Progress report for WY-CUSP: Characterization of the premier storage reservoirs and geological CO_2 storage site in Wyoming

Submitted by:

Ronald C. Surdam, *Director*
Shanna Dahl, *Deputy Director*

University of Wyoming Carbon Management Institute,
a part of the School of Energy Resources

October 30, 2012

Carbon Management
Institute

Executive summary

Reducing uncertainty in evaluations of geological CO_2 storage site scenarios requires a robust database that allows an accurate reconstruction of the targeted storage rock/fluid volume, especially with respect to spatial heterogeneity. Previous numerical simulations of the Rock Springs Uplift site (southwest Wyoming, USA) relied on a generalized regional database to populate a homogenous rock/fluid volume based on average reservoir properties. The results from this approach yielded general insights into injection/storage characteristics but lacked specificity, resulting in performance assessments plagued by substantial uncertainty. To move from idealistic, highly generalized assessments to realistic, low-risk assessments of the Rock Springs Uplift, it was necessary to acquire high-resolution data specific to the storage site of interest (carbonate and sandstone reservoirs, and confining layers in an 8 km × 8 km area). The foundation of the new database is a 4,000-meter-deep stratigraphic test well, an 8 km × 8 km 3-D seismic survey, 290 meters of high-quality core, a specialized log suite, fluid samples, and a diverse set of analytical laboratory measurements. These data made it possible to correlate seismic attributes with observations from log suites, a VSP survey, core, fluid samples, and laboratory analyses, including continuous permeability scans. From the correlation of geological characteristics with seismic data, 3-D spatial distribution volumes of reservoir and confining layer properties were constructed that represent geological heterogeneity at the targeted CO_2 storage site. Consequently, the latest numerical simulations and performance assessments are characterized by substantially lower geological uncertainties.

The new CO_2 plume migration simulations – for a set of defined CO_2 injection rates and volumes – occupy larger rock/fluid volumes and display pronounced marginal irregularities when compared to early simulations derived from homogenous reservoir parameter volumes. The spatial distributions of the injected CO_2 plumes in previous simulations are conical with few marginal irregularities, whereas in the new simulations, the CO_2 plumes occupy a larger up-dip volume and display pronounced marginal irregularities. These irregularities denote zones of higher porosity and permeability, such as collapsed breccias associated with karst zones and/or dolomitized grainstone zones in the Madison Limestone.

Using the new numerical simulations which include heterogeneous rock/fluid parameter distributions, it is apparent that in all injection/storage scenarios of > 1 Mt/year CO_2, substantial displaced fluid production/treatment is essential to manage pressure and maintain the integrity of confining layers. The total dissolved solids concentrations of the formation fluids retrieved from the Madison Limestone range from 80,000 to 90,000 ppm, and will necessitate customized water treatment strategies and facilities at the surface. The new data and upgraded evaluations demonstrate that the Rock Springs Uplift in southwestern Wyoming remains an outstanding large-scale geological CO_2 storage site, and provides a realistic basis for designing commercial CO_2 injection/storage operations on the Uplift.

The 2010 U.S. Environmental Protection Agency Greenhouse Gas Reporting Program reports that in the Greater Green River Basin of southwest Wyoming, the CO_2 emissions from stationary sources (sources that emit more than 25,000 tons of CO_2 per year) total 29+ million tons annually, or approximately 50 percent of Wyoming's annual CO_2 emissions. These CO_2 sources include coal-fired power plants, gas and trona processing plants, pipeline compression stations, chemical production facilities, and gas-field complexes, among others. The Rock Springs Uplift in the center of the Greater Green River Basin is ideally located to serve as a large-scale commercial geological CO_2 storage facility for half of all of Wyoming's industrial CO_2 emissions. The new numerical simulations suggest that the Madison Limestone has the ability to permanently store the annual CO_2 emissions from stationary sources in the Greater Green River Basin for 130 years (i.e., a total of 3.8 billion tons). The overlying Paleozoic Weber Sandstone on the Rock Springs Uplift has additional commercial-scale CO_2 storage capacity.

The Rock Springs Uplift has the attributes to serve as a regional CO_2 storage site, and importantly, this site could be used as a storage/surge tank to supply CO_2 to EOR projects throughout Wyoming.

Progress report

WY-CUSP site characterization

The ultimate goal of the Wyoming Carbon Underground Storage Project (WY-CUSP) is to demonstrate that successful commercial-scale CO_2 storage can be achieved in Wyoming. WY-CUSP focuses primarily on site characterization of Wyoming's most promising CO_2 and natural gas storage reservoirs (the Pennsylvanian Weber/Tensleep Sandstone and Mississippian Madison Limestone) and premier CO_2 storage site (Rock Springs Uplift).

The characterization work is creating an expanded and more robust database for carbon storage on the Rock Springs Uplift (i.e., 4-way closure; 2,200 mi^2 area; 10,000 feet of structural closure; multiple stacked confining layers, some of which trap helium; and a 1,000-foot-thick section of high-potential CO_2 storage reservoirs at depths and pressures where CO_2 will be supercritical; 8,000 feet of vertical separation from overlying fresh water aquifers). Results from the application of both the FutureGen and USGS diagnostic protocols for evaluating CO_2 storage capacity suggest that the Weber Sandstone and Madison Limestone on the Rock Springs Uplift could store approximately 26 billion tons of CO_2.

Led by the University of Wyoming Carbon Management Institute (CMI) in the School of Energy Resources, WY-CUSP is supported by the US Department of Energy ($9,975,000), the State of Wyoming ($6,977,572), and industry matching funds. All available surface data and most of the available subsurface data pertaining to the storage reservoirs, confining layers, and structural setting have been collected. On the Rock Springs Uplift (RSU), only 19 wells penetrate the targeted Paleozoic stratigraphic storage interval in a 2,000-square-mile area.

Geological uncertainty reduction via a more robust database

Geological uncertainty related to the RSU site has been significantly reduced by the acquisition of an 8 km by 8 km (5 mile by 5 mile) seismic survey surrounding the targeted RSU storage site. In addition, an approximately 4,000-meter-deep (12,810 feet) stratigraphic test well was drilled in order to acquire a more robust database for the area covered by the 3-D seismic survey described above. The seismic survey was conventionally processed and later reprocessed to increase the signal/noise ratio, thereby enhancing attribute characteristics.

Two hundred and ninety meters of high-quality core, a specialized log suite, fluid samples, and a diverse set of analytical laboratory measurements and petrographic observations were retrieved from the stratigraphic test well. As a result, velocity-porosity relations established from log data for different rock types have allowed us to use seismically-derived interval velocities for porosity estimates along targeted stratigraphic intervals (**Figure 1**). From these relations, 3-D spatial distribution volumes of reservoir and confining layer properties (property models) were constructed that yield an improved understanding of geological heterogeneity at the targeted CO_2 storage site.

New CO_2 injection/storage performance assessments

The new CO_2 plume migration simulations – for a set of CO_2 injection rates and volumes – occupy larger rock/fluid volumes and display marginal irregularities when compared to early simulations derived from homogenous reservoir parameter volumes. For example, in the Madison Limestone, the spatial distributions of the injected CO_2 plumes in previous simulations are conical with few marginal irregularities, whereas in the new simulations, the CO_2 plumes occupy a substantially larger up-dip volume and display more marginal irregularities (**Figure 2**). These irregularities denote zones of higher porosity and permeability, such as collapsed breccias associated with karst zones and/or dolomitized zones in the Madison Limestone.

Using the new numerical simulations including heterogeneous rock/fluid parameter distributions, all injection/storage scenarios of > 1 Mt/year CO_2 require substantial displaced fluid production/treatment to manage pressure and maintain the integrity of confining layers. The total dissolved solids concentrations of the formation fluids retrieved from the Madison Limestone range from 80,000 to 90,000 ppm, and will necessitate customized water treatment strategies and facilities at the surface. When compared with the initial CO_2 capacity evaluations, the new and much-improved performance assessments of both the

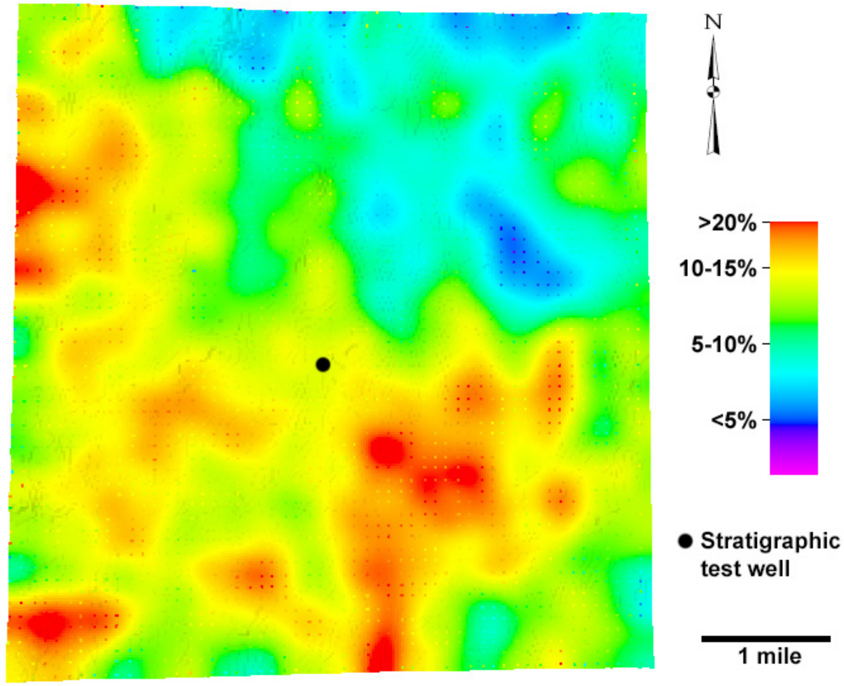

Figure 1. Surface from a porosity volume for the Madison Limestone (this slice represents porosity distribution of the upper portion of the Middle Madison Limestone). CMI scientists constructed the porosity volume by correlating 3-D seismic interval velocities with well log porosities to evaluate petrophysical heterogeneity. The black dot represents the location of the RSU#1 stratigraphic test well.

Madison Limestone and Weber Sandstone reduce the estimated CO_2 storage capacity of the RSU by 50%. The new data and upgraded evaluations demonstrate that the Rock Springs Uplift in southwestern Wyoming remains an outstanding large-scale geological CO_2 storage site, and provides a realistic basis for designing commercial CO_2 injection/storage operations on the Uplift. Without pressure management, even at relatively low CO_2 volumes, the fluid injection causes the injection plume to approach fracture gradients quickly.

CCUS

The 2010 U.S. Environmental Protection Agency Greenhouse Gas Reporting Program reports that in the Greater Green River Basin of southwest Wyoming, the CO_2 emissions from stationary sources (sources that emit more than 25,000 tons of CO_2 per year) total 29+ million tons annually, or approximately 50 percent of Wyoming's annual CO_2 emissions. These CO_2 sources include coal-fired power plants, gas and trona processing plants, pipeline compression stations, chemical production facilities, and gas-field complexes, among others. The Rock Springs Uplift in the center of the Greater Green River Basin is ideally located to serve as a large-scale commercial geological CO_2 storage facility for half of all of Wyoming's industrial CO_2 emissions. The new numerical simulations suggest that the Madison Limestone has the ability to geologically store the current annual CO_2 emissions from the Greater Green River Basin for 130 years (3.8 billion tons total). The overlying Paleozoic Weber Sandstone on the Rock Springs Uplift has additional commercial-scale CO_2 storage capacity.

Wyoming has 2 billion barrels of stranded oil ("pay zone" oil) that could be recovered via CO_2 flooding techniques, according to reports by the University of Wyoming Enhanced Oil Recovery Institute. If stranded oil in the "residual oil zone" is included, that amount could increase to 4–8 billion barrels of stranded oil in Wyoming. At present, Wyoming has 340 mmcf of CO_2 per day available from the ExxonMobil Shute Creek gas processing plant and 50 mmcf/day from the ConocoPhillips Lost Cabin gas processing plant. All of this CO_2 is under contract for existing EOR projects. Where will the CO_2 required to recover an additional 2–8 billion barrels of strand-

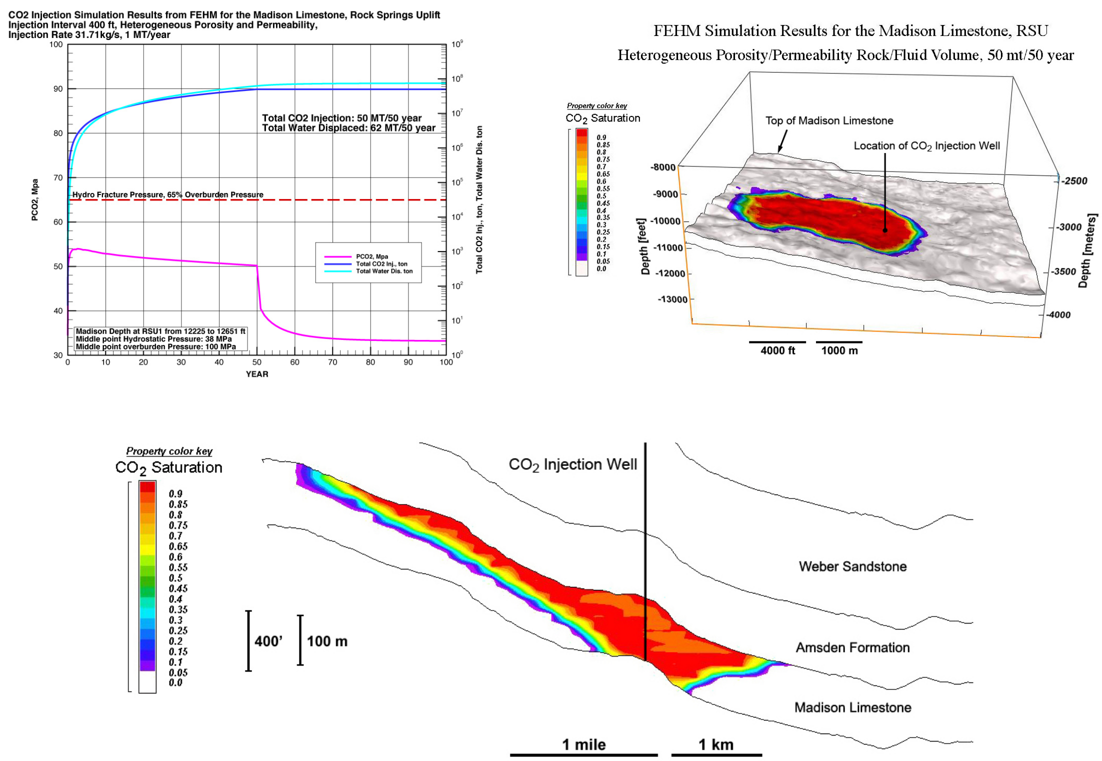

Figure 2. CO_2 injection simulation from LANL's Finite Element Heat and Mass Transfer (FEHM) software for the heterogeneous porosity and permeability volume of the Madison Limestone at the Rock Springs Uplift: a) change in pressure evolution, amount of CO_2 injected, and volume of displaced fluids over time, b) incline view of CO_2 plume on the top of the Madison Limestone, and c) up-dip cross section of the CO_2 plume.

ed oil in Wyoming come from? Denbury Resources plans to produce 600 mmcf/day at its Riley Ridge gas processing plant by 2017; however, the company intends to construct a 20-inch CO_2 pipeline to Montana to provide CO_2 to the Bell Creek, Cedar Creek Anticline, and beyond. Thus, at best, Wyoming may have 500 mmcf/day (26,300 tons/day) of CO_2 available for the next ten years, most of which is already under contract, and therefore unavailable for new EOR projects. However, assuming that this amount of CO_2 is available and that it takes 10 mcf of CO_2 to recover a barrel of oil, it will take 110 years to recover the 2 billion barrels of stranded oil in the pay zone, and 220 to 440 years to recover the stranded oil in the residual oil zone. In contrast, if the 1.2 bcf of anthropogenic CO_2 generated annually in southwestern Wyoming was captured and put to use, 2 billion barrels of stranded oil could be recovered in approximately 17 years.

A plan that requires serious consideration involves using the RSU as a CO_2 storage/surge tank: capturing the anthropogenic CO_2 currently emitted in southwestern Wyoming, storing it in the RSU, and retrieving it from storage on a schedule that optimizes the availability of CO_2 for tertiary recovery of stranded oil in Wyoming, particularly with respect to the Bighorn and Powder River basins. This plan has the following advantages: 1) it makes a waste product (CO_2 emissions) valuable; 2) it eliminates a critical shortage of CO_2 in Wyoming; 3) the CO_2 can be sequestered in the depleted oil fields once the stranded oil is recovered; 4) at least 2 billion barrels of stranded oil can be recovered in a timely fashion; 5) one half of the CO_2 emissions from stationary sources in Wyoming can be eliminated; and 6) the use of coal for power production in southwestern Wyoming can continue. When we objectively consider the "U" in CCUS, this plan deserves serious consideration.

Carbon Management Institute
As of September 30, 2012

	AML Funding	DOE Funding
Total Funding	6,977,572	9,975,000
Supplies	174,163	12,711
Salaries	983,839	290,270
Fringe	302,875	83,215
Travel	164,998	10,055
Equipment	20,877	0
Other	29,571	0
Sub-Contracts	3,397,462	8,659,116
Total Expenses	5,073,785	9,055,367
Remaining	$1,903,787	$919,633

WY-CUSP expenditures to date

Reentry of stratigraphic test well
In the fourth quarter of 2012, the stratigraphic test well (RSU#1) will be reentered in order to retrieve vital data, including drill stem tests, fluid/gas samples (isotopic data), and injectivity tests for both the Madison Limestone and Weber Sandstone. Once these tests are complete, geophones will be installed and the well will be completed as a monitoring well. A detailed well reentry plan and work plan appears on the following pages.

The following services will be provided pursuant to the terms and conditions of the Integrated Well Services Agreement between Baker Hughes Oilfield Operations, Inc. and the University of Wyoming dated September 10, 2010.

Addendum to Exhibit A
Scope of Work

Subtask 2.3: Design and construction of the completion of a stratigraphic test well on the Rock Spring's Uplift for geologic and geophysical characterization.
Subtask 2.4: Design and execute well test on the Madison, Weber and Nugget formations to recover formation fluid samples to be used in completing regulatory requirements.
Subtask 2.5: Design and execute well test on the Madison and Weber formations to determine fracture gradient and injectivity of formation to reduce uncertainty for future CO2 storage in the zones.
Subtask 2.6: Design and execute casing integrity test to satisfy regulatory permitting requirements.
Subtask 2.7: Design and execute the deployment of Geo-seismic monitoring devices to long term monitor and record seismic activities around the well bore.

Scope of work includes provision of project management all materials and services including any 3rd party items and well site supervision. Duties include sourcing of service rigs, surface and down hole equipment or services, operations relative to completeing the well as outlined above, safety oversight of well operations, provision of well reports and updates to the University and interfacing with the needed service suppliers and third parties.

Estimated Well Cost Summary

Operator:	University of Wyoming		
Lease:	Rock Springs Uplift	AFE No.:	2
Field:			
Well Name:	RSU #1	Drilling Days:	N/A
Location:	Rock Springs	Comp. Days:	19
Project:	Madison & Weber Injection Project	P & A Days:	0

	Description		Drilling	Completion	Abandonment
SUB	**INTANGIBLES**	**GEN:**	**1510**	**1520**	**1530**
1020	Well Service Unit		$0	$143,000	$0
1030	Mob/Demob		$0	$15,000	$0
1040	Wellsite Supervision		$0	$102,600	$0
1050	Contract Services		$0	$19,050	$0
1060	Wellsite Accomodations		$0	$13,600	$0
1080	Transportation		$0	$75,000	$0
1090	Fuel/Water/Power		$0	$53,500	$0
1110	Location		$0	$20,000	$0
1120	Environmental		$0	$28,450	$0
1130	Equipment Rental		$0	$123,865	$0
1140	Bits		$0	$48,000	$0
1150	Drilling/Compl Fluids		$0	$84,500	$0
1160	Cementing		$0	$185,000	$0
2000	Tubular/Wellhead Services		$0	$27,900	$0
2010	Logging/Formation Eval/Testing		$0	$356,000	$0
2020	Perforating		$0	$105,000	$0
2030	Stimulation/Sand Control		$0	$224,000	$0
2040	Completion Services		$0	$111,250	$0
2060	Miscellaneous		$0	$90,000	$0
2070	Administrative		$0	$50,447	$0
2080	Contingencies		$0	$844,273	$0
	Total Intangibles		**$0**	**$2,720,434**	**$0**
	TANGIBLES	**GEN:**	**1610**	**1620**	**1640**
1010	Tubulars		$0	$26,000	$0
1040	Wellhead Equipment		$0	$30,000	$0
	Total Tangibles		**$0**	**$56,000**	**$0**
	FACILITIES & SUPPORT (GEN: 1630)		**$0**	**$875,000**	**$0**
	Total Cost		**$0**	**$3,651,434**	**$0**
	Completed Producer Cost			**$3,651,434**	

Carbon Management Institute
University of Wyoming

Completion Program
April 24, 2012

General Information

Well Name: RSU #1
API Number: 049-037-07154
Field, Co., State: Rock Springs Uplift, Sweetwater County, Wyoming
Location: 2090' F.N.L. – 678" F.E.L. Section 16, T20N, R101W
Lat. = 41.7212614N Long. = 108.794820W

Directions: Go 24 miles east out of Rock Springs on I-80 to exit 130 (Point of rocks) take WY377/CR15 for 7 miles toward Jim Bridger Power Plant Surge Pond Dam. Turn left on haul road *(caution traffic on haul road is left-handed)* to location.
Elevation: 6841.2 ft @ GL 68XX ft @ KB
TD: 12,810 ft
PBTD: 12,747 ft
Regulatory: Wyoming Oil & Gas Conservation Commission
Phone – 307-234-7147

	OD, IN	ID, IN	DRIFT,IN	WT,#/FT	GRADE	DEPTH, FT.	EST TOC, FT	CAP., BBL/FT	BURST, PSI	COLLAPSE, PSI
Surface	10 3/4	10.05	9.894	40.5	J-55, STC	2000	0		3,130	2,090
Intermediate	7	6.276	6.151	26	N-80,Butress	9,750	1800	.0981	7,240	5,410
Liner	3 1/2	2.992	2.867	9.20	L-80,FJ-150	12,747	9,264	.0087	10,160	10,530
PBR	NA	4/4.75	NA	NA	NA	9464		NA	NA	NA
Tie-back	3 1/2	2.992	2.867	9.20	L-80,FJ-150			.0087	10,160	10,530
Tubing	2 3/8	1.995	1.901	4.70	N-80			.00387	9,980	9,840
Tubing	2.063	1.751	1.657	3.25	N-80			.00298	11,180	10,590

Safety Considerations: Top Pressure 5792 psi *(80% of 7" burst)*.

Nugget Zone: 9,220-9,270 ft

Weber Zone: 11,190-11,220 ft
11,268-11,294 ft
11,392-11,412 ft

Madison Zone: 12,342-12,374 ft
12,380-12,430 ft
12,459-12,470 ft

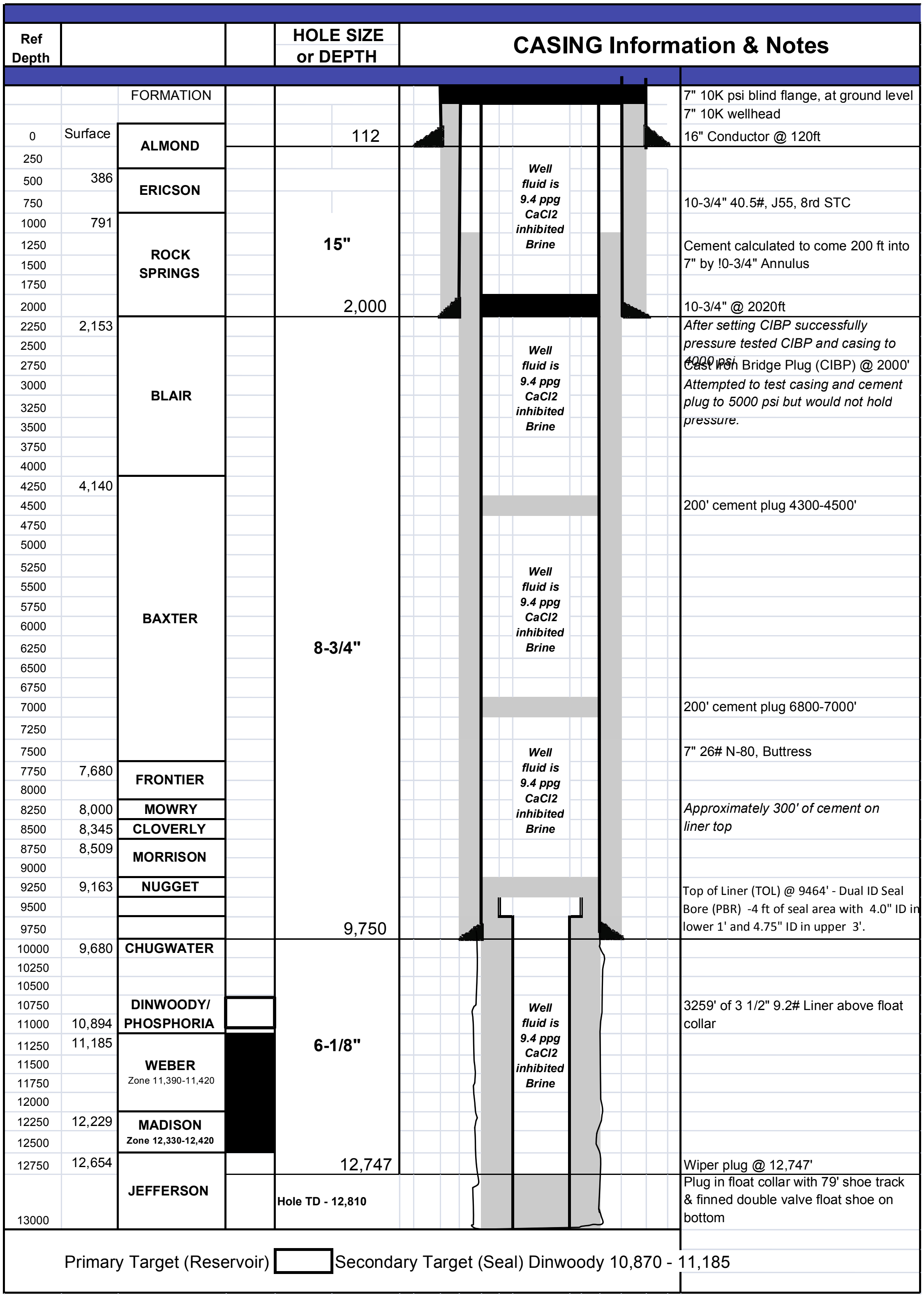

Figure 1 – TA Configuration (Current status of wellbore)

RSU#1 Well Completion Program – 4/24/2012

Casing Integrity Test Procedure

Requirement: A mechanical integrity shall be maintained continuously and be reviewed at least every five (5) years. The test used to determine mechanical integrity shall be a two-part test approved by the administrator, who shall approve only those tests that have been approved first by the U.S. Environmental Protection Agency's Office of Drinking Water.

(A) Part one of the mechanical integrity test shall demonstrate the absence of leaks through the packer, tubing, casing, and well head.

(B) Part two of the mechanical integrity test shall demonstrate the absence of fluid movement behind the casing.

1 Mobilize workover rig with power swivel, pump, annular preventer/BOP, 100 bbl metal rig pit and two (2) 500bbl fluid storage tanks.
2 Rig up workover rig with auxiliary equipment.
3 Rig up annular preventer/BOPs and record high/low test on assembly.
4 Mix 75 BBLs un-weighted water base polymer mud in rig pit and measure density. *(Approx 8.4-8.8ppg)*
5 Pickup a bottom hole assembly (BHA) with 6 ¼” bit and scrapper to clean out the 7” casing.
6 Trip-in-hole (TIH) with the BHA on 2 3/8” tubing to 2000’, close pipe rams and pressure test 7” casing to 0.5 psi/ft gradient. If pressure test is successful drill out cast iron bridge plug at 2000’ and TIH hole to the cement plug at approximately 4300’.
7 After plug is tagged close pipe rams and pressure test 7” casing to 0.5 psi/ft gradient. If pipe does not test then repair *casing as necessary.* If pressure test is successful drill out cement plug and TIH to the next cement plug at approximately 6800’.
8 After plug is tagged close pipe rams and pressure test 7” casing to 0.5 psi/ft gradient. If pipe does not test then repair *casing as necessary.* If pressure test is successful drill out cement plug.
9 Continue in hole with BHA to cement at the top of the polished bore assembly (PBA) estimated to be at 9164’ and remove any cement to top of PBA. (Top of liner (TOL) expected to be at 9464’)
10 Circulate well until the hole is free of any debris and the well fluid density is constant.
11 Close pipe rams and pressure test liner lap, liner top and 7” casing to 0.5 psi/ft gradient after a successful test is obtained trip-out-of-hole (TOH). If pipe does not test then repair *as necessary and retest.*
12 Pick up and TIH with a BHA and tapper tubing string of 2” and 2 3/8” to clean out the 3½” liner (2.867 drift). Clean liner to the rubber plug at plug back total depth (PBTD) of 12,747’. After tagging rubber plug close pipe rams and pressure test liner, liner lap and casing to a 0.5 psi/ft gradient and record on chart.
13 After a successful pressure test is obtained circulate hole clean and TOH. If pipe does not test then repair *casing as necessary.*
14 Prepare to run CBL and casing inspection logs.
15 Move in and rig up (MIRU) a cased-hole wireline truck with its auxiliary equipment.
16 Run CBL and Collar Locator logs from TD to TOC on 7” casing (expected TOC ~ 800’). This will require multiply runs because of pipe sizes and pressure while logging conditions. Make first run without any pressure on the casing and then a second one with 1000 psi of pressure on the casing. If CBL does not conclusively show acceptable cement bonding, perform remedial squeezes as needed, retest and re-log.

RSU#1 Well Completion Program – 4/24/2012

Formation Fluid Sampling & Injection Test Procedure

17 Run baseline RPM and Temperature cased-hole logs over entire liner.
18 TIH with guns and CCL.
19 Perforate the Madison interval (12,342-12,374; 12,380-12,430 & 12,459-12,470) with wireline guns as directed by geologist. Pump into perforates with water to confirm perforations are open to formation.
20 TOH with wireline, rig down and release wireline unit.
21 TIH with a 3½" formation test assemble and packer. Run the tubing as dry as possible without exceeding collapse pressure of tubing string so that the maximum draw down will be applied to recover the maximum fluid possible from the formation.
22 Rig up well test equipment and prepare to flow test well. Set the packer 25 ft above the perforations and open the formation test tools for flow. After adequate well flow is accomplished shut test tools and TOH to recover formation fluids.
23 Pick up 3½" retrievable packer on a tapered tubing string and TIH.
24 Set packer 25 feet above Madison perforations at approximately 12,317 ft.
25 MI and RU pumping equipment for injection test.
26 Pump step injection test as directed by site supervisor while monitoring pressure on annulus to determine packer is holding and injection is into open perforations. Record all test information on a chart.
27 After step test is completed and all information is captured then pump into the Madison formation with water tagged with a radioactive tracer at a constant pressure and rate which does not exceed the formation fracture gradient established during the step injection test.
28 TOH with Packer assembly and lay down tools.
29 MI and RU wireline equipment and run RPM / Spectral Gamma Ray (RA tracer log) with a temperature survey from bottom of well to 500' above the top of the Dinwoody interval (10,870-11,185').
30 TOH with wireline tools and rig down wireline unit.
31 PU & TIH with a 3½" Cement Retainer on a tapered string and set it at 12,317'.
32 Pressure-test the retainer to confirm isolation.
33 Mix and pump a minimum of 50 sks of cement. Spot slurry to end of tubing. Sting back into retainer and squeeze-off perforations. Once squeeze pressure is reached or when one barrel of slurry remains in tubing pick up and dump any remaining slurry on top of the cement retainer. Pick up 10 stands and reverse circulate well returns clean.
34 After well returns are clear of cement circulate and condition well fluids to ensure a uniform well fluid density. Pressure test to ensure well bore isolation from Madison formation.
35 After isolation is established tab bottom to insure adequate depth for the testing of the Weber formation (a minimum of 150 ft below lowest perforations approximately 11,412').
36 TOH with Retainer setting assembly and lay down tools.
37 MI and RU wireline equipment
38 TIH with guns and CCL.
39 Perforate the Weber interval (11,190'-11,220'; 11,268'-11,294' &11,392'-11,412') with wireline guns as directed by geologist. Pump into perforates with water to confirm perforations are open to formation.

40 TOH with wireline and release equipment.
41 TIH with a 3½” formation test assemble and packer. Run the tubing as dry as possible without exceeding collapse pressure of tubing string so that the maximum draw down will be applied to recover the maximum fluid possible from the formation.
42 Rig up well test equipment and prepare to flow test well. Set the packer 25 ft above the top perforations and open the formation test tools for flow. After adequate well flow is accomplished shut test tools and TOH to recover formation fluids.
43 Pick up 3½” retrievable packer on a tapered tubing string and TIH.
44 Set packer 25 feet above Weber perforations at approximately 11,165 ft.
45 MI and RU pumping equipment for injection test.
46 Pump step injection test as directed by site supervisor while monitoring pressure on annulus to determine packer is holding and injection is into open perforations. Record all test information on a chart.
47 After step test is completed and all information is captured then pump into the Weber formation with water tagged with a radioactive tracer (different than that used on the Madison formation) at a constant pressure and rate which does not exceed the formation fracture gradient established during the step injection test.
48 TOH with Packer assembly and lay down tools.
49 MI and RU wireline equipment and run RPM / Spectral Gamma Ray (RA tracer log) with a temperature survey from bottom of well to 500’ above the top of the Dinwoody interval (10,870-11,185’).
50 TOH with wireline tools and rig down wireline unit.
51 PU & TIH with a 3½” Cement Retainer on a tapered string and set it at 11,180’.
52 Pressure-test the retainer to confirm isolation.
53 Mix and pump a minimum of 50 sks of cement. Spot slurry to end of tubing. Sting back into retainer and squeeze-off perforations. Once squeeze pressure is reached pickup out of retainer and reverse circulate well returns clean while washing down to the retainer.
54 After well returns are clear of cement, circulate and condition well fluids to ensure a uniform well fluid density. Wait 12 hours and then pressure test to ensure well bore isolation from Weber formation.
55 TOH with Retainer setting assembly and lay down tools.
56 MI and RU wireline equipment
57 TIH with guns and CCL.
58 Perforate the Nugget interval (9,220’-9,270’) with wireline guns as directed by geologist. Pump into perforates with water to confirm perforations are open to formation.
59 TOH with wireline and release equipment.
60 TIH with a 7” formation test assemble and packer. Run the tubing as dry as possible without exceeding collapse pressure of tubing string so that the maximum draw down will be applied to recover the maximum fluid possible from the formation.
61 Rig up well test equipment and prepare to flow test well. Set the packer 25 ft above the perforations and open the formation test tools for flow. After adequate well flow is accomplished shut test tools and TOH to recover formation fluids.
62 TIH with a 7” retrievable packer on tubing string and set it at 9200’.
63 Mix and pump a minimum of 50 sks of cement. Spot slurry to end of tubing. Set the packer and squeeze-off perforations. Once squeeze pressure is reached pickup 5 stands and reverse circulate well returns clean. If a seal is not established repeat squeeze procedure as necessary to accomplish a successful squeeze.

64 TOH and lay down packer assembly.
65 PU a 7” BHA consisting of a bit and scrapper.
66 TIH assembly and clean well out to the top of the liner.
67 Circulate well at liner top until well returns are free of any cement or well debris.
68 TOH and lay down the 7” BHA.
69 PU and TIH with a 3½” BHA with a bit and scrapper.
70 Clean out liner to the retainer at 11,180’.
71 Circulate well at retainer depth until well returns are free of any cement or well debris.
72 Continue to circulate and condition well fluids to ensure a uniform well fluid density.
73 Circulate well with fluid containing corrosion inhibitors.
74 TOH and lay down BHA.
75 Pressures test the casing to 1000 psi and hold for 30 minutes while recording the pressure.
76 Secure well and submit well samples, results of step rate tests and logs to DEQ.

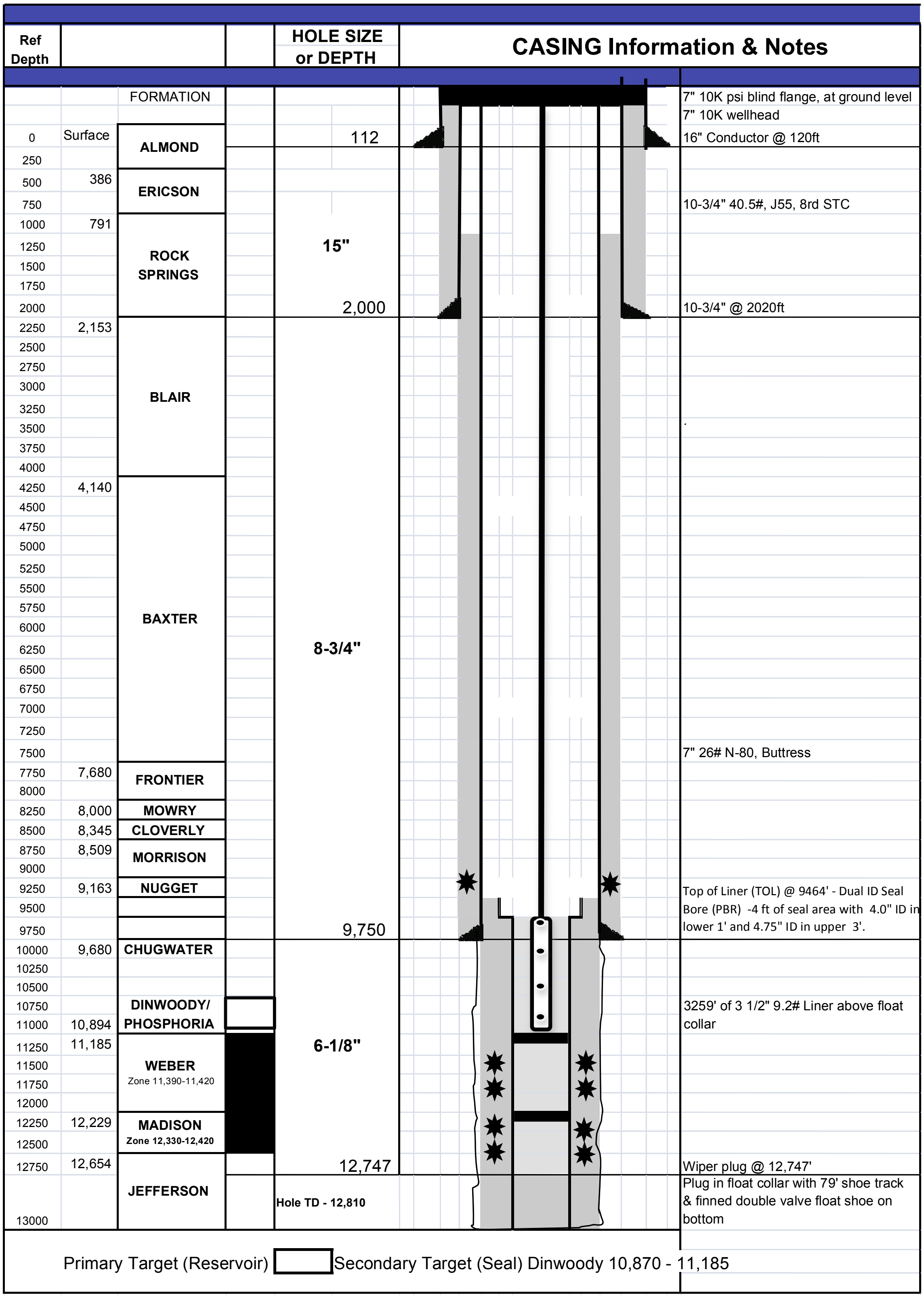

Figure 2 - Well Diagram for Well Monitoring

RSU#1 Well Completion Program – 4/24/2012

Well Monitoring Completion Procedure

Potential Issue: A mechanical integrity test will establish casing integrity before we set the array but this well configuration will not have a tubing- casing annulus to monitor during the well monitoring period.

77 Test casing and 3½" liner to 1000 psi for 30 minutes while recording on chart.
78 MI and RU 1 3/4" coil tubing unit with electric line installed inside coil and prepare to run Micro-seismic sondes on wireline.
79 Run the array on wireline hanging below the coil.
80 Position bottom of coil at deepest depth designed for array and establish circulation.
81 Check to see that array is communicating with surface.
82 Mix and spot cement slurry at bottom of coil and start laying cement in the casing while pulling array up to its setting position. Adjust as required to have array in position when cement is clear of coil.
83 Cut and hang coil in well head.
84 Install well head with wireline penetrations.
85 Release equipment and rig up surface equipment for long term micro seismic data collection.