Wellington Small Scale Carbon Storage Project

Summary of Experience, Conclusions, and Recommendations

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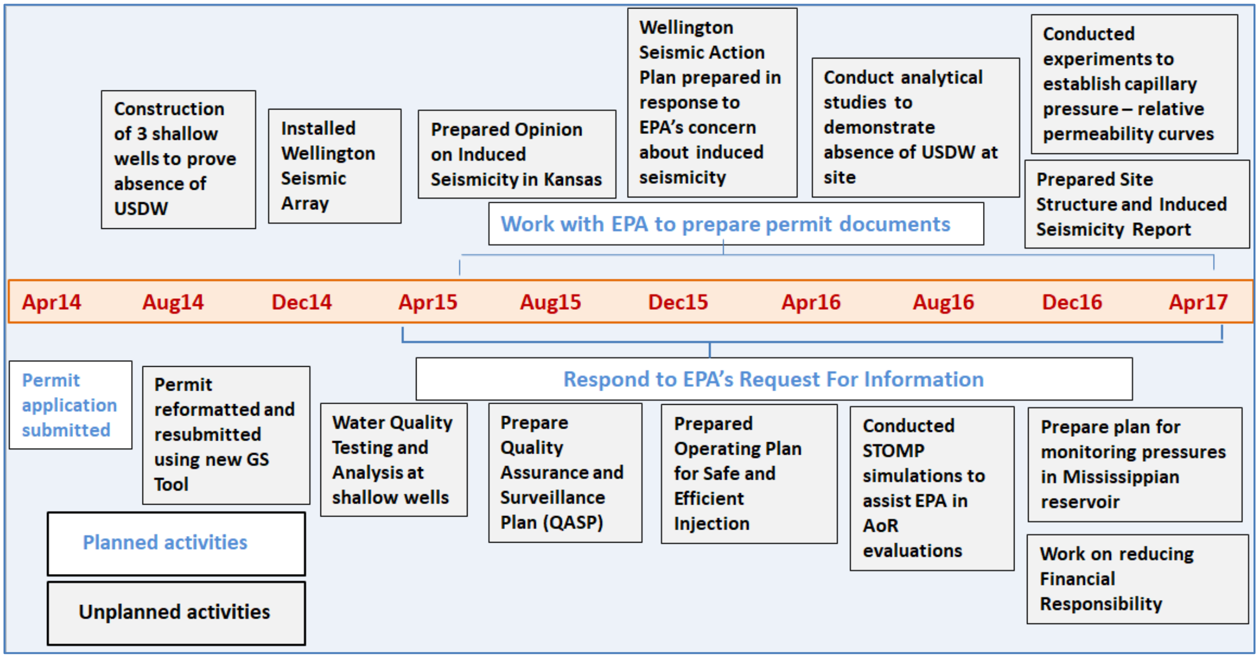
1.0 Experience with the Permitting Process

1.1 Permitting Time Line

The Wellington Class VI permit application was submitted to the U.S. EPA in April 2014. The 1468 page document was prepared in a format similar to the Archer Daniel Midland's Class VI permit application. After the submission, EPA requested a resubmittal of the entire application in May 2014 in a format compatible with the newly released web-based Class VI Geologic Sequestration (GS) Tool (https://epa.velo.pnnl.gov/share/page/operators), which required substantial additional work to be performed. The GS tool was developed to function as a communication and data repository for Class VI applications.

The Wellington permit submittal was one of the first applications for a newly constructed CO2 sequestration well since promulgation of the Class VI Rule in 2011. During the application process, it was realized that were many technical issues for which guidance and precedence was lacking. For example, the Class Rule did not have any formal regulations/guidelines for addressing the subject of induced seismicity. As shown in the permit timeline below, the Wellington team had to expend time and budget on many activities that were unanticipated at commencement of the project. Several of the first-of-a-kind studies conducted in pursuit of the permit and the accompanying reports are expected to serve as a guide and template for future CO2 sequestration projects.



1.2 Permit Review Process

A project kick-off meeting was held at the EPA Region VII headquarters in Lenexa, Kansas, on August 20, 2014. Following the meeting, KGS/Berexco started receiving EPA's comments and Requests for Additional Information (RAI) pertaining to various sections of the permit application. These RAI were initially in the form of email communication, and towards the end of 2014 the RAI requests were forward as *RAI Tables*. Each table dealt with a certain aspect of the permit application, such as the Area of Review, Testing and Monitoring, Emergency and Remedial Response (ERRP), etc.

Starting in spring 2015, a Request for Information (RFI) section was added to the GS Tool and all further communication and exchange of documents between the EPA and KGS/Berexco were channelized through this web-based application. KGS would receive an RFI through the GS Tool and submit their response using the same tool. There could be several back and forth exchanges between KGS and EPA before an RFI was deemed completed by the EPA. A total of 29 RFI were received and responded to between April 2015 and July 2017. Many of the RFI's, especially those related to addressing seismic risk, financial assurance, Underground Sources of Drinking Water (USDW), and Emergency Remedial Response Plan required extensive research.

1.3 Communications with EPA

Communication with the EPA was very formal and at times found to be inefficient. At numerous occasions during the permit preparation and review process, a need was felt to discuss or seek immediate clarification on technical issues as the research was conducted and documents prepared. It would have been preferred if EPA staff could be consulted on the phone on such matters. Instead a formal request via email had to be made for a conference call at a future date, and an agenda prepared for discussion, which resulted in lost time and focus. The headquarters were almost always required to be present on the conference calls and the Region 7 staff had to seek their approval on all decisions.

1.4 Final Status of Project

The EPA informed the project team on March 10, 2017 that all permit attachments were complete and that the only outstanding issue to be resolved prior to issuing a permit was establishing a trust fund to cover financial assurance.

1.6 Cost

The cost of acquiring the permit was unnecessarily prohibitive. We estimate that approximately 6 man years were spent working on the permit. Additional time was spent on data acquisition, processing, and analyses.

2.0 Permit Challenges

2.1 Area of Review (AoR) Delineation and Verification

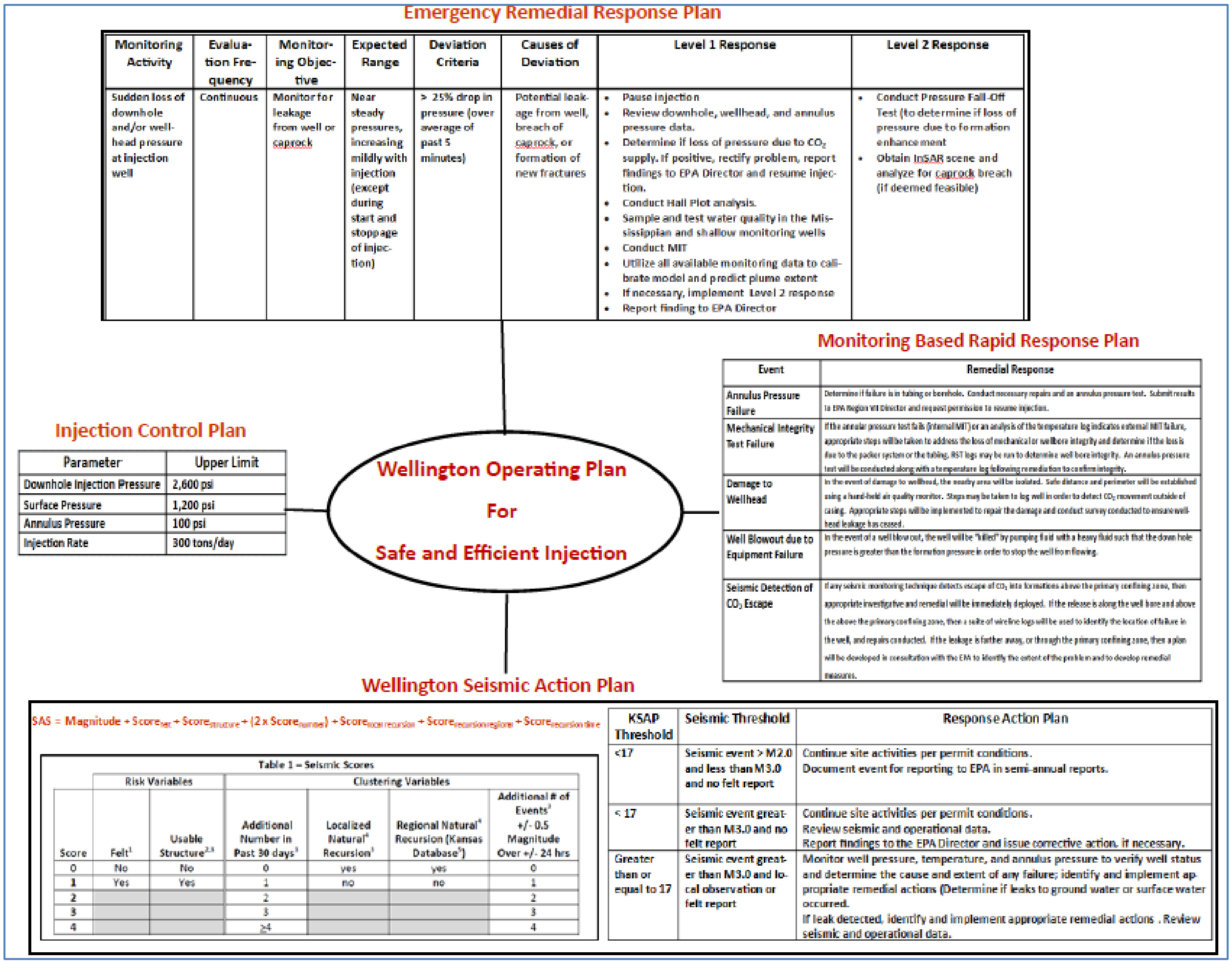
Extensive and advanced geologic characterization had to be conducted and incorporated in a CMG- based multiphase model. EPA hired a consultant to verify the modeling results using PNNL's STOMP modeling software. Due to incompatibility issues, the STOMP model could not be successfully run for almost a year. Eventually, the Wellington project team learnt to use the STOMP model and recreate the data sets in the format required by EPA. This caused substantial delays in the review process.

2.2 Reducing Financial Assurance Costs and Demonstrating Absence of USDW

In January 2015, EPA assessed the financial obligation of the Wellington project at up to $70.01 million (M), which translates to an estimated annual cost of approximately $2M (3% of face value) as premium for an insurance policy/bond or deprived interest to finance a trust fund. Further compounding matters was the (default) 50 year post-injection monitoring period, which would have resulted in prohibitive costs. The challenge therefore was to reduce the financial obligation, most of which was associated with protecting an Underground Source of Drinking Water (USDW) at the site. To demonstrate the absence of any USDW at the site, KGS constructed 3 new wells, implemented region wide water quality sampling/testing, and conducted geologic research. The water levels in the new wells were monitored for a period of 6 months, and the data was utilized to estimate the formation hydraulic properties, which revealed aquiclude like conditions in any potential USDW. The regional water quality information collected for the study was carefully analyzed in order to develop a verifiable conceptualization of the hydrogeology, and to delineate the boundaries of brackish water with TDS greater than 10,000 mg/l. The finding were documented in 5 separate reports published for the EPA , which successfully demonstrated the absence of a USDW at the site, resulting in lowering of the financial obligation to $6.1M from $70.01M. Approximately 12 human-months were expended to achieve the desired outcome.

2.3 Addressing Risk of Induced Seismicity and Developing an Operating Plan for Safe Injection

As large earthquakes started to occur in fall 2014, EPA expressed concerns about proceeding with the permit unless the (seismic) risks of injection could be satisfactorily addressed. This required conducting innovative research and monitoring seismicity in a dedicated network of seismometers installed for the Wellington project. In order to ensure safety and to mitigate the impacts of catastrophic events, the Wellington Plan for Safe and Efficient Injection was developed to address EPA's concerns. This first-of-a-kind plan can serve as a template for future CO_2 sequestration projects, and consists of 4 sub-plans as shown in the figure below: Monitoring Based Rapid Response Plan, Wellington Seismic Action Plan, Emergency Remedial Response Plan, and the Injection Control Plan. A snap shot of the plans is shown below.



2.4 Reducing the Default Post Injection Site Care (PISC) Period

In order to reduce the default Class VI PISC period, research was conducted to develop geochemical criteria for verifying stabilization of the plume and pressure fronts.

2.5 Quality Assurance and Surveillance Plan (QASP)

Significant effort was expended to prepare the 169 page QASP document, which was one of the first of its kind. A substantial amount of time was spent acquiring specification of instruments which even the manufacturers were not used to dealing with. The analytical methods for testing a couple of geochemical parameters were not standardized and required research to establish. Maintaining the EPA required annulus pressure and ensuring strength of packers to withstand the pressures required additional research as well. QA/QC procedures for new technologies and instrumentation, such as the U-tube, needed to be prepared. Pressure and CO_2 monitoring plans had to be prepared for the Mississippian reservoir overlying the confining zone. Additionally plans and protocols for using sulfur hexafluoride as a tracer also had to be developed so as to distinguish between CO_2 used for storage in the Arbuckle aquifer and CO_2 used for Enhanced Oil Recovery (EOR) in the overlying Mississippian reservoir.

3.0 Critique of Class VI Rule

3.1 Overall Geologic Framework Not Considered

A significant amount of effort was expanded on the project to characterize the formations from the surface to the basement. The hydrogeologic information derived from this effort indicated that there were many layers of hydraulic impedance which would prevent CO_2 from reaching the surface or entering any USDW at the site. However, there was no provision for considering this critical information in the application process while determining the potential for CO_2 containment. Beneficial information that could not be utilized due to the narrow focus of EPA on the injection and confining zones include,

- The presence of hydraulic baffle zones within the injection zone that would prevent pressure build up underneath the overlying confining zone and restrict the CO_2 in the lower regions of the injection zone.
- The entry pressure at the base of the confining zone is significantly higher than the incremental pressure of only a few psi projected for the proposed injection.
- There are several very thick confining zones above the primary confining zone which will prevent escape of CO_2 even in the event of a breach of the primary confining zone.
- Even in the very unlikely event that there is a breach in the primary confining zone, the overlying Mississippian oil reservoir is highly under pressurized and can trap any escaping CO_2. The introduction of CO_2 would in fact assist in oil production.
- Faults in the project area are typically not younger than Mississippian age and terminate about 3,500 feet below ground. Therefore the risk of CO2 escaping to the surface or into near-surface USDWs due to fault dilation is minimal.

3.2 USDW

There is no formal definition by the EPA of what constitutes a USDW with respect to water extractability or hydraulic permeability. Even a tight shale formation can be a potential USDW (if Total Dissolved Solids is less than 10,000 mg/l) even though it is technically and economically not feasible to withdraw any meaningful quantity of water from such a formation for potable consumption.

3.3 Financial Assurance (FA)

The costs associated with a) remediating a USDW (up to $60M), and b) creating a hydraulic barrier (up to $6M) are too high and should be more realistic. Furthermore, EPA should clarify how these costs were derived. Also, there is no realistic relationship between the amount of CO_2 injected and the cost for remedial measures. Approximately the same (upper limit) FA cost was estimated by EPA for the Wellington project (with 40,000 tons of injection) as the FutureGen project where 22 million tons were slated to be injected.

The EPA has not specified what technology and measures will need to be implemented to remediate a USDW and create a hydraulic barrier in the injection zone. The applicant was asked to commit to a remedial measure without having an opportunity to estimate the cost independently or even determine its feasibility/effectiveness.

The financial criteria of profitability and assets of the applicant for self-insurance should be relaxed and correspond with the potential risks and costs of failure. In its present form, only large and highly profitable companies can qualify for self-insurance.

3.4 Induced Pressure Limits

As per Class VI rule, the pressure in the injection zone cannot exceed 90% of fracture gradient. This appears to be unnecessarily restrictive for injection zones with baffles as the highest pressure is at the injection well, and typically the pressure is increased at the injection well as part of a stimulation plan to enhance injectivity. A better limiting criterion would be that pressures at the bottom of the injection zone not exceed the entry pressure at the base of the confining zone.

3.5 Lack of Closure Criteria

The Class VI rule states that the applicant can request closure when the plume and pressures have stabilized but does not specify what the stabilization criteria are. We proposed quantifiable closure criteria in the application for both the plume and the pressures, but the EPA would not commit to the same.

4.0 Additional Soft Observations

4.1 Hesitancy in Dealing with Federal Regulators/Authorities

Potential future applicant in Kanas such as oil and gas operators, refineries, and power plants are hesitant to work with EPA and divulge site, operational, or business information to federal authorities.

4.2 Public Perception

CCUS faces a public perception problem from both the left and right sides of the political spectrum. This must be addressed urgently if the CCUS technology is to flourish. The criticism from the left is that geologic sequestration is an attempt to continue use of fossil fuels and will result in contamination of freshwater resources. On the right, there is general skepticism of climate change and resistance to any government role in carbon management. Both sides have a common concern about induced seismicity.

4.3 Avoid Including Non-pertinent Topics, Weak Arguments, and Vagueness

Do not include information that is either not pertinent to permit acquisition or vague in nature. For example, in the original Illinois permit, a statement was made that “groundwater movement is slow” while describing the general movement of water in the subsurface. The applicant was asked by EPA to quantify slow as opposed to fast. As a regulating body, the EPA is required for validate every detail in the application for record or else be held liable for negligence in potential litigation. Therefore, brevity should therefore be a guiding principle and strategy for the applicant.

4.4 Regulatory Uncertainty Led to Undesirable Project Outcome

The uncertain PISC period and the potential for the applicant to be held liable for an indefinite period resulted in a request by the permittee, an oil operator, for setting aside additional funds, which led to the demise of the project.

4.5 Financial Coverage Difficult to Obtain

Oil and gas operators obtain financial protection via a pollution liability policy or bond. These are standardized instruments that have evolved over years as experience was gained in the industry. EPA’s requirement that financial documents reference Class VI rules and special coverage (including seismicity) has resulted in hesitancy for some insurers and re-insurers. AIG which invested time and effort in understanding how to evaluate risks for geologic sequestration project is no longer providing coverage in this field.

5.0 Conclusions

- The default PISC period of 50 years will prevent commercial scale adoption of CCUs and should be replaced with monitoring based criteria for stabilization of plume and pressure fronts.

- Lack of formal national/global carbon emissions policy is preventing adoption of CCUS.

- Creation of an industry-financed trust fund may be beneficial to facilitate adoption of technology and minimize risk.

- Adoption of substantive or procedural limitations on claims would mitigate risks.

- Laws and regulations regarding ownership of pore space and long-term stewardship is needed.

6.0 Recommendations

- The EPA should have in-house capability to evaluate multiphase simulation modeling results submitted by applicants in their native software platform (such as CMG, Eclipse, Tough, etc). If this is not possible, then a versatile interface should be developed that can recreate model input files for EPA's preferred modeling software STOMP. The interface should be capable of handling constitutive relationships and boundary/initial conditions that are not common in existing modeling codes.

- EPA's (Excel based) Financial Assurance costing tool should be capable of realistically accounting for the amount of CO_2 injected while deriving cost estimates for projects.

- As was found for the Wellington project, a permit applicant may be able to fulfill self-insurance criteria (and thereby avoid high coverage costs) but may be unwilling to share guarded information regarding profitability and assets with federal authorities. The EPA should allow for independent auditors to validate the financial strength of the applicant without divulging Profit & Loss, Balance Sheet, and Cash Flow statement items to federal authorities.

- Data acquisition process (i.e logs to be acquired and test to be conducted) should be standardized along with geologic characterization methodologies. This will result in ensuring that the most advanced approaches are implemented for hydrogeologic characterization of the subsurface.

- The applicant should be allowed to utilize the results of such advanced characterization in order to more realistically ascertain the impacts of injection and abatement of risks.

- Mathematical technologies should be developed for evaluating risks in a rigorous numerical framework.

- A common framework should be developed for addressing seismic risk.

- The Wellington Operating Plan for Safe Injection which includes a seismic rapid response plan could be used as a template to develop a generic safe operating plan at a geologic sequestration site.

- Site non-endangerment and closure criteria should be developed so as to enable the applicant to estimate the PISC period.

- A QASP template should be developed which can be signed off by the applicant as a condition of the permit and an agreement to fulfill the required QA/QC protocols.

- The costs associated with a) remediating a USDW, and b) creating a hydraulic barrier are too high and should be more realistic. Furthermore, EPA should clarify how these costs were derived.

- States should be encouraged to acquire Class VI primacy. Most entities that may seek a permit are more comfortable dealing with state (rather than federal) regulators. Berexco was able to obtain a Class II permit in 15 days, and was very critical of the review process duration for the Class VI permit.

- The amount of commercial scale CO2 injection at a sequestration site is in many cases of similar magnitude as the injection occurring at Class I wells. Class I wells have been injecting liquid waste for nearly a century without any documented adverse effects. This information can be used as an analogue while evaluating/estimating the impacts of commercial scale injection.

- The GS Tool should enable tracking document submissions so as to track the submittal/review process.

- Pressure monitoring of deep sedimentary basins should be conducted nationwide so that the impact of injection can be quantified and the available storage capacity of saline aquifers established.

- As CCUS technology evolves, there will be a need to conduct field based experiments. A separate injection class or set of rules should exist for such small scale research projects.

- Induced seismicity is a critical issue that needs to be addressed if CCUS is not to meet the fate of the nuclear industry. There was high optimism add excitement when the nuclear industry was in its infancy. First Three Mile Island, then Chernobyl and now Fukishima appear to have halted the spread of this technology. Continued earthquakes associated with waste disposal may result in a similar outcome for CCUS.