Unitization of geologic formations for the purpose of monetizing geologic sequestration credits

James A. Sorensen*[1], Lynn D. Helms[2], Steven A. Smith[1], David W. Fischer[3], Edward N. Steadman[1], John A. Harju[1]

[1]Energy & Environmental Research Center (EERC)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018

[2]North Dakota Department of Mineral Resources, Oil & Gas Division
Bismarck, ND 58505

[3]Fischer Oil and Gas
Grand Forks, ND 58201

Abstract

A formal process is needed to address key engineering, environmental, regulatory, and legal issues associated with the implementation of large-scale geologic sequestration projects. Oil and gas regulatory agencies in the United States use a process commonly referred to as "unitization" to organize oil fields into units for the purpose of secondary and tertiary recovery operations. The process by which petroleum fields become unitized may provide a useful model for the selection of appropriate injection target formations and the governing of geological sequestration projects. The process may be viably applied to petroleum reservoirs, saline aquifers, and coal seams. Application of the unitization process to CO_2 sequestration may result in the establishment of "geological sequestration units" (GSUs).

Keywords: CO_2, geological sequestration, regulatory, unitization

Introduction

The Plains CO_2 Reduction (PCOR) Partnership is one of seven regional partnerships that the U.S. Department of Energy's (DOE's) National Energy Technology Laboratory (NETL) established in order to perform a nationwide assessment of carbon sequestration opportunities. One of the primary functions of the PCOR Partnership is to facilitate the implementation of geologic sequestration strategies. Phase I included reconnaissance-level determination of the potential sequestration capacity of numerous geologic sinks in the region, including oil fields, coal seams, and brine formations. Over the course of evaluating over 1900 oil pools, three coal beds, and two saline aquifer systems throughout the PCOR Partnership region, it became apparent that although each of the three types of geologic targets generally utilize different mechanisms for sequestration (for example, dissolution into oil vs. dissolution into saline water vs. adsorption onto coal), there are several properties they have in common that may dictate the conditions under which large-scale injection of CO_2 can be conducted. For instance, all three types of targets must have competent seals and other trapping mechanisms. From a legal standpoint, each may have privately held mineral rights associated with them. All three will also require a framework for accounting that is based on detailed characterization data, sound engineering design, and an equitable legal and regulatory process. The development of carbon credit markets for CO_2 sequestered in geological formations will require proper accounting of injected CO_2, which will be well served by a streamlined process that takes these conditions and issues into account. Such a system has already been established in the unitization process under which the U.S. petroleum industry currently operates. In order to facilitate the implementation of geologic sequestration projects, the PCOR

Partnership proposes that target injection zones be referred to collectively as “geological sequestration units” (GSUs).

Methodology

The PCOR Partnership recognizes the challenges facing the injection of CO_2 in geological media, especially with respect to monetization of geologic sequestration credits. The development of markets for carbon credits associated with geologic sequestration will require action from several diverse communities. As with many disciplines and technologies, a broadly recognized framework is needed to facilitate effective communication between the scientific, engineering, regulatory, and legal communities. With this in mind, the PCOR Partnership is working to facilitate the development of a monetization framework which is based on the establishment of GSUs.

The term “geological sequestration unit” was chosen to acknowledge the legal and regulatory process that will be necessary to inject large volumes of CO_2 across areas consisting of numerous mineral ownership tracts; it was not chosen to represent entire geologic units or formations. The concept is to apply the process by which petroleum fields become unitized to the governing of geological sequestration projects. In modern hydrocarbon production field practices, prior to initiation of subsurface activities that will affect the fluid distribution and production within an area, mineral ownership tracts may be legally combined to form a larger working area. The process of combining individual tracts is referred to as “unitization,” and the working area created by this process is referred to as a “unit.” The effective result of unitization is the protection of correlative rights of all mineral owners within the designated area and coordinated injection and reservoir management practices that improve the efficiency of petroleum extraction. It is anticipated that a similar unitization process will need to be developed prior to injection of CO_2 for sequestration in geological formations. Unitization will facilitate monetization by establishing a technical and legal framework by which CO_2 injection can be implemented. The value of these credits will be largely based on the ability to quantify and verify the amount of CO_2 in a given geological target. The physical and legal boundaries of that target must be established as part of the monetization process.

The process of formally organizing a tract of land and its corresponding geologic injection target formation into a GSU according to the oil field unitization model does not address the issue of pore space value. The issue of pore space value and ownership will have to be addressed primarily through the legal system, either through the application of relevant case law or through the legislative process. Examinations of American and Canadian case law related to hazardous waste injection and natural gas storage have been used to provide insight on the issue of pore space value and ownership and suggest that such issues are largely unresolved in many jurisdictions [1]. The Interstate Oil and Gas Compact Commission has recommended that states and provinces consider the potential need for new legislation to clarify and address pore space ownership issues and that such legislation use existing natural gas storage and enhanced oil recovery (EOR) statutes as guides for new laws [2]. While hazardous waste injection and natural gas storage laws have been considered as potential models for protecting correlative rights that may be associated with the injection of CO_2 into geologic formations [1, 2], the oil field unitization model for establishing GSUs provides a prescriptive methodical approach to developing a legal and regulatory framework for large-scale geologic sequestration.

The first step in promulgating a process to establish GSUs within a given jurisdiction is to identify or establish a government agency or commission that has the power and authority to evaluate and authorize the establishment of GSUs. In the United States, the authority to establish oil field units is generally held by the agency at the state level that oversees and regulates oil and gas production activities. Oil fields are typically unitized for the purpose of implementing secondary or tertiary EOR projects, which often require coordinated injection and production of fluids across a field or

portion of a field. The oil field unitization rules and methods of the North Dakota Department of Mineral Resources, Oil and Gas Division (NDDMR-OGD), provide an excellent example in the PCOR Partnership region of a decades-old approach that can be modified for the purpose of establishing GSUs. The NDDMR-OGD unitization process will be used as a primary point of reference throughout this paper. This paper will focus primarily on the technical aspects of unitization, as they will likely have the broadest applicability to a wide variety of jurisdictions at the state/provincial, national, and international levels.

The Oil Field Unitization Process in North Dakota

NDDMR-OGD regulates the drilling and production of oil and gas in North Dakota. The mission of the agency is to encourage and promote the development, production, and utilization of oil and gas in such a manner as will prevent waste, maximize economic recovery, and fully protect the correlative rights of all owners. The ultimate mandate of the agency is that North Dakota landowners, royalty owners, producers, and the general public realize the greatest possible good from these vital natural resources. To that end, the establishment of oil field units is often considered to be an appropriate means of realizing the goals of NDDMR-OGD. In order for an oil field to be unitized in North Dakota, NDDMR-OGD must find that the following have been demonstrated by the petitioner:

1) The unitization of the field is reasonably necessary in order to effectively and substantially increase the ultimate recovery of oil.
2) One or more of said unitized methods of operation are feasible, will prevent waste and will with reasonable probability result in the increased recovery of substantially more oil than would otherwise be recovered.
3) The estimated additional cost, if any, of conducting such operations will not exceed the value of the additional oil and gas so recovered.
4) Such unitization is for the common good and will result in the general advantage of the owners of the oil and gas rights.

If all of these are demonstrated, then NDDMR-OGD can create the unit and provide for the unitization, all upon such terms and conditions as may be shown by the evidence to be fair, reasonable, equitable, and which are necessary to protect, safeguard, and adjust the respective rights and obligations of the several persons affected. The petition must set forth a description of the proposed unit area with a map, must allege the existence of the facts required to be found by the commission, and must have attached thereto a proposed plan of unitization applicable to such proposed unit area [3].

The evidence and facts referred to in the North Dakota state law [3], while not specified in the law itself, by matter of practice include detailed geologic and engineering reports on the field or fields being considered for unitization. NDDMR-OGD requires such reports as part of the unitization process. The technical reports of successful unit applications generally provide data on the geology of the reservoir, including lithological descriptions and maps showing the structure of the reservoir formation and its productive intervals, interval thickness, and porosity and permeability. Some geologic reports include key supplemental information such as core descriptions and analyses, geophysical data, and geochemical data. Engineering reports provide in-depth discussions of reservoir properties, fluid properties, reservoir performance and pressure history, oil-in-place calculations, reserves, unitization parameters, pressure maintenance, and economic evaluation of the proposed unitization plan. The body of evidence presented to NDDMR-OGD by the petitioners will also include predictions, usually based on robust modeling exercises, of the incremental fluid production and, if applicable, the effects of the injection and production activities on neighboring reservoirs that may be expected from the implementation of the unitization plan.

Those who petition NDDMR-OGD must submit a unitization plan that contains fair, reasonable, and equitable provisions for several aspects of oil recovery. Some of those provisions that may be applicable to the establishment of GSUs include:

1) The efficient unitized management of the further development and operation of the unit area. This includes the designation of a unit operator by the owners of a simple majority of the working interest in the unit area.
2) The creation of an operating committee to have general overall management and control of the unit and the conduct of its business and affairs and the operations carried on by it.
3) The time when and conditions under which and the method by which the unit must or may be dissolved and its affairs wound up.

The use of public hearings is the primary mechanism in the decision-making process for considering the unitization of oil fields in North Dakota. Each petition for unitization must go through a series of public hearings at which the testimony of the petitioners, expert witnesses, and other stakeholders is heard by NDDMR-OGD. Notification of the schedule for public hearings is given to all potentially affected parties (landowners, royalty owners, operators, etc.) via mailed invitations, while the public at large is notified through notices in local newspapers.

Application of North Dakota Oil Field Unitization Process to Development of GSUs

Many of the aspects of the oil field unitization process used by NDDMR-OGD may be applied to a similar process to establish GSUs. In fact, much of the North Dakota oil field unitization process for secondary and tertiary EOR projects may be modified to provide the backbone structure of a unitization process for large-scale geologic sequestration projects. Starting with the mission statement, recall that the ultimate mandate of NDDMR-OGD is that North Dakota landowners, royalty owners, producers, and the general public realize the greatest possible good from the state's oil and gas resources. Using this as a guide for the sequestration of CO_2, key elements of a mission statement for the agency responsible for the oversight and regulation of CO_2 sequestration activities and, therefore, establishment of GSUs, may include the prevention of CO_2 leakage outside of target injection zones, the maximization of economic CO_2 sequestration, and the full protection of the correlative rights of all potentially affected owners and stakeholders.

Before describing a unitization process for geologic sequestration, it is worth noting that most oil and gas reservoirs will have an advantage over saline aquifers and coal seams when it comes to selecting potential GSU locations. Specifically, an oil or gas reservoir is a geological feature that is characterized by a reservoir rock with porosity and permeability sufficient to allow for the movement of fluids and is competently sealed above by impermeable rock. These universal characteristics of oil reservoirs help to expedite the unitization process for oil fields, whether it be for EOR or CO_2 sequestration projects. The oil field unitization process also has the built-in advantage of being based on a wealth of data from many wells in relatively close proximity to each other. These data include well logs that provide detailed porosity and permeability values for the entire field and years (often decades) of formation fluid production and reservoir pressure historical data. The high economic return often associated with oil fields also results in the collection of expensive rock core, geomechanical, geophysical, and geochemical analyses data for many fields. All of these diverse data sets are then typically brought together to develop highly accurate and precise hydrodynamic models for a vast majority of the oil fields that may be considered for unitization. Unfortunately, most target zones within saline aquifers and many coal seams are not nearly as well characterized as the typical oil field. Many of the data sets routinely associated with oil field unitization will not exist for most saline aquifers and coal seams that may be proposed as GSUs. That being said, the general approach outlined in this paper for the establishment of GSUs can still be applied to target zones within saline aquifers and coal seams, although a significant

amount of field-based geologic, hydrogeologic, and hydrogeochemical characterization should be conducted prior to considering large-scale CO_2 injection in areas where such data are sparse.

Once a sufficient amount of geologic and engineering background data have been assembled, an application to classify a target injection zone as a GSU may be prepared. In order for a target injection zone to be classified as a GSU, the regulating agency should find that the following have been demonstrated by the petitioner:

1) The unitization of the field is reasonably necessary in order to effectively and substantially maximize the injection of CO_2 and minimize impacts to potable groundwater resources.
2) Said sequestration method of operation is feasible and will with reasonable probability result in the net reduction of CO_2 emissions relative to the CO_2 source.
3) The estimated costs of sequestration and MMV activities are economically viable such that long-term operation and monitoring can be anticipated with reasonable probability.
4) Such unitization is for the common good and will result in the protection of correlative rights of potentially affected owners and the health and safety of the general public and the environment.

As with the oil field unitization process in North Dakota, the geologic sequestration unitization process should require detailed geologic and engineering reports on the specific oil field, saline aquifer target zone, or coal seam being considered for classification as a GSU. The technical reports of successful unit applications should provide a discussion and interpretation of readily available data on the geology of the injection target zone and the primary sealing formation above the target zone, including lithological descriptions and maps of key parameters. Supplemental information such as core descriptions and analyses, geophysical data, and geochemical data should be presented where available. Engineering reports providing in-depth discussions of reservoir properties, seal properties, formation fluid properties, and injectivity should be provided. For oil fields, reservoir performance, pressure history, and oil-in-place data should be included as well. The results of modeling exercises conducted to predict the fate and movement of the injected CO_2 within the proposed GSU will be a critical component of a GSU application. Finally, it is crucial that a low probability of contamination of groundwater resources be thoroughly demonstrated.

While oil field unitization rules regarding unit management, operations, and timing issues may be applicable to the GSU process, key provisions that are not included in the NDDMR-OGD rules but which would likely be required as part of a unitization plan for geologic CO_2 sequestration may include:

1) The enumeration of methods and technologies that will be used to periodically conduct measurement, monitoring, and verification (MMV) activities to ensure effective, long-term sequestration of CO_2 within the GSU. This should include a schedule for conducting MMV activities.

2) The establishment of baseline geologic, hydrogeochemical, and hydrodynamic characteristics of the injection target zone, primary and secondary sealing formations, and regional geologic setting.

As with the oil field unitization process in North Dakota, it is suggested that the use of public hearings, including the participation of the GSU operators, expert witnesses, and other stakeholders be a significant part of the decision-making process for considering the establishment of GSUs. Public hearings enable all potentially affected parties the opportunity to express their views regarding the establishment of the proposed GSU. While the process is designed to take into consideration the concerns of interested individuals, it should also include a mechanism that

enables the regulatory agency to act according to the best interests of a majority of stakeholders. With respect to oil field unitization, most state oil and gas regulatory agencies have the authority to form statutory units. This authority allows a supermajority of mineral rights owners in conjunction with the agency to force an objecting minority to allow the project to move forward. In our modern society, this function is very important as it is often impossible to achieve 100% approval over a large enough geographical area to ensure project success.

Conclusions

GSUs may be established in petroleum reservoirs, saline aquifers, and coal seams. Unit boundaries have already been established for hundreds of oil fields as part of the field operational and regulatory processes. The establishment of a GSU within a geologic setting that does not produce hydrocarbons, such as a saline aquifer, will still require the same detailed documentation that demonstrates to the appropriate regulatory agency that the operator of the project 1) adequately understands the geology and hydrodynamics of the proposed GSU and 2) has an appropriate MMV plan in place to keep track of the injected CO_2.

Areas to be established as GSUs will be those that have been proven to provide effective storage and have known fluid migration properties. The first candidates for GSUs will be those geologic features that have already been thoroughly characterized. Since most detailed characterization of the deep subsurface has been conducted as part of hydrocarbon exploration and production activities, it is likely the first GSUs will be oil and gas fields that are currently in production, depleted oil and gas fields, and other characterized structures that are known to have effective trapping mechanisms (e.g., previously explored anticlines, pinnacle reefs, and other structures that do not have economical reserves of petroleum).

Using unitized oil fields as a model, GSUs could vary in size from as small as a few acres to as large as hundreds of square miles. The size of a GSU is directly dependent on the geologic and hydrodynamic characteristics of the area being considered as a target for CO_2 injection. Like oil field units, a GSU should only be established across an area where those characteristics have been demonstrated to be thoroughly documented and well understood. With this in mind, it will not likely be possible to declare entire regional formations or aquifer systems to be single GSUs. Geologic formations and aquifer systems are typically too heterogeneous and lacking in characterization data to adequately model large regions to the precision required for unitization. Rather, it will be necessary to identify localized areas within a formation or aquifer system that have specific characteristics, particularly with respect to competent seals, that allow for the secure long-term storage of CO_2.

References

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