

Underground Injection Control Geologic Sequestration Rule Training Workshop: Area of Review (AoR) and Corrective Action (40 CFR 146.84)

Purpose: AoR and Corrective Action

- Ensures:
 - Modeled delineation of appropriate focus area based on an understanding of the carbon dioxide plume and associated area of elevated pressure
 - Corrective action is performed appropriately

2

The purpose of the UIC Class VI area of review (AoR) and corrective action requirements are to ensure that:

- The AoR is delineated using computational modeling that accounts for the physical and chemical properties of all phases of the injected carbon dioxide stream and is based on available site characterization, monitoring, and operational data.
- Corrective action is performed on all deficient artificial penetrations and natural conduits (faults and fractures) located within the AoR as appropriate, regardless of ownership.

Remember that the definition for an AoR for a Class VI well is the region surrounding the GS project where USDWs may be endangered by injection activities. Corrective Action is “the use of UIC Program Director-approved methods to assure that artificial penetrations/wells located within the AoR do not serve as conduits for the movement of fluids into USDWs.”

AoR and Corrective Action for Class VI Wells

- Class VI requirements differ from the AoR and corrective action requirements for other UIC injection well classes:
 - Area permits prohibited
 - Computational modeling required
 - Phased corrective action allowed at UIC Program Director's discretion
 - Carbon dioxide compatible materials required for well construction

3

The AoR for Class VI wells differs from other well classes. AoRs for other well classes can be delineated by using a zone of endangering influence or fixed radius method and have the option to use area permits.

The AoR for Class VI wells must be delineated using computational modeling that accounts for the physical and chemical properties of all phases of the injected carbon dioxide stream and is based on available site characterization, monitoring, and operational data. Area permits are prohibited.

One quick note here regarding injection well permits and computational modeling. Just because area permits are not allowed does not mean that the individually permitted injection wells are evaluated in isolation. On the contrary, all the Class VI injection wells proposed to be located within the same AoR must be evaluated holistically in order to appropriately and completely assess the effects on reservoir pressure from multiple injection points. The combined influence of multiple injection wells should be reflected in the required AoR and Corrective Action Plan submitted with the Class VI permit application. The approved permit provided to each individual Class VI injection well would define its own operating conditions.

Phased corrective action can be used for Class VI wells, at the discretion of the UIC Program Director. If the Director approves of phased corrective action, he or she must ensure that the method used by the owner or operator to demarcate what regions of the AoR will be corrected on a phased basis will provide sufficient protection to USDWs. The details regarding how corrective action will be phased must be included in the UIC Program Director-approved AoR and Corrective Action Plan.

Also, it is important to use well construction materials that are compatible with injection of carbon dioxide and protect against potential corrosivity.

AoR and Corrective Action: UIC Program Director Reviews

- AoR and Corrective Action Plan
 - With permit application
- AoR Delineation
- Report on Status of Corrective Action
 - Prior to authorizing well operation
- AoR Reevaluations
 - Periodically throughout operational phase

4

There are 4 main components of AoR and corrective action for Class VI wells that the UIC Program Director will need to review: the AoR and Corrective Action Plan, the AoR delineation, the report on status of corrective action, and AoR reevaluations.

•The AoR and corrective action plan will be submitted with the permit application and describes how owners/operators will delineate and periodically reevaluate the AoR and perform all necessary corrective action on deficient artificial penetrations and natural conduits located within the AoR. The Director should evaluate the plan in connection with the geologic and proposed operating data for a site.

•Prior to authorization of well operation, the Director will receive the initial AoR delineation and the report on status of corrective action.

•AoR reevaluations will need to be periodically reviewed by the UIC Program Director throughout the operational phase of the project.

AoR and Corrective Action Plan

- Describes:
 - AoR delineation and periodic reevaluation of the AoR
 - Corrective action on improperly plugged or abandoned artificial penetrations



40 CFR 146.84(b)

5

The UIC Class VI GS rule requires owners or operators to submit an AoR and Corrective Action Plan with the Class VI permit application. The Plan describes how the owner or operator will:

- Delineate the AoR using computational modeling.
- Identify all artificial penetrations and any natural conduits within the AoR.
- Determine that abandoned wells within the AoR are properly plugged, and
- Perform corrective action on any deficient/improperly plugged wells and natural conduits located within the AoR as necessary.

Owners or operators of other well classes must prepare AoR and corrective action plans, however Class VI plans have some unique aspects, which we will discuss here.

These slides go over highlights but for all the details of the AoR and Corrective Action Plan requirements, see the table in Section 3 of the Draft Primacy Application and Implementation Manual – and see the UIC Class VI GS Rule in the *Federal Register* at 75 FR 77230.

AoR and Corrective Action Plan Sample Table of Contents

AoR and Corrective Action Plan	
I.	Facility Information
II.	Planned Computational Modeling
III.	Corrective Action Plan and Schedule
A.	Pre-Injection Corrective Action Schedule
B.	Plan for Site Access
C.	Phased Corrective Action Schedule
D.	Justification of Phased Corrective Action
E.	Attachments
1.	Preliminary maps of the AoR with deficient wells identified
2.	Plugging schematics
IV.	AoR Reevaluation Plan and Schedule
A.	Reevaluation Strategy
B.	Proposed Reevaluation Cycle
C.	Triggers for More Frequent AoR Reevaluations

6

This is a sample table of contents for an AoR and Corrective Action Plan that the UIC Program Director may receive. It incorporates all the required elements of the plan that need to be reviewed.

This is adapted from the template in Appendix A of the Draft UIC Program Class VI Well Project Plan Development Guidance.

AoR modeling and corrective action are distinct processes, but they are related. The next few slides will discuss them separately.

AoR Delineation Plan Elements

- Description of computational model
- Modeling assumptions
- Site and operational data inputs
- Additional modeling approaches, if required

40 CFR 146.84(b)(1)

7

Use of computational models to delineate the AoR is unique in the UIC GS Rule, and owners or operators must provide information about the planned delineation procedures.

Required information on the AoR Modeling method includes:

- The computational code to be used and any code attributes (e.g., governing equations, code verification), as required by the UIC Program Director. For proprietary models, the model code can be submitted to the UIC Program Director under the provisions of confidential business information (CBI).
- Relevant modeling assumptions that will be made and the physical processes that will be included in the AoR delineation model.
- The site characterization and anticipated operational data on which the model will be based.
- Any additional general modeling approaches that the owner or operator plans on utilizing, as required by the UIC Program Director.
- Note that modeling uncertainty should also be evaluated and considered when reviewing Class VI injection well permit application materials. The draft UIC Class VI AoR Evaluation and Corrective Action Guidance provides a detailed discussion of how modeling uncertainty should factor into permitting decisions.

AoR Delineation Plan Elements

- Descriptions of the frequency of AoR reevaluations
- Potential triggers for AoR reevaluations
- Description of how monitoring, site characterization, and operational data will inform AoR reevaluations

40 CFR 146.84(b)(2)(i)-(iii)

8

The Plan should describe how often the AoR will be reevaluated and why this is appropriate based on site specific information.

Potential triggers include: unexpected changes in rate or direction of carbon dioxide plume movement or formation pressures; changes in project operation (adding more wells, increasing injection rates or volumes); following a seismic event; following an exceedance of Class VI permit conditions or newly available site characterization information.

The plan must discuss how new data will be used to revise the AoR model and delineation, tie closely to how operating data will be collected and how the Class VI Testing and Monitoring Plan will be implemented as well (specific types of monitoring data, how model parameters will be adjusted, impacts of other Class VI injection wells located within the AoR, etc.).

Corrective Action Plan Elements

- Methods to identify improperly plugged or abandoned artificial penetrations
- Methods that will be used to assess the integrity of penetrations
- Methods that will be used to perform corrective action and schedule for required actions
- Site access

40 CFR 146.84(b)(2)(iv)



9

The Corrective Action Plan and Schedule is included in the AoR and Corrective Action Plan. The pre-injection corrective action plan should describe:

- Methods that will be used to identify wells in the AoR.
- Methods that will be used to assess the integrity of abandoned wells to determine if they are in need of corrective action.

If corrective action on any wells is needed, the plan should describe how it will be performed to ensure USDW protection and address exposure of the wells to carbon dioxide. Keep in mind that sometimes the necessary corrective action may be beneficial in converting identified improperly plugged or abandoned artificial penetrations over to monitoring wells. This action would have to be described in both the required AoR and Corrective Action Plan for a Class VI injection well and in the required Testing and Monitoring Plan. The Draft UIC Program Class VI Well Project Plan Development Guidance discusses the benefits of using wells for more than one purpose, as appropriate and approved by the Director.

The owner or operator will also describe a plan for securing site access to all wells needing corrective action prior to injection and throughout the lifetime of the GS project.

Unique for Class VI: Phased Corrective Action

- Justification of phased corrective action and schedule
- UIC Program Director considerations:
 - Injection rate, volumes, duration
 - Composition of the CO₂ stream and impacts on native/formation fluids
 - Number, density, quality of wells
 - Workload issues and site access
 - Modeling certainty

40 CFR 146.84(b)(2)(iv)

10

Phased corrective action is also unique for Class VI wells, and if the well operator wants to phase corrective action, they need to provide justification and the schedule for conducting corrective action on a phased basis in the plan. The appropriateness of performing phased corrective action would be informed by the site characterization data and AoR delineation modeling predictions.

If the UIC Program Director approves of phased corrective action, he or she must ensure that the method used by the owner or operator to demarcate what regions of the AoR will be corrected on a phased basis will provide sufficient protection to USDWs.

In reviewing and determining whether to allow phased corrective action, the Director should consider:

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

AoR and Corrective Action Plan Updates

- Consider:
 - AoR model revisions
 - Matches between modeled predictions and monitoring data
 - Plume movement
 - Corrective action needs
 - Land use changes

11

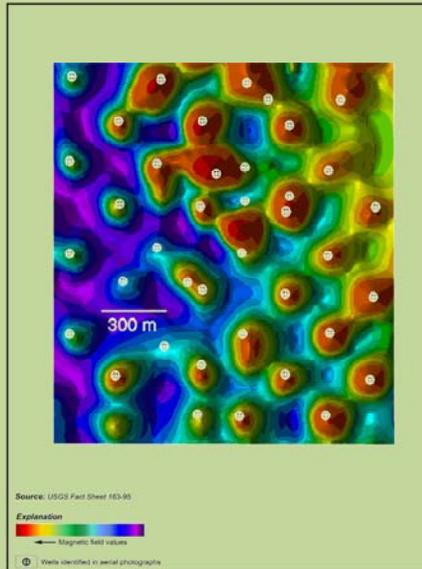
As described earlier, the GS Rule requires the owner or operator to periodically review the AoR and corrective action Plan in the context of the most recent AoR reevaluation and monitoring and operational data to determine whether the AoR and corrective action Plan should be updated. The owner or operator must either update the plan or demonstrate that no update is needed.

Considerations for determining the need to update the AoR and Corrective Action Plan include:

1. 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.
2. 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.
3. 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.
4. 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?
5. Have land use changes potentially affected the owner or operator's ability to secure rights to access wells identified as needing corrective action?

AoR Delineation

- Computational modeling to predict migration of the carbon dioxide plume and formation fluids



40 CFR 146.84(c)(1)

12

The AoR delineation uses computational modeling which should account for the **multiphase flow and buoyancy of carbon dioxide** and be informed by site characterization data. The model should accurately predict the lateral and vertical migration of the carbon dioxide plume and formation fluids. The owner/operator must disclose code assumptions, relevant equations, and scientific basis of the model. The UIC Program Director may allow the use of proprietary models. The Director must review all model related data when making permit decisions, however it is possible that proprietary information may be claimed as confidential.

The model should address carbon dioxide movement during both the operational and the post-injection site care (PISC) phases of the Class VI injection well lifecycle.

The Draft UIC Program Class VI Well AoR Evaluation and Corrective Action Guidance, currently out for public comment and to be finalized after the comment period closes, includes information on available AoR modeling software, both public access and proprietary models, but does not promote any one model specifically.

Image: Total Field Aeromagnetic Map, Cook Creek Oil Field, Arcadia, Oklahoma (from USGS, 1995).

AoR Delineation (cont'd.)

- Identifies natural conduits, artificial penetrations, plugged wells, and wells requiring corrective action
- UIC Program Director reviews model outputs and identified artificial penetrations

40 CFR 146.84(c)(2)-(3)

13

Additionally, the AoR delineation identifies all artificial penetrations in the AoR and those wells which are plugged or require corrective action. Natural conduits and artificial penetrations (or wells) are identified as part of the AoR delineation. The owner or operator should describe each well's type, construction specifications, date drilled, location, depth, and record of plugging or completion. This information is found in well databases or by using aerial or ground surveys. The owner or operator should provide the UIC Program Director with their sources for identifying these wells. The Director will also receive information on which wells have been plugged and which still require corrective action. Wells requiring corrective action include: wells with insufficient records, improper plugging, or materials incompatible with the carbon dioxide stream. The owner or operator will have to physically access those identified wells with insufficient plugging records in order to determine whether corrective action is needed at that well site.

To evaluate the AoR delineation submitted by the owner or operator, the Director can independently conduct a detailed, critical evaluation of the delineation model. The Director should ensure that all relevant site characterization data are used, that sensitivity analyses incorporate the full range of reasonable model input parameters, and that model assumptions are reasonable based on site conditions. In cases where the owner/operator's model and the Director's model vary, the Director should request additional information or justification from the owner or operator.

The UIC Program Director can also use outside services, such a consultant or a qualified USGS, DOE or EPA laboratory. The modeler should have no conflict of interest with the GS site in question (e.g., the UIC Program Director will not want to hire the same firm used by the owner/operator).

The UIC Program Director can evaluate the identification of artificial penetrations by cross-referencing with well databases and performing direct field reconnaissance if necessary. He or she may request additional information for wells with insufficient plugging records. The Director should require more information from the owner or operator if insufficient activities were performed to locate wells or if wells requiring corrective action were not identified.

Report on Status of Corrective Action

- Received after corrective action is performed
 - Description of all corrective action activities, including methods and materials
- UIC Program Director ensures:
 - Proper plugging methods/materials
 - Well integrity/specification assessed using reconnaissance when necessary

40 CFR 146.84(d)

14

The report on the status of corrective action will be submitted to the UIC Program Director after corrective action is performed and includes a description of all activities that occurred. The Director should ensure that proper well plugging methods and materials were used and should consider any issues that may arise due to potential corrosivity of the carbon dioxide stream. The Director should also verify that well reconnaissance activities for assessing well integrity and well specifications were conducted as necessary.

AoR Reevaluation

- Determines whether the previous AoR delineation is adequate
- Different submissions requirements for confirmation of previous delineation and revised delineation

40 CFR 146.84(e)



15

The AoR reevaluation determines whether the previous AoR delineation is still adequate and what, if anything, additionally needs to be provided to the UIC Program Director. However, for example, if the monitoring information submitted for the Class VI injection well does not match up with the AoR delineation model results, an AoR reevaluation may be warranted. For all AoR reevaluations, the Director will receive: site characterization data which informs model development; a comparison of operational data and model inputs; and monitoring data.

For confirmation that the *previous* AoR delineation is adequate, the reevaluation consists of a demonstration using graphs or maps showing that modeling predictions and monitoring data are consistent.

For a *revised* AoR delineation, the Director will receive:

- The revised AoR overlain on a regional map, which may also show the locations of identified artificial penetrations;
- Graphs or maps showing the model calibration and model fit;
- A table detailing model input parameters/values; and
- Any monitoring or operational data required to help show why the AoR delineation was revised (i.e. data and initial model results do not match)

There are a number of different triggers that might warrant model recalibration. There is a five-year default period for AoR reevaluation [40 CFR 146.84 (b)(1)(i)] although the UIC Program Director can determine an earlier reevaluation and subsequent model recalibration if conditions trigger the need.

UIC Program Director Review of AoR Reevaluations

- UIC Program Director uses AoR reevaluation to:
 - Verify carbon dioxide plume/pressure front predictions
 - Identify wells requiring corrective action
- Evaluation
 - Independent demonstration using monitoring data

16

AoR reevaluations use monitoring and operational data to ensure that the carbon dioxide plume and pressure front are moving as predicted, while also identifying additional wells that will require corrective action. The reevaluation must confirm that the operating/monitoring data still match the initial model results. If this is the case, then the modeling results may still stand.

For confirmation that the *previous* AoR delineation is adequate and model recalibration is NOT necessary, the Director can independently evaluate the demonstration by comparing monitoring and modeling data and ensuring that all monitoring, operational, and site characterization data are accounted for.

For a *revised* AoR delineation, the Director can independently evaluate the revised delineation the same way he or she evaluated the initial AoR delineation to ensure that all monitoring, operational, and site characterization data are accounted for.

UIC Program Director Review of AoR Reevaluations (cont'd.)

- Submission of AoR reevaluations:
 - At least every 5 years
 - As specified in AoR and Corrective Action Plan
 - When monitoring data and modeling predictions significantly differ
- Revisions to AoR and Corrective Action, Emergency and Remedial Response, Financial Responsibility Demonstration if AoR reevaluated

40 CFR 146.84(e)-(f)

17

AoR reevaluations must be submitted to the UIC Program Director:

- At least every 5 years;
- As specified in the AoR and corrective action plan; or,
- When monitoring data and modeling predictions differ significantly.

Note that the initial AoR delineation, based on initial site characterization data and projected operational data, will likely require more conservative assumptions in AoR modeling than in later AoR reevaluations. Based on additional operational and monitoring data collected during operations, it is possible that some modeling assumptions could justifiably be less conservative (more realistic) over time for subsequent AoR reevaluation modeling.

Owners and operators must periodically update the AoR and Corrective Action Plan, Emergency & Remedial Response Plan and Financial Responsibility demonstration to incorporate data and information from AoR reevaluations – revisions to the AoR and Corrective Action Plan may also impact testing and monitoring activities.

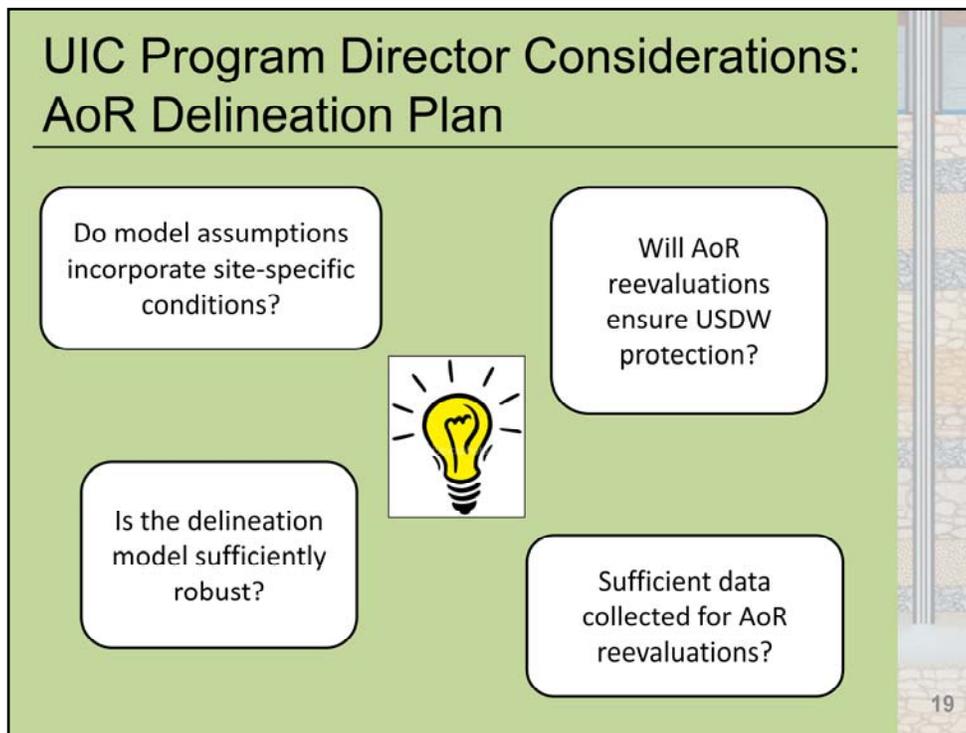
Some Class VI Program AoR and Corrective Resources

- For more information on area of review and corrective action, refer to:
 - Draft UIC Program Class VI Primacy Application and Implementation Manual
 - Draft UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance
 - EPA's Class VI Web site:
<http://water.epa.gov/type/groundwater/uic/class6/gclass6wells.cfm>

18

Some Class VI Program AoR and corrective action resources which are currently available are:

- The Draft UIC Program Class VI Primacy Application and Implementation Manual.
- The Draft UIC Program Class VI Well AoR Evaluation and Corrective Action Guidance.
- And EPA's Class VI website:
<http://water.epa.gov/type/groundwater/uic/class6/gclass6wells.cfm>.



The UIC Program Director will review the operator's proposed AoR plan for completeness and to verify that it will ensure that the GS project is operated in a manner that protects USDWs.

Questions that the UIC Program Director will want to consider while reviewing the AoR delineation plan include:

1. Do the model assumptions incorporate all site-specific conditions (such as site geology, subsurface pressures and fluid movement, and proposed operating data)?
2. Is the delineation model sufficiently robust to accurately predict carbon dioxide plume and pressure front movement? Is sufficient information submitted regarding modeling assumptions and calibration?
3. Are the conditions and schedule for AoR reevaluations sufficient to address changes in operational conditions or monitoring data and ensure protection of USDWs?
4. Have the geologic factors and operational conditions that could warrant a change in the reevaluation schedule been included in the plan?

UIC Program Director Considerations: Corrective Action Plan

Are all artificial penetrations
accounted for?



Is condition of all wells
established?

Are corrective action
techniques appropriate?

20

Questions that the UIC Program Director will want to consider while reviewing the Corrective Action Plan include:

1. Has a reasonable effort been made to locate all improperly plugged wells in the AoR, and has the condition of each well been established?
2. Are the remediation techniques proposed to be used appropriate to the number and condition of all the improperly abandoned wells in the AoR?
3. Is the plan sufficient to ensure that no wells in the AoR will serve as conduits for fluid movement into USDWs?