director discuss whether an amendment to the Testing and Monitoring Plan is needed. If the AoR reevaluation and monitoring/operating data were to indicate that the plume is moving as predicted, an amendment may not be necessary. The final decision regarding the need for an amended plan will be made by the UIC Program Director.

If a review of the data indicate that an amendment to the plan is needed, then EPA recommends that work on revising the plan begin so that the one (1) year deadline for amending this plan (along with any related amendments to other project plans) can be met [§146.90(j)(1)]. Regardless of whether a conversation with the UIC Program Director takes place, it is recommended that the owner or operator use the site-specific monitoring and operational data to prepare and present a recommendation for action on an amended Testing and Monitoring Plan.

***Step 3: Amend the testing and monitoring plan if needed.*** EPA recommends that the amended Testing and Monitoring Plan include the same categories of information that were required for the original plan that was developed before injection commenced (see Section 3.1 of this guidance document, above, for a description of the required plan elements). The amended plan might incorporate the following (as appropriate):

- Changes in monitoring/testing frequency, e.g., carbon dioxide stream analysis, ground water monitoring and carbon dioxide plume and pressure front tracking;
- New monitoring well locations;
- Additional parameters for ground water testing;
- Changes to indirect plume tracking methods, scope, or frequency;
- Additional MITs or corrosion monitoring; and

- The addition of soil gas/air or other monitoring determined to be needed to protect USDWs from endangerment.

***Step 4: Submit the amended plan***. The owner or operator must submit the amended plan to the UIC Program Director for approval within one (1) year of the AoR reevaluation or within one (1) year of any other event that triggers a Testing and Monitoring Plan review [§§146.90(j)(1)-146.90(j)(3)]. The amended plan must be approved by the UIC Program Director and would then be incorporated into the Class VI operating permit. If significant changes to the plan are needed, the UIC Program Director may need to modify the Class VI permit. A permit modification under §144.39 (e.g., to incorporate significant changes to the needed types or frequency of testing, additional monitoring locations, or new testing methods) would require notification and an opportunity for public notification and comment. See 40 CFR Part 124 for the details on the process. Minor changes to the plan as defined under §144.41 (e.g., to provide clarification or correct typographical errors), do not require a permit modification or a public process under 40 CFR Part 124. See the forthcoming *UIC Class VI Program Interim Final Primacy Application and Implementation Manual* for additional information about the procedures for modification of Class VI permits and the related plan amendments.

# 4.0 Injection Well Plugging Plan

Improperly plugged injection wells have the potential to become conduits for fluid movement into USDWs. Therefore, developing, maintaining, and implementing a Class VI Injection Well Plugging plan is important to assuring that Class VI injection wells will be plugged properly, so as to not endanger USDWs following the cessation of injection.

Owners or operators of other injection well types may be familiar with preparing an injection well plugging plan (also known as a plugging and abandonment plan), and EPA expects that developing a Class VI Injection Well Plugging Plan will involve a similar effort. However, because carbon dioxide in the presence of water has the potential to degrade the materials used to plug the injection well, the plugging of Class VI wells presents additional challenges that may not have been addressed in the course of plugging other classes of injection wells.

## 4.1 Developing the Injection Well Plugging Plan

The GS Rule, at §146.92(b), presents the required elements of a Class VI Injection Well Plugging Plan. Developing a plugging plan is also required of Class I and Class II injection well owners or operators. Many of the plugging procedures used by Class I and Class II well operators may be acceptable for Class VI injection wells. However, one important consideration is that Class VI injection wells must be plugged using methods and materials that are compatible with the carbon dioxide stream. Therefore, the owner or operator must demonstrate, to the satisfaction of the UIC Program Director, that the wells will be plugged in a manner that will resist degradation in the presence of carbon dioxide or carbonic acid.

The Injection Well Plugging Plan must be submitted with the Class VI permit application for approval by the UIC Program Director [§146.82(a)(16)], and must include a description of how the owner or operator will meet the Class VI injection well plugging requirements at §146.92.

Guidance on carrying out the approved plan (e.g., selection and emplacement of plugs and cement) will be presented in the forthcoming *Draft UIC Program Class VI Well Plugging, PISC, and Site Closure Guidance*. Exhibit 4 presents the highlights of that guidance document.

### Exhibit 4: Draft UIC Program Class VI Well Plugging, PISC, and Site Closure Guidance Highlights

The forthcoming *Draft UIC Program Class VI Well Plugging, PISC, and Site Closure Guidance* provides information describing how to correctly plug and abandon injection wells, conduct PISC monitoring, and perform site closure activities. Furthermore, the guidance discusses under what conditions the PISC monitoring timeframe may be lengthened or shortened, and how the owner or operator of a Class VI project may demonstrate to the UIC Program Director that the risk posed to USDWs has reduced during the PISC phase.

The introductory section reviews the various phases of a GS project, and the Class VI requirements pertaining to well plugging, PISC, and site closure. Remaining sections of the guidance address the following topics:

- Injection and monitoring well plugging;
- PISC monitoring;
- Demonstration of an alternative post-injection site care timeframe;
- Demonstration of reduction or risk posed to USDWs; and
- Site closure.

For each section, the Guidance:

- Explains various approaches to perform activities necessary to comply with well plugging, PISC, and site closure requirements. Illustrative examples are provided in several cases.
- Provides references to other, more comprehensive documents and published scientific literature for further information.
- Explains various approaches for how and when to report to the UIC Program Director the results of activities related to well plugging, PISC, and site closure.

The following information must be described, to the UIC Program Director's satisfaction, in order to ensure that the planned injection well plugging activities are sufficient to protect USDWs from endangerment [§146.92(b)]. Appendix C presents a sample template of an injection well plugging plan.

- Appropriate tests or measures to determine bottom-hole reservoir pressure [§146.92(b)(1)]. The purpose of testing bottom-hole reservoir pressure is to determine the appropriate density of plugging fluids to achieve static equilibrium prior to plug placement;
- Appropriate testing methods to ensure external mechanical integrity [§146.92(b)(2)]. An external MIT is necessary to ensure that the long-string casing and cement that are left in the ground after the well is plugged will maintain their integrity over time. The forthcoming *Draft UIC Program Class VI Well Testing and Monitoring Guidance* provides additional information on performing MITs;
- The type and number of plugs to be used [§146.92(b)(3)];

- The placement of each plug, including the elevation of the top and bottom of each plug [§146.92(b)(4)]. EPA recommends that the plan describe the placement of all plugs; schematics and drawings may be appropriate to demonstrate this;
- The type, grade, and quantity of material to be used in plugging [§146.92(b)(5)]. EPA recommends that the plan demonstrate that the cement is appropriate to withstand contact with the carbon dioxide or acidified formation fluids; and
- The method of plug placement, e.g., the balance method, retainer method, or two-plug method [§146.92(b)(6)].

EPA recommends that the owner or operator consider the following when developing the injection well plugging plan:

- The **location and thickness** of the lowermost injection zone and USDW-containing strata, which dictate the location of all plugs;
- **Well construction details**, particularly the depth of the bottom of the intermediate and surface casings, which would affect the number of plugs and the types and amount of cement needed;
- Types of **subsurface formations penetrated by the well** and their geochemistry, which may influence both plugging methods and the types of cement needed (for open-hole plugging). EPA recommends drilling out the casing before plugging the well to avoid the potential for the casing to corrode;
- The **composition of the carbon dioxide**, which can affect appropriate plugging and cementing materials; and
- **If the well will operate under an injection depth waiver**, EPA recommends that the injection well plugging plan describe any additional considerations to protect USDWs below the injection zone.

## 4.2 UIC Program Director's Evaluation of the Injection Well Plugging Plan

The UIC Program Director will evaluate the owner or operator's proposed Class VI Injection Well Plugging Plan in conjunction with the geologic site characterization data, proposed construction plans, and proposed operating conditions that are submitted with the Class VI permit application. Therefore, the owner or operator must demonstrate, to the satisfaction of the UIC Program Director, that the planned injection well plugging will prevent the well from serving as a conduit for fluid movement, particularly given the corrosiveness of carbon dioxide in the presence of water.

The UIC Program Director will evaluate the proposed Injection Well Plugging Plan to verify that all of the elements required in §146.92(b) are present, and that they account for all site-specific conditions to ensure that USDWs are protected from endangerment. For example, the UIC Program Director may evaluate the following:

- Are the plugs and the cement that the owner or operator proposes to use appropriate for the injectate and formation fluid geochemistry, including any geochemical changes anticipated during the injection period?

- Is the proposed placement of the plugs and cement appropriate based on the location of the injection zone, any production zones, any USDW containing strata, other geologic features, and the location of the bottom of the surface and intermediate casings?
- Is the proposed plugging plan appropriate to the planned construction of the well, e.g., to the sizes and depths of the various casing strings or the use of horizontal drilling techniques?
- Are the proposed post-injection tests of the well (e.g., MITs and bottom-hole reservoir pressure tests) sufficient to characterize the well integrity and formation pressures?
- If an injection depth waiver is to be granted, does the proposed well plugging plan protect USDWs both above and below the injection zone?

The submittal, evaluation, and approval of the Injection Well Plugging Plan may be an iterative process, involving multiple drafts of the plan until all required information is submitted in an appropriate format and level of detail. If the UIC Program Director has reason to believe, based on the site-specific conditions, that additional data are needed to sufficiently address risk at the site, it is within his/her authority to request that additional information be collected or additional activities be included in the Injection Well Plugging Plan. The approved injection well plugging plan is enforceable, whether or not it is a condition of the permit, because the plan itself and the UIC Program Director's approval are required by the GS Rule.

Interaction and conversation between the owner or operator and UIC Program Director on the proposed plugging methods and materials are encouraged. Such discussions prior to developing and submitting the plan can increase the chance that the proposed plan is approved and can minimize the need for plan revisions.

Appendix F of this guidance document presents a checklist of questions and considerations that UIC Program Directors may use when evaluating the proposed Class VI Injection Well Plugging Plan. See the forthcoming *UIC Class VI Program Primacy Application and Implementation Manual* for additional information describing how the UIC Program Director may evaluate the Injection Well Plugging Plan.

## 4.3 Amending the Injection Well Plugging Plan

The GS Rule does not require formal periodic reviews and amendments to the Injection Well Plugging Plan throughout the injection phase (i.e., following any AoR reevaluations, as with other project plans) because changes to this plan would not be implemented until the end of injection activities. However, EPA suggests that owners or operators discuss how any changes in facility operations or any other data that would warrant amendments to the other plans may affect the Class VI Injection Well Plugging Plan. EPA also recommends that the owner or operator review the Injection Well Plugging Plan if there are significant changes to the facility, such as the addition of another Class VI injection well, or if any adverse events requiring an emergency response occur.

The GS Rule requires that the owner or operator submit a notice of intent (NOI) to plug the injection well to the UIC Program Director at least sixty (60) days prior to plugging [§146.92(c)]. If any changes have been made to the original Injection Well Plugging Plan (e.g.,

based on operational and monitoring data or data collected during AoR reevaluations), the owner or operator must submit a revised plan at the same time as providing the NOI [§146.92(c)].

Prior to plugging the injection well, owners or operators may choose to consider the operational and monitoring history of the facility and identify whether any information or events warrant amendment of the injection well plugging plan. Data that may be considered include:

- **Monitoring data** related to carbon dioxide plume and formation fluid chemistry;
- **MIT results**, including any mechanical integrity problems that may have occurred during the injection phase;
- **Operational data** (e.g., injection rates and volumes); and/or
- Any **significant changes to the facility** that may affect plugging of the injection well.

EPA encourages early interaction if the owner or operator or the UIC Program Director believe that changes to the injection well plugging plan are needed to ensure that the well is properly plugged in a manner that will be protective of USDWs. These discussions can also help the owner or operator understand the UIC Program Director's expectations for the process. If the Injection Well Plugging Plan requires amendment, such open communication between the owner or operator and the UIC Program Director can improve the chances that the amended plan will be approved with as few revisions as possible.

EPA recommends that the amended Class VI Injection Well Plugging Plan include the same type of information that was included in the original plan developed before injection commenced (see Section 4.1 of this guidance document, above, for a description of the required elements). The amended plan must be approved by the UIC Program Director, and would then be incorporated into the permit. If significant changes to the plan are necessary, the UIC Program Director may need to modify the permit. A permit modification under §144.39 (e.g., to incorporate significant changes to planned injection well plugging activities because the initially planned activities were later determined to be inadequate) would require notification to the public and an opportunity for comment. See 40 CFR Part 124 for the details on the process. Minor changes to the plan as defined under §144.41 (e.g., to provide clarification or correct typographical errors), do not require a permit modification or a public process under 40 CFR Part 124. See the forthcoming *UIC Class VI Program Interim Final Primacy Application and Implementation Manual* for additional information about the procedures for modification of Class VI permits and the related plan amendments.

## 5.0 Post-Injection Site Care (PISC) and Site Closure Plan

Following cessation of injection activities, Class VI injection well owners or operators must conduct extensive site monitoring until the movement of the carbon dioxide plume and pressure front have ceased and the injectate does not pose a risk to USDWs.

The PISC requirements for GS projects incorporate a combination of both a fixed timeframe and a performance standard approach that recognizes that carbon dioxide plumes and associated pressure fronts may continue to move in the subsurface for long periods of time, while

accounting for the variety of site-specific circumstances that may be brought to bear on determining the appropriate time for PISC [§146.93].

The Class VI injection well PISC and Site Closure Plan will ensure—prior to commencement of carbon dioxide injection—that the owner or operator and the UIC Program Director agree on the procedures that need implementing to ensure that site monitoring continues after injection operations cease. The plan will also help ensure that appropriate procedures are in place to protect USDWs from endangerment. The PISC and Site Closure Plan will also help identify the appropriate types and amounts of data needed to determine that the injected fluid and the carbon dioxide plume and pressure front do not endanger USDWs, and it will support a determination of the conditions that warrant an end to PISC (i.e., there is no longer a risk of endangerment to USDWs) [§146.93(a)].

## 5.1 Developing the Post-Injection Site Care and Site Closure Plan

The GS Rule, at §146.93(a) presents the required elements of a PISC and Site Closure Plan. Owners or operators must submit a PISC and Site Closure plan that outlines the proposed post-injection monitoring strategies and how non-endangerment of USDWs will be demonstrated throughout the PISC period.

EPA suggests that, in developing the PISC and Site Closure Plan, owners or operators consider how non-endangerment will be demonstrated (i.e., what post-operational monitoring data will be needed to make this demonstration), and develop a plan that collects an appropriate amount and the appropriate types of data. EPA also recommends that owners or operators consider how the data collected during PISC will eventually inform a non-endangerment demonstration to ensure that enough data are generated (i.e., a sufficient history) to make a satisfactory demonstration.

Guidance on how to perform the activities to be carried out under the approved Class VI PISC and Site Closure Plan (e.g., performing the necessary monitoring) will be presented in the forthcoming *Draft UIC Program Class VI Well Plugging, PISC, and Site Closure Guidance*, which will be available in the future on EPA's website at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm. Exhibit 4 of this guidance document presents the highlights of the forthcoming *Draft UIC Program Class VI Well Plugging, PISC, and Site Closure Guidance*.

The PISC and Site Closure Plan must be submitted with the Class VI permit application for approval by the UIC Program Director [§146.82(a)(17)], and it must include a description of how the owner or operator will meet the requirements of §146.93(a). The sections below provide a description of the required elements, how they may be described in the plan to demonstrate to the UIC Program Director's satisfaction that the plan is sufficient, and considerations for owners or operators as they develop the plan. Appendix D of this guidance document presents a sample template of a PISC and Site Closure Plan.

### *5.1.1 Pre-injection and predicted post-injection pressure differentials in the injection zone*

The Class VI PISC and Site Closure Plan must include a prediction of the magnitude of the pressure differential between pre-injection and post-injection [§146.93(a)(2)(i)]. These predictions are integral to estimating the risk of endangerment to USDWs and, therefore, the amount of monitoring that will be necessary throughout the PISC timeframe. Pressure differential plots should be provided at various locations within the AoR as a function of time.

Predictions of pressure differential will be provided by the computational modeling performed for the AoR delineation (see Section 2.1 of this guidance document). As with the AoR delineation, estimates of pressure decline should be based on site-specific geologic data (e.g., injection zone permeability, compressibility, the volume of the formation, and the presence of lateral stratigraphic confining features) and the planned injection volumes and rates.

### *5.1.2 Predicted position of the carbon dioxide plume and pressure front at site closure*

Also, the PISC and Site Closure Plan must include the predicted position of the carbon dioxide plume and associated pressure front at site closure, as demonstrated by the AoR reevaluation process [§146.93(a)(2)(ii)]. Site closure refers to the point at the end of PISC, following a demonstration that fluid movement has slowed and pressures have declined to the point that there is no longer a risk of endangerment to USDWs from the carbon dioxide injection activities. These predictions are integral to determining the area(s) where there may be a risk of endangerment to USDWs during PISC and, therefore, the area(s) that must be subject to PISC monitoring. These predictions should be presented as information overlain on regional base maps.

The predictions of the extent of the carbon dioxide plume and pressure front will be provided by the computational modeling performed for the AoR delineation and reevaluations under §146.84(b); see Section 2.1 of this guidance document. It is expected that the owner or operator would use these modeling results in order to comply with this plume position prediction requirement. As with the AoR delineation, these plume predictions should be based on the site-specific geologic data (e.g., injection zone permeability, compressibility, the volume of the formation, and the presence of lateral stratigraphic confining features), and planned injection volumes and rates.

### *5.1.3 Monitoring location, methods, and proposed frequency*

The Class VI PISC and Site Closure Plan must describe the owner or operator's planned monitoring regime to be conducted following the cessation of injection [§146.93(a)(2)(iii)]. In general, it is recommended that post-injection monitoring be an extension of relevant operational-phase monitoring activities, including ground water monitoring and carbon dioxide plume and pressure front tracking.

In the early post-injection phase, it may be appropriate to continue monitoring at the same locations, parameters, and frequency as specified in the operational-phase Class VI Testing and

Monitoring Plan. Thus, the PISC and Site Closure Plan may resemble certain aspects of the Testing and Monitoring Plan (see Section 3 of this guidance document). Reduced monitoring frequencies and parameters may be appropriate as the owner or operator demonstrates, based on monitoring data, that movement of the carbon dioxide plume and pressure front is slowing and that no geochemical changes are occurring. Conversely, if there is evidence of changes in ground water chemistry or plume movement, additional monitoring may be warranted.

As with injection-phase monitoring, appropriate monitoring technologies may vary depending on site-specific conditions; therefore, the techniques used to collect and interpret this data are not specified in the GS Rule. In developing a post-injection monitoring regime, EPA recommends that the owner or operator consider what data will be needed as inputs for the non-endangerment demonstration. That demonstration will need to be based on a sufficient monitoring history to demonstrate that pressures have declined and that there is no risk of endangerment to USDWs from GS activities.

#### *5.1.4 Schedule for submitting post-injection site care monitoring results*

The owner or operator must propose in the Class VI PISC and Site Closure Plan an appropriate schedule for reporting all testing and monitoring results collected during post-injection monitoring [§146.93(a)(2)(iv)]. The owner or operator and the UIC Program Director may wish to consider the submittal of these reports as an opportunity to discuss the rate of fluid movement, pressure changes, and any other significant processes within the subsurface, as well as whether modifying the testing frequency is appropriate.

Many of the considerations for developing the operational-phase Testing and Monitoring Plan may also be used in planning for post-injection site monitoring. Discussions between the owner or operator and the UIC Program Director are encouraged—as the Class VI PISC and Site Closure Plan is developed, and as PISC monitoring proceeds.

#### *5.1.5 Demonstration of an alternative post-injection site care timeframe*

At the UIC Program Director's discretion, the owner or operator may demonstrate during the permitting process that an alternative post-injection site care timeframe, other than the 50 year default, is appropriate and ensures non-endangerment of USDWs [§146.93(a)(2)(v)].

The demonstration must be based on site-specific information, including the results of site-specific computational modeling; the predicted timeframe for pressure decline; the predicted rate of carbon dioxide plume migration; site-specific chemical processes that will result in carbon dioxide trapping; the predicted rate of carbon dioxide trapping; characterization of the confining zone(s); laboratory analyses or studies to verify the information on trapping; the presence of potential conduits for fluid movement and the quality of abandoned well plugs within the AoR; the distance between the injection zone and USDWs above and/or below the injection zone; and any additional site-specific factors determined by the UIC Program Director.

The demonstration must meet the criteria at §146.93(c)(2) for ensuring the quality and accuracy of the data and models on which the demonstration is based. This demonstration would be submitted as part of the permit application, per §146.82(a)(18), in addition to the PISC and Site

Closure Plan. The PISC and Site Closure Plan would reference this demonstration and include information about the appropriate alternative timeframe, if applicable.

The following factors may be considered and included in developing the post-injection site care and site closure plan:

- The predicted **size and shape of the AoR**, which would affect the number and location of monitoring wells or the extent of geophysical surveys;
- Predicted **pressure changes** during and following injection, e.g., the rate at which pressures are predicted to decline, which would impact appropriate testing frequencies;
- The **site characteristics**, depth and proximity of USDWs and the depth and thickness of the confining zone(s), which may affect the amount of monitoring needed;
- Baseline subsurface aqueous- and solid-phase **geochemistry** at the site and the **composition of the carbon dioxide,** which would impact ground water monitoring needs; and
- Planned **information needs for non-endangerment demonstrations** for determining the end of the PISC period.

### *5.1.6 Site Closure Plan*

EPA recommends that owners or operators also describe in their PISC and Site Closure Plan how they plan to close the site following the conclusion of the PISC period. Site closure activities may include: plugging all monitoring wells, removing all surface equipment, and restoring the site to its prior condition (e.g., planting vegetation).

The primary activity associated with site closure is plugging all monitoring wells in a manner that will not allow movement of injection or formation fluids that endangers a USDW [§146.93(e)]. An improperly abandoned monitoring well poses as great a threat to USDWs as an improperly abandoned injection well. EPA anticipates that plugging monitoring wells will involve similar activities as those required for plugging the injection well(s), i.e., flushing the well with a buffer fluid, testing the external mechanical integrity of the well, and emplacing cement in the well in a manner that will prevent fluid movement that may endanger USDWs. Owners or operators may consider the same types of information in planning the closure of monitoring wells as they did for plugging the injection well: well depth and construction; the location, type, and depth of subsurface formations penetrated; and how the composition of the carbon dioxide may impact plugging materials. See Section 4.1 of this guidance document, above, and the forthcoming *Draft UIC Program Class VI Well Plugging, PISC, and Site Closure Guidance* for additional information on well plugging.

## 5.2 UIC Program Director's Evaluation of the Post-Injection Site Care and Site Closure Plan

The UIC Program Director will evaluate the owner or operators proposed Class VI PISC and Site Closure Plan in connection with the geologic and proposed operating data submitted with the Class VI permit application. Therefore, the owner or operator must demonstrate in the proposed PISC and Site Closure Plan, to the satisfaction of the UIC Program Director, that the planned PISC will be adequate to detect any endangerment to USDWs from injection operations.

The UIC Program Director will evaluate the proposed PISC and Site Closure Plan to verify that all required elements as described in §146.93(a) are present and that they account for all site-specific conditions to ensure that USDWs are protected from endangerment. For example:

- Are predictions of pressure decline and fluid movement consistent with AoR modeling and do they accurately reflect geologic and operating data?
- Is the proposed carbon dioxide plume and pressure front tracking appropriate to the predicted changes in subsurface conditions during post-injection?
- Is the proposed post-injection monitoring (e.g., ground water quality monitoring) adequate to provide early warning of USDW endangerment?
- If an alternative PISC timeframe is proposed, does substantial data exist to demonstrate that an alternative timeframe would be protective of USDW and does it meet the criteria at §146.93(c)(2)?

EPA envisions that the submittal, evaluation, and approval of the PISC and Site Closure Plan will be an iterative process. This may involve multiple rounds of drafts until all required information is submitted in an appropriate format and level of detail. In particular, if the owner or operator plans to demonstrate that an alternative PISC timeframe is appropriate, it is recommended that they discuss this with the UIC Program Director, including the types of data that are available to support the demonstration. The demonstration must be submitted as part of the permit application [§146.82(a)(18)], and the timeframe must be incorporated into the PISC and Site Closure Plan. If the UIC Program Director has reason to believe (e.g., based on site-specific conditions) that additional data are needed to sufficiently address the risk at the site during the post-injection phase, it is within his or her authority to request that additional monitoring be performed. The approved PISC and Site Closure Plan is enforceable, whether or not it is a condition of the permit, because the plan itself and the UIC Program Director's approval are required by the GS Rule [§146.93(a)].

Interaction and conversation about the proposed monitoring and other site care activities are encouraged. In particular, it is important that the owner or operator discuss with the UIC Program Director how he or she plans to demonstrate a reduction in risk to USDWs posed by the GS project during the PISC period. Such demonstrations can support reductions in the frequency of PISC monitoring or reduce the PISC monitoring timeframe (i.e., by allowing a non-endangerment demonstration to be demonstrated in less than 50 years after the cessation of injection). EPA recommends that the owner or operator discuss the anticipated data that will be used and how it will be presented and analyzed. Details regarding the demonstration of a reduction of risk are included in the forthcoming *Draft UIC Program Class VI Well Plugging, PISC, and Site Closure Guidance*.

The owner or operator must notify the UIC Program Director, in writing, of their intent to close the site at least 120 days prior to site closure and cessation of PISC activities [§146.93(d)]. At this time, the owner or operator should submit to the UIC Program Director any changes to the PISC and Site Closure Plan. In some cases, the owner or operator or another entity may wish to continue use of PISC monitoring wells after site closure (and therefore the monitoring wells may

not be plugged). If this is the case, the owner or operator must describe how the integrity of these wells will be monitored and pressure controls will be implemented.

Appendix F of this guidance document presents a checklist of questions and considerations that UIC Program Directors may use when evaluating the proposed PISC and Site Closure Plan. See the forthcoming *UIC Class VI Program Interim Final Primacy Application and Implementation Manual* for additional information on how the UIC Program Director might evaluate the PISC and Site Closure Plan.

## 5.3 Amending the Post-Injection Site Care and Site Closure Plan

Upon cessation of injection, the GS Rule requires that owners or operators either submit an amended PISC and Site Closure Plan or demonstrate to the UIC Program Director, through monitoring data and modeling results, that no amendment to the plan is needed [§146.93(a)(3)].

The GS Rule does not require formal periodic reviews and amendments to the PISC and Site Closure Plan during the injection phase (i.e., following AoR reevaluations, as with other project plans), because it is not expected that changes to this plan would be implemented until the end of injection activities. However, during the operational phase, it may be beneficial if owners or operators discuss with the UIC Program Director how any changes in facility operations, or any other data that warrants amendments to the other plans, may impact the planned PISC and site closure activities. If any adverse events or a significant deviation from predicted performance occur, the UIC Program Director may require a review of the PISC and Site Closure Plan. EPA recommends that the owner or operator also undertake a review of the plan if there are significant changes to the facility, such as the addition of an injection well, or if any adverse events requiring the implementation of an emergency response occur.

During post-injection monitoring, EPA expects the owner or operator to continue to review the PISC and Site Closure Plan. As the owner or operator performs post-injection monitoring, they may take into account similar considerations that guide amendments to the other project plans. For example, if carbon dioxide plume and pressure front tracking data indicate a divergence from modeled predictions or ground water monitoring data indicates leaching/ mobilization of contaminants (or reductions in previously observed reactions), an amendment to the PISC and Site Closure Plan may be appropriate.

**The PISC Timeframe**

The GS Rule sets a default timeframe of fifty (50) years of PISC, and it affords the UIC Program Director the discretion to shorten the PISC timeframe if the owner or operator can demonstrate that there is substantial evidence that the GS project no longer poses a risk of endangerment to USDWs [§146.93(b)]. Likewise, the UIC Program Director may lengthen the PISC timeframe if, after fifty (50) years, USDWs still may become endangered.

The purpose of reviewing the PISC and Site Closure Plan is to consider:

- Whether site care is adequate to ensure that USDWs are protected from endangerment from carbon dioxide injection activities (or provide early warning of potential endangerment);

- Whether changes to monitoring are needed, e.g., if the types or frequency of monitoring can be reduced as data indicate a post-injection stabilization of the carbon dioxide plume and pressure front; and
- Whether appropriate amounts and types of data are being collected to support an eventual non-endangerment demonstration, and whether making this demonstration before the required fifty (50) year PISC timeframe is appropriate. The UIC Program Director may determine whether a shorter or longer PISC timeframe is necessary.

As discussed earlier, the GS Rule does not set a required frequency or a schedule for the review of the PISC and Site Closure Plan during the PISC phase; however, EPA encourages the owner or operator and UIC Program Director to discuss the monitoring data collected during the PISC phase in order to identify whether amendments to the plan are needed. These discussions can coincide with the reporting schedule identified in the owner or operators original PISC and Site Closure Plan [§146.93(a)(2)(iv)].

EPA encourages the owner or operator and the UIC Program Director to coordinate and discuss monitoring data and other information about the facility throughout PISC. This dialogue is an important part of the process to ensure that the GS project is (and continues to be) managed appropriately to protect USDWs and that compliance with the Class VI operating permit is achieved. These discussions can also help the owner or operator understand the UIC Program Director's expectations, including whether an amended PISC and Site Closure Plan is needed and, if so, improve the chance that the amended plan will be approved by the UIC Program Director with minimal revisions.

If any changes to the original Class VI PISC and Site Closure Plan are needed at the time of cessation of injection, the owner or operator must submit an amended PISC and Site Closure Plan for the UIC Program Director's approval within thirty (30) days of making the changes [§146.93(a)(4)]. If the UIC Program Director determines that a plan amendment is needed during the post-injection phase, the owner or operator and UIC Program Director are encouraged to agree on a schedule for submittal of the amended PISC and Site Closure Plan.

If an amendment is needed, the amended Class VI PISC and Site Closure Plan may include the same type of information that was included in the original plan developed and submitted with the Class VI permit application (see Section 5.1 of this guidance document, above, for a description of the required plan elements).

Any amendments to the PISC and Site Closure Plan (either at the time of cessation of injection or during the PISC phase) must be incorporated into the Class VI operating permit once they are approved by the UIC Program Director. If significant changes to the plan are needed, the UIC Program Director may need to modify the permit. A permit modification under §144.39 (e.g., to incorporate a plan with significant changes to the initially planned types or frequency of monitoring or an expansion of the area covered by post-injection monitoring) would require notification to the public and an opportunity for comment. Minor changes to the plan, as defined under 40 CFR §144.41 (e.g., to provide clarification or correct typographical errors), do not require a permit modification or a public process under 40 CFR Part 124. See the forthcoming *UIC Class VI Program Interim Final Primacy Application and Implementation Manual* for

additional information about the procedures for modification of Class VI permits and the related plan amendments.

## 6.0 Emergency and Remedial Response Plan

While the goals of proper siting, construction, and operation of a GS project are to prevent the occurrence of an emergency or adverse event, advance planning is vital for mitigating the effects of such an event, if it should ever occur. The Class VI Emergency and Remedial Response Plan helps ensure that in the unlikely event of an emergency or USDW endangerment, an approved process is implemented in order to facilitate and expedite the necessary and appropriate response efforts. Evidence of advance planning can also allay public concerns about the project's safety. The Emergency and Remedial Response Plan will apply over the life of the GS project, including throughout the PISC period [§146.94(a)].

The purpose of requiring an Emergency and Remedial Response Plan is to ensure that owners or operators can comprehensively plan for what actions would be necessary in the unlikely event of an emergency. The plan will also ensure that operators know which entities and individuals are to be notified, and what actions need to be taken, to expeditiously mitigate any emergency situations and protect USDWs from endangerment.

### 6.1 Developing the Emergency and Remedial Response Plan

The GS Rule, at §146.94(a), requires that the Emergency and Remedial Response Plan describe the measures that would be taken in the event of adverse conditions at the GS project, such as a loss of the well's mechanical integrity, or if movement of injection or formation fluids caused an endangerment to a USDW. The Class VI Emergency and Remedial Response Plan must be submitted with the Class VI permit application for approval by the UIC Program Director [§146.82(a)(19)]. It must include a description of how the owner or operator will meet the requirements of §146.94 and it must demonstrate, to the satisfaction of the UIC Program Director, that in the event of an emergency, the appropriate response actions would be performed in a timely manner to prevent or mitigate any damage to USDWs.

The GS Rule does not identify the specific elements of the Emergency and Remedial Response Plan. EPA envisions that each plan will be site-specific and risk-based, and depend on a variety of factors, including the nature of any movement of carbon dioxide or other fluids, the presence of USDWs, and what, if any, impacts could result from carbon dioxide movement.

The paragraphs below describe an EPA-recommended process that an owner or operator may undertake in developing an Emergency and Remedial Response Plan. This approach includes considerations of site-specific factors, potential risk scenarios to USDWs or resources, and appropriate response actions and personnel. Appendix E of this guidance document presents a sample template for a Class VI Emergency and Remedial Response Plan. For more information on reaching out and communicating with the public on any potential Class VI injection well project, see the *Public Participation Considerations for Geologic Sequestration Projects Fact Sheet,* available on EPA's website at http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm.

1. **Identify and list resources/infrastructure.** EPA recommends that the plan identify all potentially impacted environmental resources (e.g., ground water or surface water) or infrastructure (e.g., the well or nearby structures) near the well; such information will be of interest to the public. This list may be based on site-specific data collected in the site characterization and AoR processes.

   Potentially impacted resources or infrastructure near Class VI injection wells may include: the injection well, any public water systems, private drinking water wells, other deep wells within the AoR, aquifers and USDWs, surface water bodies, the soil column, buildings or other structures, biosphere/ecosystems, the atmosphere, and the geosphere.

2. **Identify potential risk scenarios.** EPA recommends that the plan consider, for each identified resource or infrastructure element potentially at risk, any potential adverse events that may occur (e.g., a well blowout, equipment failure, fluid movement, metals leaching, contamination of the water supply, earthquakes/land deformation, or carbon dioxide seeps into buildings that endanger occupants). The purpose of this analysis is to consider the "worst case" scenarios and to ensure that response plans are in place for all eventualities. It may be appropriate to describe categories of risks if the responses would be similar (e.g., if any type of damage to the well would be addressed by engaging the services of an environmental contractor).

   The Class VI Emergency and Remedial Response Plan may also consider whether the likelihood of the event is high, medium, or low, and tier the actions in the plan accordingly. For example, if baseline geochemical analyses indicate that no potentially mobilized contaminants are found in the rock matrix, ground water contamination from injection activities may be considered a low-risk scenario. However, it is still important that the scenario be considered and included in the plan.

3. **Describe response actions** to address the identified risk scenarios, e.g., remedial cementing of the well or treatment of ground water or drinking water supplies. Some situations may require an immediate response (e.g., shutting down the well) while other "non-immediate" actions would occur following consultation with the UIC Program Director.

   High-impact risk scenarios may warrant special consideration in the Emergency and Remedial Response Plan. For example, if all residents in the vicinity of the well rely on one USDW for their drinking water supply, the plan might highlight how the owner or operator would respond expeditiously to any evidence of the contamination of that supply (including notifying the public of such an event).

   All response actions must be initiated by immediately ceasing injection, taking all steps reasonably necessary to identify and characterize any release, notifying the UIC Program Director within 24 hours, and implementing the approved Class VI Emergency and Remedial Response Plan [§146.94(b)].

4. **Identify the personnel and equipment** needed to implement the response actions. These personnel may include first responders (e.g., fire departments or haz-mat units), GS project facility staff, or environmental contractors. Where facility staff is identified as responding personnel, the plan might describe their relevant training and verify that qualified staff is always onsite during operations. EPA also recommends that the plan identify where the necessary equipment will be procured.

EPA recommends that the Emergency and Remedial Response Plan also include the following information:

- **Facility emergency 24-hour contacts**, including phone/pager numbers and e-mail addresses;
- A list of **people to notify in case of an adverse event** (e.g., local water systems, carbon dioxide generators and pipeline operators, nearby land owners, the permitting authority, other states or countries in the AoR, or Regional Response Teams);
- The **location of the well**, such as the specific town or county (this often drives who are first responders, applicable local ordinances, etc.);
- A **map of the area**, including the location of the well and nearby population centers or sensitive environments. This map may be an adaptation of or enhancement to the map of the AoR required at §146.82(a)(2);
- **Schematics and diagrams of the facility and well**, including the location of monitoring equipment and emergency shutoffs; and
- A **communications plan and emergency notification procedures** that describe potential audiences (e.g., the public, community leaders), communication methods (e.g., newspapers or public service announcements), audiences, and messages.

The details of an Emergency and Remedial Response Plan may be influenced by a variety of site-specific factors. EPA recommends that the following be considered in planning for emergency and remedial response:

- The **size of the site and the AoR**, including the volume of carbon dioxide injected and proposed operating conditions and properties of the carbon dioxide. For larger AoRs, more resources and infrastructure are potentially impacted;
- The **number of wells in the AoR and their age** (for converted wells), which may affect the likelihood of a well failure or fluid movement;
- The **composition of the carbon dioxide and subsurface geochemistry and mineralogy**, which would impact the potential for contamination of ground water or private and public water supplies;
- **Proximity and depth to potentially affected USDWs** or other drinking water sources and public water supplies;
- Resources located in the AoR, e.g., the **presence of communities and sensitive populations**, drinking water systems, residences, land uses, population centers, or buildings;

- Whether the project will **operate under an injection depth waiver**. See the GS Rule and the forthcoming *Draft UIC Program Class VI Injection Depth Waiver Application Guidance* for more information about Class VI injection wells operating under approved waivers; and
- **Procedures for immediate well shut-down** and creating alternate options for the carbon dioxide stream.

## 6.2 UIC Program Director's Evaluation of the Emergency and Remedial Response Plan

The UIC Program Director will evaluate the owner or operators proposed Class VI Emergency and Remedial Response Plan in connection with the geologic and proposed operating data submitted with the Class VI permit application in determining whether to approve the plan. Therefore, the owner or operator must demonstrate in the proposed Emergency and Remedial Response Plan, to the satisfaction of the UIC Program Director, that any needed response will be adequate for mitigating any adverse events that may arise during injection and through the PISC period.

The UIC Program Director will evaluate the proposed Emergency and Remedial Response Plan to verify that it meets the requirements of §146.94(a) and that the plan accounts for all site-specific conditions. For example:

- Are all potentially affected activities within the AoR, including the presence of population centers and all land uses, addressed in the plan?
- Is special consideration given to events with the highest potential of occurring or to events that may make the highest impacts?
- Are all reasonably anticipated potential adverse events at the facility addressed in the plan and are appropriate procedures, equipment, and trained personnel identified?
- Are the planned response activities appropriate to the risk scenarios identified and their potential impacts on resources or infrastructure?

The submittal, evaluation, and approval of the Class VI Emergency and Remedial Response Plan are meant be part of an iterative process. This may involve multiple rounds of drafts until all of the required information is submitted in an appropriate format and level of detail. If the UIC Program Director has reason to believe (e.g., based on site-specific conditions) that additional data are needed to sufficiently address risk at the site, it is within his/her authority to request that additional information be provided. The approved Emergency and Remedial Response Plan is enforceable, whether or not it is a condition of the permit, because the plan itself and the UIC Program Director's approval are required by the GS Rule.

Interaction and conversation are encouraged. Such discussions prior to developing and submitting the plan can increase the chance that the proposed plan will be approved and avoid the need to revise the plan.

Appendix F of this guidance document presents a checklist of questions and considerations that UIC Program Directors may use when evaluating the proposed Emergency and Remedial Response Plan. See the forthcoming *UIC Class VI Program Interim Final Primacy Application*

*and Implementation Manual* for additional information on how the UIC Program Director will evaluate the Emergency and Remedial Response Plan.

## 6.3 Amending the Emergency and Remedial Response Plan

The GS Rule requires that the Class VI Emergency and Remedial Response Plan be reviewed and, if necessary, amended following each reevaluation of the AoR [§146.94(d)]. The purpose of this review is to ensure that management of the project and all of the project plans are based on the most up-to-date information available to allow a prompt response to potential USDW endangerment. This review of the Emergency and Remedial Response Plan follows the required AoR reevaluation, which must occur at least once every five (5) years (see the *Draft UIC Program Class VI Well AoR and Corrective Action Guidance* for additional information on performing AoR reevaluations). The amended Emergency and Remedial Response Plan (or a demonstration that no amendment is needed) is due no later than one year after the reevaluation [§146.94(d)(1)].

EPA recommends that reviews of the Emergency and Remedial Response Plan continue through the post-injection phase. As the owner or operator submits monitoring data collected during PISC (See Section 5.1.4 of this guidance document), they are encouraged to discuss the results with the UIC Program Director to identify whether any amendments to the Emergency and Remedial Response Plan are needed.

EPA recommends that owners or operators use the results of the AoR reevaluation, along with the monitoring (e.g., carbon dioxide plume and pressure front tracking and ground water monitoring) and operational data (e.g., injection rates and volumes) collected since the last AoR reevaluation, to assess the need for amending the Emergency and Remedial Response Plan. The owner or operator is also encouraged to review the plan if there are significant changes to GS facility operations, such as the addition of an injection well or if any adverse events occurred that required the implementation of the Emergency and Remedial Response Plan.

The owner or operator and the UIC Program Director are encouraged to coordinate and discuss the most recent AoR evaluation, along with monitoring and operational data, and other information about the Class VI injection well during this review. This dialogue is an important part of the process to ensure that the GS project is (and continues to be) managed appropriately to protect USDWs and that compliance with the Class VI operating permit is achieved. These discussions can also help the owner or operator understand the UIC Program Director's expectations, including whether an amended plan is needed so that the UIC Program Director receives all the required information up front in order to facilitate the review process.

The sections below describe a recommended process by which the owner or operator may review and amend the Class VI Emergency and Remedial Response Plan.

***Step 1: Review the results of the AoR reevaluation,*** along with the most recent monitoring and operational data. The purpose of this review is to identify whether an amendment to the Emergency and Remedial Response Plan is needed. Topics to be considered in the review include:

- If the most recent AoR reevaluation required a revision to the AoR computational model or any changes to the prediction of plume and pressure front movement;
- Whether any of the considered emergency scenarios are more likely to occur than originally considered (e.g., if ground water chemistry is changing);
- Whether MIT results indicate increased concerns for well failures;
- If recent (or planned) land use changes brought new resources or infrastructure near or into the AoR; or
- If there has been a need to implement emergency procedures at the site, any lessons learned might be incorporated into an amended Emergency and Remedial Response Plan.

***Step 2: Discuss the results with the UIC Program Director.*** The owner or operator and the UIC Program Director are encouraged to discuss whether an amendment to the Emergency and Remedial Response Plan is needed. If the AoR reevaluation and monitoring/operating data were to show that the plume is moving as predicted, an amendment may not be needed. The final decision regarding the need for an amended plan will be made by the UIC Program Director.

If a review of the data indicate that an amendment to the Emergency and Remedial Response Plan is necessary, then EPA recommends that work on revising the plan begin so that the one (1) year deadline for amending this plan (along with any necessary amendments to other related project plans) can be met. In lieu of a conversation with the UIC Program Director, the owner or operator might use the site-specific monitoring and operational data to prepare and present a recommendation for action on an amended Emergency and Remedial Response Plan.

***Step 3: Amend the emergency and remedial response plan if needed.*** EPA recommends that the amended Emergency and Remedial Response Plan include the same categories of information that were in the original plan developed before injection commenced (See Section 6.1 of this guidance document). EPA recommends that the amended plan include the following information (as warranted):

- The addition of newly identified resources or infrastructure at which responses may be needed, e.g., additions to the facility, new construction within the AoR, or newly identified resources based on changes to the modeled AoR;
- Updates to the list of responding personnel or their training;
- Modifications to communications and notification procedures to address population or land use changes; and
- Lessons learned if any events necessitated the prior implementation of the Emergency and Remedial Response Plan.

***Step 4: Submit the amended plan***. The GS Rule requires that the owner or operator submit the amended Emergency and Remedial Response Plan to the UIC Program Director for approval within one (1) year of the AoR reevaluation or within one (1) year of other event that triggers an Emergency and Remedial Response Plan review[§§146.94(d)(1) and 146.94(d)(2)]. The owner or operator and UIC Program Director are encouraged to negotiate a schedule for submitting amendments to the Emergency and Remedial Response Plan during the post-injection monitoring phase.

The amended plan must be approved by the UIC Program Director and would then be incorporated into the Class VI permit. If significant changes to the plan are needed, the UIC Program Director may need to modify the permit. A permit modification under §144.39 (e.g., to incorporate a plan that involves additional resources or infrastructure) would require notification to the public and an opportunity for comment. See 40 CFR for more details on the process. Minor changes to the plan as defined under 40 CFR §144.41 (e.g., to provide clarification or correct typographical errors), do not require a permit modification or a public process under 40 CFR Part 124. See the forthcoming *UIC Class VI Program Interim Final Primacy Application and Implementation Manual* for additional information about the procedures for modification of Class VI permits and the related plan amendments.

# Appendix A

# Sample Template of an Area of Review and Corrective Action Plan

## Appendix A: Sample Template of an Area of Review and Corrective Action Plan

### Facility Information

Facility name:

Facility contacts (names, titles, phone numbers, email addresses):

Location (town/county/etc):

### Planned Computational Modeling

**Model Name:**
**Model Authors/Institution:**
**Description of model:**

**Model Inputs and Assumptions**:

*EPA recommends that this section describe how each of the following types of information will be used to inform the delineation. Reference geologic reports and data submitted with the Class VI permit application as appropriate.*

- *Subsurface formations (including the type and number of formations between the uppermost USDW and the injection zone, heterogeneity of the geologic stratigraphy, and permeability);*
- *Geologic structure (including faults or fractures);*
- *Hydrogeologic information (including initial fluid pressures, horizontal and vertical gradients, ground water flow directions and velocity);*
- *Geochemistry and compatibility of injectate fluids (including soil and rock chemistry or potential mineralization reactions);*
- *Proposed operating data (e.g., injection rates and pressures and injection depths);*
- *Other injection operations, mines or other subsurface activities, and abandoned wells (including the number, depth, and description of injection points in each geologic formation); and*
- *If an injection depth waiver is being requested, explain here how the model accounts for all USDWs that can be affected.*

## Corrective Action Plan and Schedule

**Pre-Injection Corrective Action Schedule**

| Well Name/ Location | Planned Date of Corrective Action | Planned Corrective Action Method | Notes |
|---|---|---|---|
| *Include each deficient well in the AoR.*<br><br>*References to map(s) may be appropriate.* | | *Including the type, volume and depth of plugs to be used or other risk management strategies.*<br><br>*Reference well schematics as appropriate.* | *Considerations that drive the corrective action plans, e.g., age and maintenance of the well; cement condition; well depth/subsurface formations penetrated; or formation fluid/carbon dioxide stream geochemistry. Confirmation of site access.* |
| | | | |
| | | | |

### Plan for Site Access

*Describe here how access to all wells needing corrective action will be guaranteed.*

**Phased Corrective Action Schedule**

| Well Name/ Location | Planned Date of Corrective Action | Planned Corrective Action Method | Notes |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

### Justification of Phased Corrective Action

*Describe why corrective action on certain wells can be deferred based on preliminary information about the AoR.*

### Attachments

Preliminary maps of the AoR with deficient wells identified
Plugging schematics

## Area of Review Reevaluation Plan and Schedule

### Reevaluation Strategy

*Describe what will be involved in an AoR reevaluation, including the types and amount of input data that will be used to update the model, e.g., operating data, carbon dioxide plume and pressure front tracking results, geochemical monitoring data, or information on other operators in the AoR.*

### Proposed Reevaluation Cycle

*Describe the frequency at which reevaluations are planned (in no case can this be less often than every five (5) years). Present a justification, based on:*

- *Anticipated plume movement relative to land uses or other features that may be potentially affected or intersected.*
- *Neighboring projects expected to come online or that will also be injecting carbon dioxide.*
- *Development, land-use changes, and population growth.*
- *Phased corrective action, if planned.*
- *Modeling issues, i.e., whether any uncertainty in the model or assumptions may warrant frequent reevaluations.*
- *Planned injection volumes and rates.*
- *Public opinion or concerns.*

**Triggers for More Frequent AoR Reevaluations**

| **Trigger** | **Time Frame for Reevaluation** |
|---|---|
| Change in rate, direction, or extent of carbon dioxide plume movement | *e.g., within one month of detection* |
| Operating changes, e.g., carbon dioxide injection rates/volumes | |
| New owners or operators in AoR/ new injection well(s) online | |
| New site characterization data | |
| Seismic Event or Other Emergency | |
| Violation of Permit Conditions | |
| Other… | |
| | |

# Appendix B

# Sample Template of a Testing and Monitoring Plan

## Appendix B: Sample Template of a Testing and Monitoring Plan

### Facility Information

Facility name:

Facility contacts (names, titles, phone numbers, email addresses):

Location (town/county/etc.):

### Carbon Dioxide Stream Analysis

| Parameter/Analyte | Frequency |
|---|---|
| pH | |
| Temperature | |
| Etc… | |
| | |

Sampling methods:

Analytical techniques:

Laboratory to be used/ chain of custody procedures:

Quality assurance and surveillance measures:

### Continuous Recording of Injection Pressure, Rate, and Volume; Annulus Pressure

- *Describe the recording devices to be used, quality assurance and surveillance measures, the frequency at which the information will be recorded, and how the data will be recorded and reported.*

### Corrosion Monitoring

- *Describe the corrosion monitoring method to be used and associated quality assurance and surveillance measures, and a schedule for performing the quarterly tests (e.g., anticipated testing dates) and how the data will be reported.*

## Ground Water Quality Monitoring

| **Monitoring well name/location/map reference:**<br>**Well depth/formation(s) sampled:** | |
|---|---|
| **Parameter/Analyte** | **Frequency** |
| Aqueous and pure phase carbon dioxide | |
| Total dissolved solids | |
| pH | |
| Specific conductivity (SC) | |
| Temperature | |
| *Other parameters (e.g., major anions and cations; trace metals; tracers; hydrocarbons; and volatile organic compounds)* | |
| | |

Sampling methods:

Analytical techniques:

Laboratory to be used/ chain of custody procedures:

Quality assurance and surveillance measures:

Plan for guaranteeing access to all monitoring locations:

## External Mechanical Integrity Testing

- *Describe specific MIT(s) to be employed, associated quality assurance and surveillance measures, anticipated testing dates, and plans to record and report the results.*

## Pressure Fall-Off Testing

- *Describe the pressure fall-off tests to be employed, associated quality assurance and surveillance measures, anticipated testing dates, and plans to record and report the test results.*

## Carbon Dioxide Plume and Pressure Front Tracking

### Direct Pressure Monitoring

| Well Location/Map Reference | Depth(s)/Formation(s) | Frequency |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

Quality assurance and surveillance measures:

Plan for guaranteeing access to all monitoring locations:

**Indirect Carbon Dioxide Plume and Pressure Front Tracking**

- *Describe indirect methods to be used (e.g., types of indirect surveys to be performed, the planned areal extent/resolution of geophysical surveys, and planned frequency/schedule) and their associated quality assurance and surveillance measures, and plans to record and report the results.*

- *If indirect methods cannot be used, describe why.*

**Surface Air Monitoring and/or Soil Gas Monitoring (*if required by the UIC Program Director*)**

| Monitoring Location/Map Reference | Frequency |
|---|---|
| | |
| | |
| | |
| | |

Sampling methods:

Analytical techniques:

Laboratory to be used/ chain of custody procedures:

Quality assurance and surveillance measures:

Plan for guaranteeing access to all monitoring locations:

**Additional Monitoring (*if required by the UIC Program Director*)**

- *Describe testing techniques and methods and their associated quality assurance and surveillance measures, testing frequency (e.g., anticipated test dates), and plans to record and report the results.*

**Attachments**

Map showing monitoring well locations; boundary of geophysical survey areas

Monitoring well schematics.

# Appendix C

# Sample Template of an Injection Well Plugging Plan

## Appendix C: Sample Template of an Injection Well Plugging Plan

### Facility Information

Facility name:

Facility contacts (names, titles, phone numbers, email addresses):

Location (town/county/etc):

**Planned tests or measures to determine bottom-hole reservoir pressure:**

**Planned external mechanical integrity test(s):**

### Information on Plugs:

| | Plug #1 | Plug #2 | Plug #3 | Plug #4 | Plug #5 | Plug #6 | Plug #7 |
|---|---|---|---|---|---|---|---|
| Diameter of Boring in Which Plug Will be Placed | | | | | | | |
| Depth to Bottom of Tubing or Drill Pipe | | | | | | | |
| Sacks of Cement to be Used (each plug) | | | | | | | |
| Slurry Volume to be Pumped | | | | | | | |
| Slurry Weight | | | | | | | |
| Top of Plug | | | | | | | |
| Bottom of Plug | | | | | | | |
| Type of Cement or Other Material | | | | | | | |
| Method of Emplacement (e.g., balance method, retainer method, or two-plug method) | | | | | | | |

### Attachments:

Injection well construction plan/schematics showing depth to tubing stub, exposed formation intervals, casing diameters, depths, etc.

Information on formations, depths to USDWs, etc.

Schematic/drawings of the placement of all plugs.

# Appendix D

# Sample Template of a PISC and Site Closure Plan

## Appendix D: Sample Template of a PISC and Site Closure Plan

### Facility Information

Facility name:

Facility contacts (names, titles, phone numbers, email addresses):

Location (town/county/etc):

### Pre- and Post-Injection Pressure Differential

Figure: Predicted pressure changes (pre-injection to the cessation of injection).
*Source: AoR delineation modeling.*

### Predicted Position of the Carbon Dioxide Plume and Associated Pressure Front at Site Closure

Figure: Map showing the extent of the carbon dioxide plume and pressure front at site closure.
*Source: AoR delineation modeling.*

### Post-Injection Monitoring Plan

### Ground Water Quality Monitoring

| **Monitoring well name/location/map reference:**<br>**Well depth/formation(s) sampled:** | |
|---|---|
| **Parameter/Analyte** | **Frequency** |
| Aqueous and pure phase carbon dioxide | |
| Total dissolved solids | |
| pH | |
| Specific conductivity (SC) | |
| Temperature | |
| *Other parameters (e.g., major anions and cations; trace metals; tracers; hydrocarbons; and volatile organic compounds)* | |
| | |

Sampling methods:

Analytical techniques:

Laboratory to be used/ chain of custody procedures:

Quality assurance and surveillance measures:

Plan for guaranteeing access to all monitoring locations:

## Carbon Dioxide Plume and Pressure Front Tracking

### Direct Pressure Monitoring

| Well Location/Map Reference | Depth(s)/Formation(s) | Frequency |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

Quality assurance and surveillance measures:

Plan for guaranteeing access to all monitoring locations:

### Indirect Carbon Dioxide Plume and Pressure Front Tracking

- *Describe indirect methods to be used (e.g., types of indirect surveys to be performed, the planned areal extent/resolution of geophysical surveys, and planned frequency/schedule) and their associated quality assurance and surveillance measures, and plans to record and report the results.*

## Surface Air Monitoring and/or Soil Gas Monitoring (*if required by the UIC Program Director*)

| Monitoring Location/Map Reference | Frequency |
|---|---|
| | |
| | |
| | |
| | |

Sampling methods:

Analytical techniques:

Laboratory to be used/ chain of custody procedures:

Quality assurance and surveillance measures:

Plan for guaranteeing access to all monitoring locations:

## Additional Monitoring (*if required by the UIC Program Director*)

- *Describe testing techniques and equipment and their associated quality assurance and surveillance measures, testing frequency (e.g., anticipated test dates), and plans to record and report the results.*

## Proposed Schedule for Submitting Post-Injection Monitoring Requests

| Planned Testing/Monitoring | Reporting Schedule |
|---|---|
| Ground Water Quality Monitoring Data | *E.g., quarterly* |
| Carbon Dioxide Plume and Pressure Front Tracking Data | |
| Direct Pressure Monitoring Data | |
| Indirect Carbon Dioxide Plume and Pressure Front Tracking Data | |
| Surface Air Monitoring and/or Soil Gas Monitoring Data (if required by the UIC Program Director) | |
| Additional Monitoring Data (if required by the UIC Program Director) | |

## Alternative Post-Injection Site Care Timeframe

*Describe the alternative post-injection site care timeframe, if a demonstration submitted under 40 CFR §146.82(a)(18) is approved by the UIC Program Director.*

## Site Closure Plan

Planned Remedial/Site Restoration Activities:

*Describe plans for removing all surface equipment and restoring vegetation.*

Information on Plugs for Monitoring Well #1:

| | Plug #1 | Plug #2 | Plug #3 | Plug #4 | Plug #5 | Plug #6 | Plug #7 |
|---|---|---|---|---|---|---|---|
| Diameter of Boring in Which Plug Will be Placed | | | | | | | |
| Depth to Bottom of Tubing or Drill Pipe | | | | | | | |
| Sacks of Cement to be Used (each plug) | | | | | | | |
| Slurry Volume to be Pumped | | | | | | | |
| Slurry Weight | | | | | | | |
| Top of Plug | | | | | | | |
| Bottom of Plug | | | | | | | |
| Type of Cement or Other Material | | | | | | | |
| Method of Emplacement (e.g., balance method, retainer method, or two-plug method) | | | | | | | |

# Appendix E

# Sample Template of an Emergency and Remedial Response Plan

## Appendix E: Sample Template of an Emergency and Remedial Response Plan

### Facility Information

Facility name:

Facility contacts (names, titles, phone numbers, email addresses):

Location (town/county/etc):

### List of Resources/Infrastructure

- *List/describe the resources and infrastructure that may be impacted by an adverse event (e.g., wells, USDWs, surface water bodies, sensitive nearby environments, structures). Indicate the potential for any risk scenarios to be of high impact e.g., if all people in the area are served by a single drinking water source.*

| **Infrastructure/Resource-Specific Events and Response Plan**<br>*Describe the type(s) of adverse event(s) that may occur at each resource/infrastructure; whether the risk is considered to be high, medium, or low; and planned response actions, response staff, and equipment. Exhibit E-1 at the end of this appendix provides examples of potential adverse events and corresponding response actions at Class VI well sites.* |
|---|
| **Infrastructure: Injection well (map reference)**<br>Potential adverse event #1: *e.g., a well blowout*<br>Risk level:<br>Potential response action(s):<br>Response personnel:<br>Equipment:<br><br>Potential adverse event #2:<br>Risk level:<br>Available response action(s):<br>Response personnel:<br>Equipment:<br>*Etc…* |
| **Resource: USDW**<br>Potential adverse event #1:<br>Risk level:<br>Available response action(s):<br>Response personnel:<br>Equipment: |

| |
|---|
| **Resource: [Name of municipality] water supply (map reference)**<br>Potential adverse event #1:<br>Risk level:<br>Available response action(s):<br>Response personnel:<br>Equipment: |
| **Resource: [Name of surface water body] (map reference)**<br>Potential adverse event #1:<br>Risk level:<br>Available response action(s):<br>Response personnel:<br>Equipment: |
| *List other applicable resources/infrastructure.* |

**Staff Training and Exercise Procedures:**

**Communications Plan and Emergency Notification Procedures:**

- Emergency response contact(s) and role(s):
- Communication methods (e.g., Internet, newspapers, public service announcements):
- Audience:
- Other contacts: e.g., local water systems, carbon dioxide source(s) and pipeline operators, land owners, other states or countries in the AoR, Regional Response Teams (Regional Response Teams represent geographic regions of the U.S. and are made up of representatives from federal agencies as part of the National Response Team)

**Attachments:**
Safety and Health Plan
Map of the AoR showing resources and infrastructure

| Exhibit E-1<br>Examples of Potential Adverse Class VI Events and Emergency Response Options | |
|---|---|
| **Adverse Event** | **Potential Response Actions** |
| Leaking well/Loss of mechanical integrity | o Stop injection.<br>o Repair the well by plugging it with cement.<br>o Pull and replace the tubing or the packer.<br>o Create a hydraulic barrier by increasing reservoir pressure upstream of the leak.<br>o Install chemical sealant barrier to block leaks. |
| Well blowout | o Stop injection.<br>o Close the blowout preventer; insert rams into the well.<br>o Kill the well by pumping a fluid down the well bore that is heavier than the blowout fluid until the well stops flowing.<br>o Drill another hole to intersect the well and pump fluid down. |
| Ground water contamination | o Stop injection.<br>o Pump carbon dioxide-contaminated groundwater to the surface and aerate it to remove carbon dioxide.<br>o Apply "pump and treat" methods to remove trace elements.<br>o Drill wells that intersect the accumulations in groundwater and extract carbon dioxide. |
| Surface water contamination | o Stop injection.<br>o Shallow surface water bodies that have significant turnover (e.g., shallow lakes) or turbulence (e.g., streams) will quickly release dissolved carbon dioxide back into the atmosphere.<br>o Create a hydraulic barrier by increasing reservoir pressure upstream of the leak. |
| Leakage through faults and fractures | o Stop injection.<br>o Lower injection rates/pressures.<br>o Install chemical sealant barriers to block leaks. |
| Accumulation of carbon dioxide in indoor air | o Stop injection.<br>o Manage potential slow indoor releases with basement/substructure venting or pressurization.<br>o Use fans to disperse carbon dioxide similar to radon fans. |
| Adapted from: World Resources Institute. *CCS Guidelines: Guidelines for Carbon Dioxide Capture, Transport, and Storage*. Washington DC. 2008. Table 8, p. 77. | |

# Appendix F

# Checklist of Recommended Considerations for Evaluating Plans and Amendments

## Appendix F: Checklist of Recommended Considerations for Evaluating Plans and Amendments

Below is a checklist of questions and considerations that UIC Program Directors may use when evaluating the proposed project-specific plans and/or amendments.

### *Geology and Hydrogeology*

- Geologic conditions, including structures and the type and number of subsurface formations:
    - The presence of faults and fractures, which may affect plume movement and containment.
    - The presence of oil/gas/water, which may impact the feasibility of geophysical tests or necessitate monitoring for released hydrocarbons.
    - The type, number, and thickness of subsurface formations between the uppermost USDW and the injection zone, which impact AoR model selection and assumptions and the amount of monitoring needed.
    - Heterogeneity of the geologic stratigraphy, permeability, or other parameters, which impact AoR model selection and assumptions.

- Baseline geochemical and mineralogical data:
    - The geochemistry of formations that are penetrated by the well, which may affect compatibility with the injectate, ground water monitoring needs and the parameters to be analyzed, and corrective action and injection well plugging methods and the types of cement.
    - Composition and mineralogy of the subsurface soil/rock matrix and the potential for mineralization reactions and porosity changes, which may impact ground water analysis.
    - Fluid pressures, horizontal and vertical gradients, groundwater flow directions and velocity of subsurface formations, which impact AoR model selection and assumptions.
    - Multiphase flow parameters, and relevant assumed relative permeability-saturation relationships and equations of state, which impact AoR model selection and assumptions.

- Hydrogeological data and USDWs:
    - Proximity and depth to USDWs or other drinking water sources, which may necessitate additional monitoring.
    - The presence of multiple subsurface layers with USDWs and the types of subsurface formations penetrated by the well, which may affect the placement of monitoring wells and injection well plugging and cement.
    - If an injection depth waiver is sought, all USDWs above and below the injection zone must be addressed.

***Land Uses and Activities in the AoR***

- Land uses include population, sociological, and demographic considerations:
    - Activities in the AoR, e.g., the presence of communities, residences, population centers, or buildings, which may drive monitoring needs.
    - The pace of development or land use changes in the region, which may impact monitoring needs or AoR reevaluation schedules (e.g., if additional wells may be drilled (or abandoned) between AoR evaluations).
    - Past and planned land use changes, which may affect the owner or operator's ability to access monitoring sites or wells for corrective action.
    - Proximity and depth to public water supplies or private wells, which may necessitate targeted monitoring and considerations for emergency and remedial response planning.
    - Environmental justice concerns and potentially disproportionate impacts on health to a particular subpopulation (low income or minority) or children's health.
    - Public input and concerns. A robust monitoring scheme may be the key to local acceptance of the project.

- Physical properties of the land due to human impacts:
    - The presence of active and abandoned wells, which must be accounted for in AoR modeling, addressed in corrective action, and may impact monitoring locations.
    - The presence (or planned presence) of other operators. Where multiple operators are involved, AoR models should account for pressure changes that may result from all injection operations in a formation or a series of hydraulically connected formations.
    - The presence (or planned presence) of mineral exploration, drilling, or abandoned wells, which can affect containment.

***Injection Well/Operations***

UIC Program Directors might consider several factors related to planned injection well operations:

- Carbon dioxide stream geochemistry:
    - The potential for impurities in the carbon dioxide stream, e.g., based on the process generating the carbon dioxide and capture technologies. This can impact the potential degradation of well materials (and therefore corrective action methods and methods to plug the injection well) and carbon dioxide analysis needs.
    - Whether the source of the carbon dioxide will vary over the life of the well. Frequent changes in the carbon dioxide source or multiple sources may necessitate more frequent carbon dioxide stream analysis.
    - If the carbon dioxide will be injected on site or be piped/transported somewhere else for injection, which may result in contamination or mixing with water.

- Operational data (e.g., injection rates and volumes) collected. This will affect the size of the AoR, and therefore required corrective action, monitoring sites, and the resources/ infrastructure to address in the emergency and remedial response plan.

- The AoR model/ predicted size and extent of the carbon dioxide plume:
    - The anticipated size and shape of the AoR, which would affect monitoring locations and the areal extent of geophysical surveys, and the resources/ infrastructure to address in the emergency and remedial response plan.
    - The anticipated rate of plume movement and which wells will be intersected by the carbon dioxide plume and pressure front, which will affect AoR reevaluation and corrective action schedules.
    - Confidence in the assumptions that will be used for AoR delineation or the general modeling approach. Significant uncertainties in AoR delineation modeling may be addressed by more frequent reevaluation and comparison to monitoring data, particularly early in the project.

***Additional Considerations for AoR Reevaluations and Plan Amendments***

- Evidence of leaching/mobilization of metals, organics, etc. which may indicate a need to change ground water monitoring parameters.
- Indications that the carbon dioxide plume is moving faster than predicted or in a different direction, which may warrant more pressure monitoring (i.e., in more locations) or more frequent geophysical surveys and AoR reevaluation.
- Comparison of model results and monitoring data. If the original model (or the previous AoR model) does not closely match monitoring results or if was there a significant change in results from the last modeling run, the modeling assumptions may need to be revised or additional inputs may be needed.
- MIT results that may indicate concerns about the well.
- Any significant changes to the facility, e.g., to injection volumes or the number of wells.
- If there are new owners or operators in the AoR or new mines or other subsurface land uses.
- If recent (or planned) land use changes brought new receptors or infrastructure near/into the AoR.
- If there has been a need to implement emergency procedures or any of the considered emergency scenarios are more likely to occur than originally considered.

**Sources of Additional Information**

Final GS Rule and Preamble (available at http://water.epa.gov/type/groundwater/uic/wells_sequestration.cfm).

EPA GS Rule Guidance documents – available, when published, at http://owpubauthor.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm.

Emergency Planning and Community Right-to-Know Act (EPCRA) Local Emergency Planning Requirements http://www.epa.gov/emergencies/content/epcra/epcra_plan.htm

EPA's Office of Emergency Management http://www.epa.gov/emergencies/

EPCRA Emergency Release Notification Requirements. http://www.epa.gov/OEM/content/epcra/epcra_report.htm

Homeport: U.S. Department of Homeland Security, U.S. Coast Guard. http://homeport.uscg.mil/mycg/portal/ep/home.do

National Oil and Hazardous Substances Pollution Contingency Plan Overview. http://www.epa.gov/OEM/content/lawsregs/ncpover.htm

National Response Team. http://www.epa.gov/OEM/content/partners/nrsrrt.htm

Regional Response Teams. http://www.epa.gov/OEM/content/partners/nrsrrt.htm; http://www.epa.gov/OEM/content/nrs/nrsworks.htm

Requirements for Oil Facility Response Plans. 33CFR part 154 subpart F.

U.S. EPA. 2008. Vulnerability Evaluation Framework for Geologic Sequestration of Carbon Dioxide. EPA 430-R-08-009. July 10.

USEPA. 2010. Technologies Available to Address Induced Faults and Fractures: Considerations for GS Sites. 816-R10-0018.

World Resources Institute. *CCS Guidelines: Guidelines for Carbon Dioxide Capture, Transport, and Storage*. Washington DC. 2008.