STATEMENT OF BASIS

Montana State University-Bozeman, Energy Research Institute
207 Montana Hall
Bozeman, MT 59717-2465

Class V Experimental Technology Well
EPA Permit No. MT52233-09515

CONTACT: Wendy Cheung
U. S. Environmental Protection Agency
Ground Water Program, 8P-W-GW
1595 Wynkoop Street
Denver, Colorado 80202-1129
Telephone: 1-800-227-8917 ext. 312-6242

This STATEMENT OF BASIS gives the derivation of site-specific UIC Permit conditions and reasons for them. Referenced sections and conditions correspond to sections and conditions in the Permit.

EPA UIC permits regulate the injection of fluids into underground injection wells so that the injection does not endanger underground sources of drinking water. EPA UIC permit conditions are based upon the authorities set forth in regulatory provisions at 40 CFR parts 144 and 146, and address potential impacts to underground sources of drinking water. In accordance with 40 CFR §144.35, issuance of this permit does not convey any property rights of any sort or any exclusive privilege, nor authorize injury to persons or property or invasion of other private rights, or any infringement of other Federal, State or local laws or regulations. Under 40 CFR §144 Subpart D, certain conditions apply to all UIC Permits and may be incorporated either expressly or by reference. CITE 147

Upon the Effective Date when issued, the Permit authorizes the construction and operation of injection wells so that the injection does not endanger underground sources of drinking water. The Permit is issued 10 years from the effective date unless terminated for reasonable cause under 40 CFR §144.40 and can be modified or revoked and reissued under 40 CFR §144.39 or §144.41. Regulations specific to Montana injection wells are found at 40 CFR 147 Subpart BB.

PART I. General Information and Description of Facility

Montana State University-Bozeman, Energy Research Institute
207 Montana Hall
Bozeman, MT 59717-2465

submitted an application for an Underground Injection Control (UIC) Program permit to construct and operate the following proposed injection well:

MT52233-09515
ZERT Class V Well
NE¼ of SW¼ Section 14, Township 2S, Range 5E
Gallatin County

The application, including the required information and data necessary to issue a UIC Permit in accordance with 40 CFR parts 144, 146 and 147, was reviewed and determined by EPA to be complete.

PROJECT DESCRIPTION

Montana State University-Bozeman, Energy Research Institute (MSU-ERI) has applied for a Class V Experimental Technology well to conduct scientific studies using food grade CO_2 injected into a shallow horizontal well. The Zero Emission Research and Technology (ZERT) field project has been developed on the MSU campus in Bozeman, Montana to determine efficacy and detection limits of various near surface CO_2 monitoring techniques as well as study the transport of CO_2. Researchers from 6 national labs, 6 universities, 5 companies, the United States Geological Survey, and the Electrical Power Research Institute have used more than 20 techniques to investigate and monitor CO_2 movement through soil, water, plants and the atmosphere at the site.

The well is located on agricultural land west of the MSU-Bozeman campus in Bozeman, Montana and consists of a stainless steel pipe 320 feet (98 meters) long, situated approximately 5.9 feet (1.8 meters) below ground surface, and slotted to allow CO_2.to flow into the subsurface. MSU-ERI has previously conducted experiments from 2007-2011. A number of papers from these studies have been published including a paper that described the chemical changes in the aquifer as a result of the introduction of the CO_2 into the subsurface (Kharaka, Y.K., et. al. 2010) [1]. The water quality results from the monitoring wells showed that there were no exceedances of drinking water maximum contaminant levels (MCLs). The proposed activity associated with this Class V experimental well will be a continuation of these previous studies. Depending upon the availability of funding, the research and injection may continue each summer for periods of up to one month, for up to 10 additional years.

[1] Kharaka, Y.K., et al., Changes in the chemistry of shallow groundwater related to the 2008 injection of CO_2 at the ZERT field site, Bozeman, Montana. Environ Earth Sci (2010) 60:273–284 DOI 10.1007/s12665-009-0401-1

PART II. Permit Considerations

Hydrogeologic Setting

The ZERT field site is on an alluvial fan (the Bozeman Fan) in the Gallatin Valley. Younger Tertiary deposits consist of conglomerate, sandstone, siltstone, and claystone deposited in fluvial environments. The Tertiary deposits crop out mostly in the uplands of the western and northeastern margins of the valley but underlie the entire valley. The alluvial fan deposits consist of a heterogeneous mix of sediments ranging in size from boulders to clay. The central part of the valley is covered with Quaternary alluvial deposits of the Gallatin and East Gallatin Rivers, as well as some of their tributaries. The Quaternary alluvial deposits are mostly made up of gravel with numerous interbeds of sand, silt, and clay

At the ZERT site, most of the injection well is found in a sandy gravel layer and below the water table during injection. The depth of the water table at the ZERT site varies seasonally but always remains quite close to the ground surface. Variation of about 3.3 feet (1 m) in depth over the year is typical. During the summer months the depth of the water table averages about 4.9 feet (1.5 m) below ground surface at the southwest end of the horizontal well. The groundwater gradient at the site is estimated to be 17 degrees west of north and the groundwater flow is high at ~6.6 feet/day (2 m/day).

PART III. Well Construction

The well casing is 320 feet (98 m) of 4 inch (10.16 cm) diameter Schedule 40, 304L stainless steel pipe. 49 feet (15 m) and 39 feet (12 m) on the southwest and northeast ends, respectively, is solid casing. The remaining central 230 feet (70 m) is slotted with a 20-slot pattern and has an open area of 0.55%. The pipe was installed by horizontal directional drilling. The average depth below ground surface of the pipe is 5.98 feet (1.8 m). The well is partitioned into 6 zones by natural rubber packers. The zones are plumbed such that a mass flow controller system delivers CO_2 to each zone independently. Within a given packer zone ¼" O.D. nylon tubing with 0.025" diameter holes spaced approximately every 5 ft distributes CO_2 along the length of the zone.

Monitoring Device

The CO_2 is split between 6 independently controlled mass flow controllers. Each mass flow controller is plumbed to one of the 6 packed off zones of the horizontal well. CO_2 is delivered to the well at a flow rate of between 0.1 and 0.3 tonne/day and at injection pressures only slightly above atmosphere (0–6 psi). The permittee will be required to monitor injection pressures, flowrates, and volume of CO_2 injected.

PART IV. Area of Review, Corrective Action Plan

Area Of Review (AOR)
Under 40 CFR §146.6, the permit AOR may be a fixed distance of not less than one quarter (1/4) mile. The AOR for this permit is defined to be a quarter mile from the injection well.

According to the data extracted from the Groundwater Information Center database (Montana Bureau of Mines and Geology) one well is located within ¼ mile of the horizontal well. This well is

upgradient, 0.22 miles from the center of the ZERT horizontal well. The water well is only used for livestock. The nearest well used for domestic water is just inside the ¼ mile AOR boundary is northeast of the ZERT well. Groundwater flow is estimated to be 17 degrees west of north.

Additionally, 5 pairs of shallow PVC monitoring wells, 4.9 feet (1.5 m) and 9.8 feet (3 m) deep, surround the ZERT well to facilitate the collection of water samples. Three additional wells, W6 (8.5 ft (2.6 m) deep), W7 and W8 (both 9.8 feet (3 m) deep) were installed to take core samples for mineral characterization. See Appendix B of the Permit.

PART V. Well Operation Requirements

Approved Injection Fluid

MSU-ERI is proposing to inject food grade CO_2 originating from the Alberta and Wyoming natural gas fields into the shallow subsurface in the vapor phase. The CO_2 injected is food grade and is used for providing carbonation in beverages.

Additionally, MSU-ERI may inject perfluorinated tracers (PFT) along with the CO_2 to better facilitate tracking of CO_2. The tracer perfluorocarbons (PFCs) are non-toxic, and have not been demonstrated to have adverse effects on biological systems. The typical ratio of injected CO_2 to tracer PFC is 40,000:1. At this ratio, the green house gas effect for PFT will be orders of magnitude below that of the CO_2 released at the same time, should leakage occur. Worldwide background levels of tracer PFCs have remained at the low parts per quadrillion levels in the atmosphere over several decades since their introduction into environmental, meteorological and geophysical research. This is unlikely to change significantly as a result of their use in geologic sequestration monitoring. For PFC experiments conducted at the ZERT Montana test facility, the total quantities of PFC released have been about 18 milliliters over 6 years of operations.

Tracer PFCs are present in the environment at levels orders or magnitude lower than other PFCs such as perfluorooctane sulfonate (PFOS) that are released into the environment from industrial processes, and the leaching of Teflon coatings. Worldwide atmospheric background concentrations of tracer PFCs are in the low parts per quadrillion levels and the annual atmospheric growth rates are increasing at less than 1 part per quadrillion per year[2]

EPA Region 8 toxicologist has reviewed the MSDS sheets from these PFCs: Perfluoroethylcyclohexane (PECH), Perfluoro(methylcyclohexane) (PMCH), Perfluoro(methylcyclohexane) (PTMCH), Perfluoro-iso-propylcyclohexane (i-PPCH), Perfluorodimethylcyclobutane (PDCB), and has determined that due to the very small quantities and virtually insolubility in water, the PFT will rapidly be transferred to air if the water is used as a source of drinking water. Therefore, any exposure will be insignificant. Only these PFCs may be injected with the CO_2 injectate.

Injection Pressure, Rate and Volume Limitation

CO_2 injection will occur continuously for a period from one week to one month per year. The rates at which CO_2 will be released were chosen to be relevant to developing monitoring strategies for geological carbon storage and thus are quite small. The mass flow controller system delivers CO_2 to the well at injection pressures only slightly above atmosphere (0–6.0 psi). The pressure needs to remain at low rates to ensure the formation surrounding the well was not distorted by the injection.

[2] Watson, T.B., Wilke, R., Dietz, R.N., Heiser, J., Kalb, P., 2007. The Atmospheric Background of Perfluorocarbon Compounds Used as Tracers. *Environ. Sci. Technol.*41(20), 6909-6913.

In the summer of 2008, Kharaka Y.K., et. al. (2010) conducted extensive groundwater sampling to better understand geochemical changes as a result of CO_2 injection. The CO_2 was injected into the shallow subsurface in the vapor phase, with a maximum flow rate 300.0 kg/day and injections up to 6 tonnes over a 30 day period. During this period, the water analysis showed no exceedances of MCLs for the parameters tested.

The maximum allowable injection pressure, rate, and volume have been set based on the operational parameters that were used in the Kharaka Y.K., et. al. (2010). The maximum allowable injection rate is 300.0 kg/day and the maximum allowed volume of CO_2 to be injection shall not exceed 6 tonnes per year. The maximum allowable injection pressure is 10.0 psi, slightly higher than the maximum 5.5 psi used during the experiments to allow for the potential need to blow out silt and dirt that may settle in the slots of the injection well during periods of inactivity.

PART VI. Monitoring, Recordkeeping and Reporting Requirements

Wellhead Monitoring
Instantaneous injection pressure, injection flow rate, cumulative fluid volume injected must be recorded on a weekly basis. The cumulative fluid volume injected for that year and the monthly minimum, average, and maximum injection pressure and injection flow rate are required to be reported as part of the Quarterly Report to the Director. EPA Form 7520-8 may be adapted and used to submit the Quarterly Reports.

Injectate Fluid Sampling Program
The injectate shall meet current drinking water standards. MSU-ERI will inject food grade CO_2 with greater than 99.9 percent by volume of pure carbon dioxide. For each lot that is injected, a copy of the Certificate of Analysis will be provided to EPA with the Quarterly Reports. This Certificate of Analysis is acceptable for the FDA and their beverage food grade CO_2 services requirement. Additionally, the Certificate of Analysis provides a beverage specification standard that the provider meets as a requirement from their buyers. This beverage specification standard is more stringent because their buyers also have taste requirements that need to be met. The CO_2 that will be used at the ZERT site must meet the beverage specification standards on the Certificate of Analysis.

During the experimental studies conducted in the summer of 2008, Kharaka Y.K. et. al. (2010) detected BTEX concentrations in their monitoring wells. Of the BTEX group, benzene was detected as high as 0.8 µg/l, compared to the MCL value of 5 µg/L, the other three were found at concentrations two or more orders or magnitude below MCL. It was determined that the BTEX originated in the CO_2 source and not in the local subsurface geology. BTEX will be required to be analyzed from the monitoring well samples.

Monitoring Well Sampling Program
Carbon dioxide, in the presence of water, can create an acidic environment, which in turn can change the subsurface chemistry and release of minerals that may contribute to the exceedance of drinking water MCLs. The effect of CO_2 injection on groundwater at the ZERT site has been monitored by the United States Geological Service (USGS) and are detailed in published journal articles. A brief summary of the Kharaka Y.K., et. al. (2010) results are provided below.

During the summer of 2008 injection, the injection rate for this experiment was 300 kg/day for the entire well. Samples were collected from the 10 shallow PVC monitoring wells (4.9 feet (1.5 m) and 9.8 feet (3 m) deep) screened at the bottom 2.5 feet (0.76 m), 3.3 - 9.8 feet (1–3 m) from the injection well. Most of the water samples for this study were obtained from the shallower groundwater wells (4.9 feet (1.5 m) deep), especially after it became clear that the water from the deeper wells was not significantly impacted by the injected CO_2.

Samples were collected before, during, and after CO_2 injection. USGS analyzed on-site for pH, Eh, conductivity, alkalinity, dissolved oxygen (DO), and temperature. Laboratory analyses for cations and metals were carried out at USGS with focus on initial concentrations of hazardous and other trace elements. Benzene, toluene, ethyl-benzene, m-, p- and o-xylene (BTEX) were also analyzed for the analysis of low levels of volatile organic compounds (VOCs) in aqueous samples and water miscible liquid samples. The USGS measured EC, pH, T, HCO_3, Na, K, Mg, Ca, Sr, Ba, Mn, Fe, F, Cl, BR, NO_3, PO_4, SiO_2, TDS, Al, As, B, Cd, Co, Cr, Cu, Li, Mo, Pb, Se, U, Zn.

The chemical data obtained for samples from shallow and deep wells prior to CO_2 injection show that the groundwater in the area is a Ca–Mg–Na–HCO_3 type water, with a fresh water salinity of about 600 mg/l TDS. The groundwater has a pH of approximately 7, and HCO_3 is the dominant anion, but the concentrations of Cl and SO_4 are relatively low. The concentrations of Fe, Mn, Zn, Pb, and other trace metals are expectedly low, at ppb levels.

During CO_2 injection, TDS levels increased to values of up to 1500 mg/L, mostly as a result of CO_2 dissolution in water (bicarbonate concentrations increased up to about 1200 mg/L) and a significant increase in calcium (~up to 240 mg/L) presumably from the dissolution of calcite. The pH decreased to values between 5.5 and 6, and the concentration of alkali earth metals increased by a factor of 2–5. The concentrations of most trace metals showed a smaller but systematic increase, although none exceeded the MCLs.

Baseline data were taken for a number of analytes found in Appendix C of the Permit prior to the experiment conducted in 2008 by Kharaka Y.K., et. al. (2010). As a condition of the permit, prior to initial injection into the ZERT Class V well, the 2B monitoring well must be sampled and analyzed for the analytes where baseline data has not been previously provided. These analytes are denoted in Appendix C of the Permit.

MSU-ERI will be required to sample once monthly from the monitoring wells and analyzed for the list of analytes that are found in Appendix C of the Permit. The sampling event will occur during the 3rd week of each month. If injection did not occur in that month, sampling is not required. Samples shall be collected by the permittee or his/her representative from the 2B and 4B monitoring well. Monitoring wells 2B and 4B are found at a depth of 4.9 feet (1.5 m) and located approximately 3.3 and 9.8 feet (1 and 3 meter), respectively, away from the ZERT well. See Appendix B of the Permit for the locations of these monitoring wells. Based on the previous study, the deeper wells (9.8 ft (3 m) depth) were not significantly impacted and therefore shallower wells were selected as monitoring wells. These two monitoring wells are the wells closest and furthest from the injection well. It may be possible in a particularly dry summer that the water level may not rise to the level of the 2B and 4B wells. If this should occur, only then will the deeper 2A and 4A wells be sampled in lieu of the 2B or 4B monitoring wells.

The analytes in Appendix C of the Permit were selected based on their potential to exist in the subsurface and if an MCL exists. Additionally, other analytes that do not have MCLs are also required to be analyzed, but do not have permit limits, to provide an indication of the general water quality and serve as indicators of significant change in the subsurface geochemisty. As previously mentioned, BTEX will also be required due to its presence in the CO_2 injectate. Given the short duration of the experiment and low volume, EPA has included the MCLs, which are enforceable standards and is not proposing to include additional analytes with health advisory limits for this permit. In the future, MSU-ERI may request for a reduction in the number of analytes sampled and/or frequency, if it can be demonstrated that there is no endangerment to USDWs. Any such request will be processed in accordance with permit modification requirements at 40 CFR section §144.39.
All samples and measurements taken for monitoring must be representative of the monitored activity. If at any time, the analysis of the monitoring well data shows an exceedance of the Permit

Limits found in Appendix C of the Permit, EPA must be notified within twenty-four (24) hours. A follow-up sample must be collected within 24 hours and submitted for analysis at the earliest opportunity, i.e. the first business day that the testing laboratory is open. If the second sample confirms the exceedance of Permit Limits, injection must cease immediately and corrective action must be taken to comply with the requirements in this permit, and EPA must be notified within twenty-four (24) hours after receiving analytical results. EPA will subsequently notify the Permittee if injection activities may resume.

Modeling
Computer modeling studies have been performed by Lawrence Berkeley National Laboratory (LBNL) to predict pressures and migration patterns of CO_2 in the ground.

Modeling results that predict some spreading on top of the water table with little CO_2 dissolved in the groundwater system[3]. Additional model simulations[4,5] for the horizontal well showed that CO_2 injection just below the water table creates an effective gas-flow pathway through the saturated zone up to the unsaturated zone. Once in the unsaturated zone, CO_2 spreads out laterally within the cobble layer, where liquid saturation is relatively low. CO_2 also migrates upward into the soil layer through the capillary barrier and seeps out at the ground surface. The simulations predicted a breakthrough time of approximately two days for the 100kg d^{-1} injection rate, which also produced a flux within the range desired for testing detection and monitoring approaches.

Transport of CO_2 through the soil, water, plants and atmosphere has been followed with many near surface detection techniques. Soil CO_2 surface flux measurements during injection have been made several times by LBNL. Their calculations of mass balance show that almost all of the CO_2 injected into the subsurface comes back out of the ground. Over the past 5 years, over 20 different monitoring techniques have been deployed at the field site.

PART VII. Plugging and Abandonment Requirements

Plugging and Abandonment Plan
Prior to abandonment, the injection well shall be plugged in a manner which cannot allow the movement of a fluid containing any contaminant into any USDW, if the presence of that contaminant may cause a violation of the primary drinking water standards under 40 CFR part 141, other health-based standards, or may otherwise adversely affect the health of persons, and in accordance with any applicable Federal, State or local law or regulation. The approved Plugging and Abandonment Plan is found in Appendix D of the Permit.

Consistent with the request from MSU Farm (the landowner), the portions of the ZERT Class V well pipe that is 24 inches or shallower from surface, will be removed. The endpoints of the remaining length of pipe in the subsurface will be documented with survey grade GPS and provided to MSU Facilities Services to be kept on permanent record. The casings of all PVC water monitoring wells will be pulled up out of the ground and the holes filled in with dirt.

Within sixty (60) days after plugging the owner or operator shall submit Plugging Record (EPA Form 7520-14) to the Director. The Plugging Record must be certified as accurate and complete by the person responsible for the plugging operation.

[3] Lewicki, J. L., C. M. Oldenburg, et al. (2007), "Surface CO_2 leakage during two shallow subsurface CO_2 releases." Geophysical Research Letters 34(24):L24402.
[4] Oldenburg, C.M., et al., *Transport of Porous Media* (2010)
[5] Oldenburg, C.M., et al., *Environmental Earth Sciences* (2010)