INTRODUCTION

This file is intended to summarize FutureGen's testing and monitoring strategy to comply with the Class VI requirements under:
- 40 CFR 146.90(d) for geochemical monitoring above the confining zone; and
- 40 CFR 146.90(g) for plume and pressure front monitoring.

The information presented in the following tabs for these monitoring strategies is compiled from the permit application revision dated May 2013 and subsequent communications in November and December 2013 and in January 2014. Copies of submitted information are also presented in the "Submissions" tab for reference purposes.

Note: This version of the table does not include questions/recommendations for the permit applicant. These are summarized in the text of the Testing and Monitoring Plan and PISC and Site Closure Plan files.

GROUND WATER/GEOCHEMICAL MONITORING ABOVE THE CONFINING ZONE - Injection Phase

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - Baseline	Frequency - DOE Active Injection Startup (Years 1-3)	Frequency - DOE Active Injection (Years 4-5)	Frequency - Commercial Injection (Years 6-20)
Ground Water Monitoring Above Confining Zone [40 CFR 146.90(d)]	Surficial aquifers	Fluid sampling (incl. pressure, temperature, geochemical parameters)	Local landowner wells	10 point locations, depths 17-49 ft	3 events minimum	None (unless conditions warrant)	None (unless conditions warrant)	None (unless conditions warrant)
			Project-installed well	1 point location, depth 23 ft				
	St. Peter	Fluid sampling (incl. pressure, temperature, geochemical parameters)	Lowermost USDW monitoring well	1 point location, approx. depth 2000 ft	3 events minimum	Quarterly	Semi-annually	Annually
	Ironton	Fluid sampling (incl. pressure, temperature, geochemical parameters)	ACZ early-detection monitoring wells	2 point locations, approx. depth 3470 ft	3 events minimum	Quarterly	Semi-annually	Annually

GROUND WATER/GEOCHEMICAL MONITORING ABOVE THE CONFINING ZONE - Post-Injection Phase

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - PISC
Ground Water Monitoring Above Confining Zone [40 CFR 146.90(d)]	Surficial aquifers	Fluid sampling (incl. pressure, temperature, geochemical parameters)	Local landowner wells	10 point locations, depths 17-49 ft	Every 5 years
			Project-installed well	1 point location, depth 23 ft	
	St. Peter	Fluid sampling (incl. pressure, temperature, geochemical parameters)	Lowermost USDW monitoring well	1 point location, depth 2000 ft	Every 5 years
	Ironton	Fluid sampling (incl. pressure, temperature, geochemical parameters)	ACZ early-detection monitoring wells	2 point locations, depth 3470 ft	Every 5 years

PLUME MONITORING - Injection Phase

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - Baseline	Frequency - DOE Active Injection Startup (Years 1-3)	Frequency - DOE Active Injection (Years 4-5)	Frequency - Commercial Injection (Years 6-20)
Plume Monitoring [40 CFR 146.90(g)] **DIRECT MONITORING**	Mt. Simon	Fluid sampling	Single-level montoring wells	2 point locations, approx. depth 4150 ft	3 events	Quarterly	Semi-annually	Annually
Plume Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon	VSP survey	ACZ and/or RAT wells	Anticipated areal extent/ resolution not specified	Once	None	None	None
		Pulsed neutron capture logging	RAT wells	2 point locations, logging across reservoir and caprock	3 events	Quarterly	Quarterly	Annually
		Integrated deformation monitoring	Microseismic monitoring stations	5 monitoring stations (surface measurements)	1 year min.	Continuous	Continuous	Continuous
		Time-lapse gravity	Gravity monitoring stations	46 monitoring stations (surface measurements)	3 events	Annual	Annual	Annual
		Microseismic monitoring	Microseismic monitoring stations and ACZ wells	5 monitoring stations plus downhole arrays at ACZ wells; anticipated areal extent/ resolution not specified	1 year min.	Continuous	Continuous	Continuous

PLUME MONITORING - Post-Injection Phase

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - PISC
Plume Monitoring [40 CFR 146.90(g)] **DIRECT MONITORING**	Mt. Simon	Fluid sampling	Single-level montoring wells	2 point locations, approx. depth 4150 ft	Every 5 years
Plume Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon	Pulsed neutron capture logging or determination of reservoir CO2 saturation	RAT wells	2 point locations, logging across reservoir and caprock	None
		Integrated deformation monitoring	Microseismic monitoring stations	5 monitoring stations; Anticipated areal extent/ resolution not specified	Continuous
		Microseismic monitoring	Microseismic monitoring stations and ACZ wells	5 monitoring stations plus downhole arrays at ACZ wells; anticipated areal extent/ resolution not specified	Continuous

PRESSURE-FRONT MONITORING - Injection Phase

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - Baseline	Frequency - DOE Active Injection Startup (Years 1-3)	Frequency - DOE Active Injection (Years 4-5)	Frequency - Commercial Injection (Years 6-20)
Pressure-Front Monitoring [40 CFR 146.90(g)] **DIRECT MONITORING**	Mt. Simon	Pressure and temperature monitoring	Single-level montoring wells	2 point locations, approx. depth 4150 ft	Continuous	Continuous	Continuous	Continuous
Pressure-Front Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon	Integrated deformation monitoring	Microseismic monitoring stations	5 monitoring stations (surface measurements)	1 year minimum	Continuous	Continuous	Continuous

PRESSURE-FRONT MONITORING - Post-Injection Phase

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - PISC
Pressure-Front Monitoring [40 CFR 146.90(g)] **DIRECT MONITORING**	Mt. Simon	Pressure and temperature monitoring	Single-level montoring wells	2 point locations, approx. depth 4150 ft	Continuous
Pressure-Front Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon	Integrated deformation monitoring	Microseismic monitoring stations	5 monitoring stations (surface measurements)	Continuous

(Scroll down for more recent submissions.)

Table 5.3 from FutureGen's May 2013 Permit Application Revision:

Table 5.3. Monitoring Frequencies by Method and Project Phase for both Planned and Considered Monitoring Activities

5.14

Monitoring Category	Monitoring Method	Baseline 3 yr	DOE Active Injection (startup) ~3 yr	DOE Active Injection ~2 yr	Commercial Injection ~15 yr	Post Injection 50 yr
Monitoring Plan Update	NA	As required	As Required	As Required	As Required	NA
CO_2 Injection Stream Monitoring	Grab sampling and analysis	Up to 6 events during commissioning	Quarterly	Quarterly	Quarterly	NA
CO_2 Injection Process Monitoring	Continuous monitoring of injection process (injection rate, pressure, and temperature; annulus pressure and volume)	NA	Continuous	Continuous	Continuous	NA
Well Mechanical Integrity Testing	Oxygen activation, radioactive tracer, and/or temperature logging	Once after well completion	Annual	Annual	Annual	NA (wells plugged)
	Injection well pressure fall-off testing	NA	Every 5 yr	Every 5 yr	Every 5 yr	NA
Corrosion Monitoring of Well Materials	Corrosion coupon monitoring	NA	Quarterly	Quarterly	Quarterly	NA
	Wireline monitoring of casing and/or tubing corrosion and cement	Once after well completion	During well workovers	During well workovers	During well workovers	NA
Groundwater Quality and Geochemistry Monitoring	Early leak-detection monitoring in above confinement zone monitoring wells	3 events	Quarterly	Semi-Annual	Annual	Every 5 yr
	USDW aquifer monitoring (continuous parameter monitoring, aqueous sample collection as indicated)	1 yr continuous monitoring, 3 sampling events	Quarterly	Annual	Annual	Every 5 yr
Injection Zone Monitoring	Single-level monitoring wells	3 events	Annual	Annual	Every 2 yr	Every 5 yr
	Multi-level monitoring wells	3 events	Quarterly	Semi-Annual	Annual	Every 5 yr
Indirect Geophysical Monitoring Techniques (surface)	Integrated deformation monitoring	2 yr min	Continuous	Continuous	Continuous	Continuous
	3D multi-component surface seismic monitoring	Once	NA	Once	Every 5 yr	NA
	Magnetotelluric (MT) sounding	3 events	Once	Once	Every 5 yr	Every 5 yr
	Time-lapse gravity	Once	Semi-Annual	Semi-Annual	Semi-Annual	Every 5 yr

Table 5.3. (contd)

5.15

Monitoring Category	Monitoring Method	Baseline 3 yr	DOE Active Injection (startup) ~3 yr	DOE Active Injection ~2 yr	Commercial Injection ~15 yr	Post Injection 50 yr
Indirect Geophysical Monitoring Techniques (downhole)	Vertical seismic profile(ing) (VSP)	Once	Once	Once	Every 5 yr	Every 10 yr
	Cross-well seismic imaging	Once	Once	Once	Every 5 yr	Every 10 yr
	Passive seismic monitoring (microseismicity)	1 yr min	Continuous	Continuous	Continuous	Continuous
	ERT	1 yr min	Continuous	Continuous	Continuous	Continuous
	Real-time distributed temperature sensing (DTS)	1 yr min	Continuous	Continuous	Continuous	Continuous
Indirect Geophysical Monitoring Techniques (wireline logging)	Pulsed-neutron capture, sonic (acoustic) logging, and gamma-ray logging	Once after well completion	Annual	Annual	Annual	NA
Surficial Aquifer Monitoring	Continuous parameter monitoring in 1 project-installed well, aqueous sample collection as indicated	1 yr continuous monitoring, 3 sampling events	Quarterly	Annual	Annual	Every 5 yr
Soil-Gas Monitoring	Samples collected for CO_2, other noncondensable gases and tracers	4 events	Quarterly	Annual	Annual to every 5 yr	Every 5 yr
Atmospheric Monitoring	Continuous CO_2 monitoring, tracer sampling and analysis	1-yr baseline monitoring	Quarterly	Semi-Annual	Annual to every 5 yr	Every 5 yr
Ecological Monitoring	Eco survey for baseline, continuous surface-water monitoring, remote sensing of vegetation conditions as indicated	Eco survey once, 1 yr baseline monitoring,	Annual	Annual	Annual to every 5 yr	Every 5 yr

Update on indirect monitoring methods from November 2013 communication:

FutureGen Response

The screening of the indirect monitoring approaches was conducted as part of the Front End Engineering Design process. The selected indirect technologies will include the following:

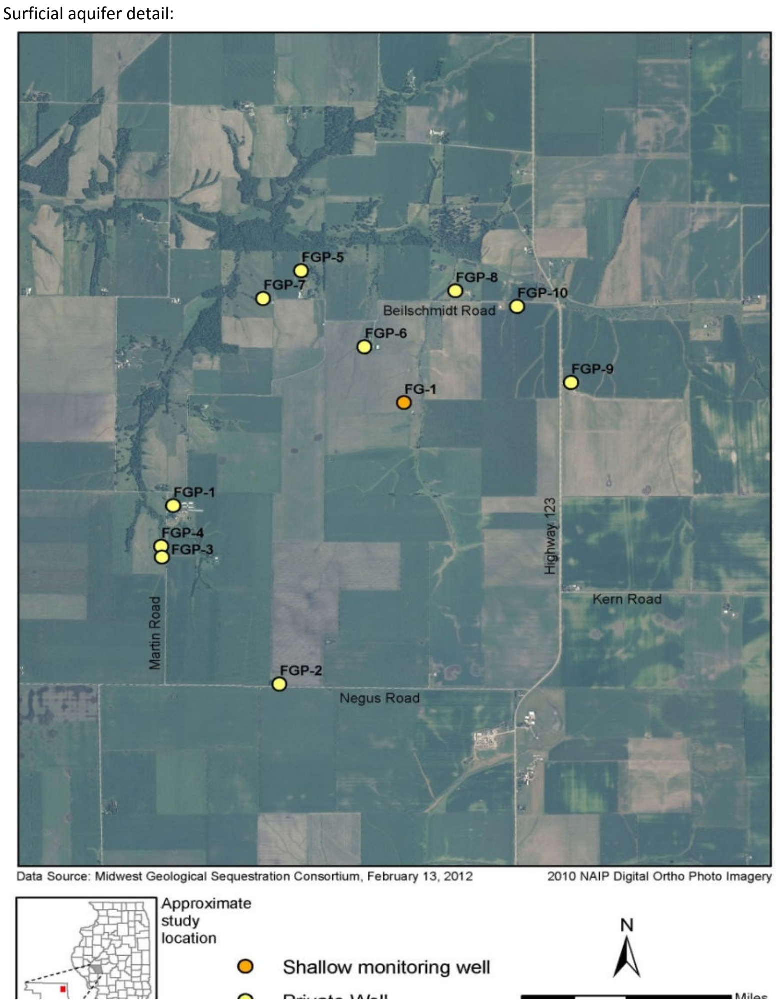
- pulsed neutron capture logging or determination of reservoir CO_2 saturation
- integrated deformation monitoring
- time-lapse gravity
- microseismic monitoring.

In addition, a baseline VSP survey in at least one of the "Above Caprock Zone" (ACZ) wells will be conducted after construction of the monitoring well network and if the EPA provides approval of the UIC permit application.

The monitoring well locations have been identified; however land owner agreements still need to be finalized. We anticipate that we will have the final agreements before the end of January, 2014 and can map the locations at that time.

Materials submitted in January 2014:

Surficial aquifer detail:



Private water supply wells:

Well ID	Status	Well Depth (ft)	Stick Up (ft)	Adjusted Depth (ft)	Land Surface Elevation (ft AMSL)	Depth to Water (ft)	Water Depth in well (ft)	Water Elevation (ft AMSL)	Diameter (ft)	Construction	Age (years)
FGP-1	domestic	30.9	1.00	29.90	630	19.02	18.02	612	5.0	brick lined	~100
FGP-2	domestic	--	--	--	641	--	--	--	Unknown	unknown	unknown
FGP-3	domestic	40.0	0.90	30.10	630	21.37	11.47	618	5.0	unknown	~100
FGP-4	inactive	28.5	0.50	28.00	627	9.40	8.90	618	3.0	brick lined	unknown
FGP-5	livestock	35.1	1.60	33.50	607	10.12	8.52	598	3.0	unknown	~60
FGP-6	inactive	34.5	0.30	34.20	620	13.04	12.74	607	3.0	cast concrete	unknown
FGP-7	inactive	49.0	2.20	46.80	614	13.39	11.19	603	0.7	steel	unknown
FGP-8	livestock	17.45	1.30	16.15	614	6.34	5.04	609	4.0	brick lined	unknown
FGP-9	inactive	22.3	1.60	20.70	630	16.34	14.74	615	5.0	brick lined	~100
FGP-10	inactive	37.1	0.40	36.70	614	15.80	15.40	599	4.0	cast concrete	unknown
FG-1	NA	23.0	2.05	20.95	635	10.16	8.11	627	0.17	PVC	new

Monitoring well location detail:

Location of Monitoring Wells

The monitoring well network (Figure 1) has been updated in accordance with discussion in the UIC application supporting documentation.

> Chapter 5 of the UIC Supporting Documentation, Section 5.1, p. 5.2: The monitoring network design was developed based on the current conceptual understanding of the Morgan County CO_2 storage site and was used to guide development of the testing and monitoring approaches described in Section 5.2. The technical approaches described in Section 5.2 should be considered working versions that over time will be updated and modified as required in response to changes in the site conceptual model and/or operational parameters.

The objective of the monitoring program is to select and implement a suite of monitoring technologies that are both technically robust and cost-effective and provide an effective means of 1) evaluating CO_2 mass balance and 2) detecting any unforeseen containment loss.

The application proposed two single-level in-reservoir (SLR) wells, one above confining zone (ACZ) well, one underground source of drinking water (USDW) well, and a one multi-level in-reservoir (MLR) well within the injection reservoir for a total of five monitoring wells.

As part of the project's design optimization, the monitoring well network design has been revised (Figure 2) to increase its effectiveness, simplify its engineering design, and hopefully eliminate any permitting challenges that might have been associated with the MLR. The revisions include eliminating the MLR well in favor of adding two fully cased reservoir access tube (RAT) wells. The revised design includes a total of seven monitoring wells summarized in Table 1 and as follows:

- **Two ACZ wells**

  These wells will be used to monitor immediately above the Eau Claire caprock in the Ironton Sandstone. **Monitored Parameters: pressure, temperature, and hydrogeochemical indicators of CO_2.**

- **Two SLR wells** (one of which is a reconfiguration of the previously drilled stratigraphic well)

  These wells will be used to monitor within the injection zone beyond the east and west ends of the horizontal CO_2-injection laterals. **Monitored Parameters: pressure, temperature, and hydrogeochemical indicators of CO_2.**

- **Two RAT wells**

  These are fully cased wells, which allow access for monitoring instrumentation in the reservoir via pulsed-neutron logging equipment. The wells will not be perforated so as to avoid two-phase flow near the borehole, which can distort the CO_2 saturation measurements. **Monitored Parameters: quantification of CO_2 saturation across the reservoir and caprock.**

- **One USDW well**

  This well will be used to monitor the lowermost USDW (St. Peter Sandstone). **Monitored Parameters: pressure, temperature, and hydrogeochemical indicators of CO_2.**

Note that the specific geographic coordinates of each well remain "proposed" because the project is in the process of finalizing legal agreements with surface landowners. Also, we believe this proposed network should substantially exceed the intent of the regulations. Thus, we respectfully ask that only those wells required to meet the minimum permit requirements be included in the permit as prerequisite permit conditions.

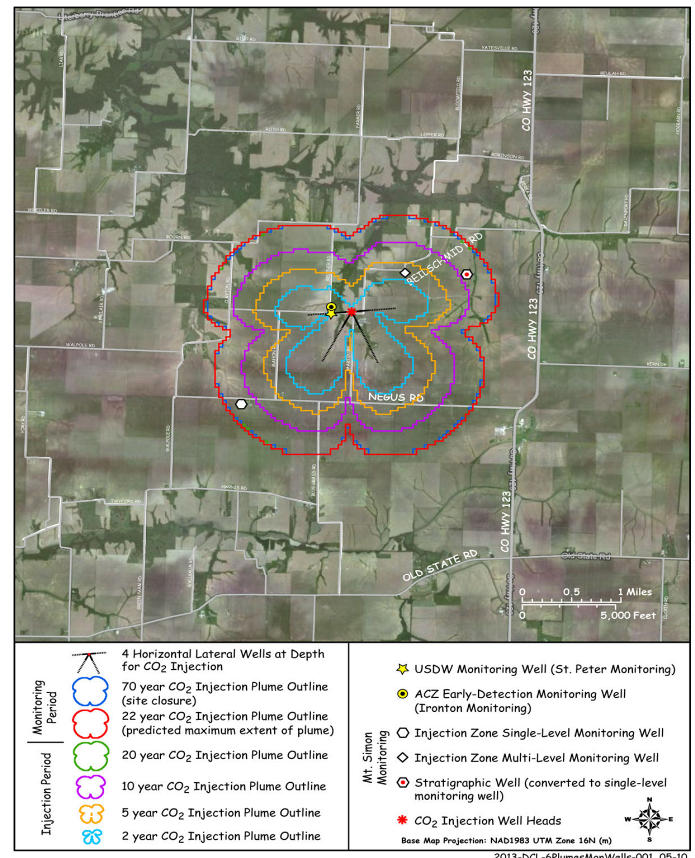
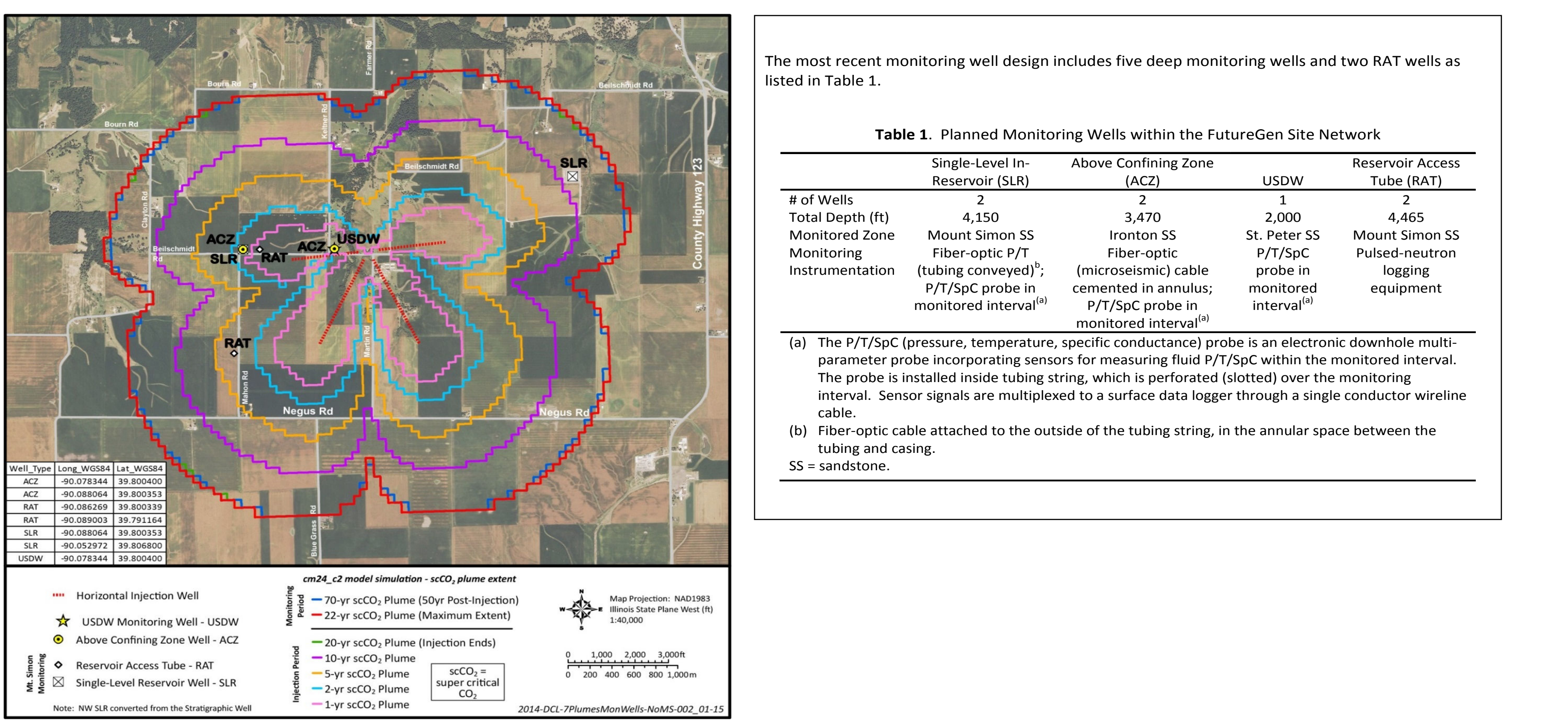


Figure 1. **Monitoring Well Network as Presented in Testing and Monitoring Plan (Chapter 5.0) of the UIC Permit Supporting Documentation as Submitted in May 2013**

Figure 2. Updated and revised plan for monitoring wells:



The most recent monitoring well design includes five deep monitoring wells and two RAT wells as listed in Table 1.

Table 1. Planned Monitoring Wells within the FutureGen Site Network

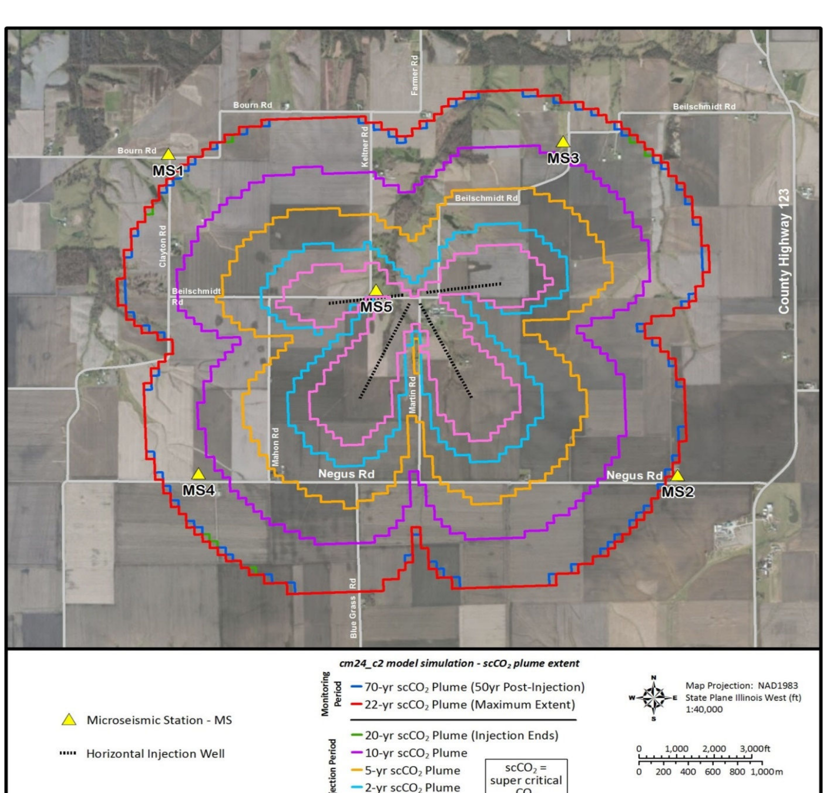
	Single-Level In-Reservoir (SLR)	Above Confining Zone (ACZ)	USDW	Reservoir Access Tube (RAT)
# of Wells	2	2	1	2
Total Depth (ft)	4,150	3,470	2,000	4,465
Monitored Zone	Mount Simon SS	Ironton SS	St. Peter SS	Mount Simon SS
Monitoring Instrumentation	Fiber-optic P/T (tubing conveyed)[b]; P/T/SpC probe in monitored interval[(a)]	Fiber-optic (microseismic) cable cemented in annulus; P/T/SpC probe in monitored interval[(a)]	P/T/SpC probe in monitored interval[(a)]	Pulsed-neutron logging equipment

(a) The P/T/SpC (pressure, temperature, specific conductance) probe is an electronic downhole multi-parameter probe incorporating sensors for measuring fluid P/T/SpC within the monitored interval. The probe is installed inside tubing string, which is perforated (slotted) over the monitoring interval. Sensor signals are multiplexed to a surface data logger through a single conductor wireline cable.

(b) Fiber-optic cable attached to the outside of the tubing string, in the annular space between the tubing and casing.

SS = sandstone.

Collocated Microseismic and Integrated Surface Deformation Monitoring Stations:



Time Lapse Gravity:

Objective. Observe changes in density distribution in the subsurface, caused by the migration of fluids; estimate the areal extent of the CO_2 plume.

Limitations and Difficulties. Sensitivity is lost with depth; there may be site-specific limitations. The solution is non-unique and is most useful when combined with other methods such as integrated surface deformation and seismic. Few implementation difficulties; requires placement of permanent station monuments and repeat accessibility.

Use at Other Sites. This technology has been successfully applied to a variety of subsurface injection studies, including carbon sequestration at Sleipner (Arts et al. 2008); aquifer recharge studies in Utah and elsewhere (Chapman et al. 2008; Davis and Batzle 2008); and to hydrocarbon waterflood surveillance in Alaska (Ferguson et al. 2007).

Analysis. Gravity changes at the surface are expected to be small but analysis of long-term trends may allow for tracking of the CO_2 plume. The cost of implementing this technology is the lowest of all methods considered and can be combined with Differential Global Positioning System (DGPS) surveys conducted as part of the integrated surface deformation monitoring to further reduce costs.

Conclusions. Gravity anomalies associated with CO_2 injection are expected to be quite small, but by averaging many measurements, meaningful signal may be observed. In addition, information obtained from annual time-lapse gravity surveys will be used to help guide the adaptive monitoring strategy. This method requires no permanent infrastructure to implement. A map of the proposed gravity stations is provided in Figure 1.

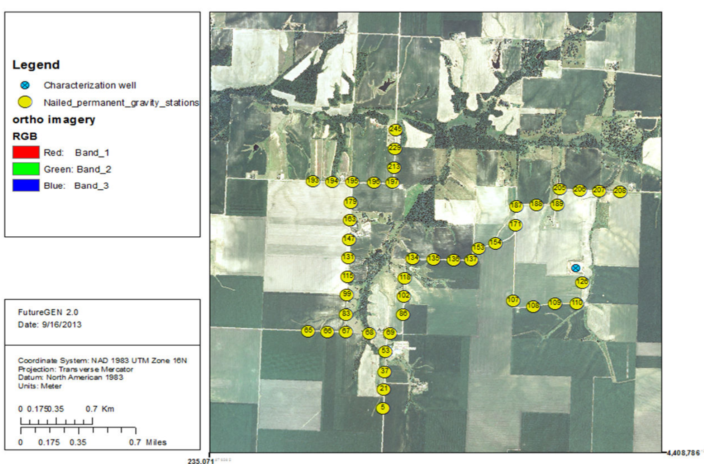


Figure.1. Location of Permanent Gravity and Supplemental DGPS Stations