Table L1. Proposed CO_2 Injection Well – Casing Specifications

TUBULAR	Depth (ft)	Size (in)	Weight (lb./ft)	Grade	Thread	Collapse/ Burst (psi)	Tensile Body/Joint (X 1000 lbs.)
Conductor	0 - 40	13-3/8	48	H-40	ST&C	770/1,730	541/322
Surface Casing	0 – 965	9-5/8	36	J-55	ST&C	2,020/3,520	564/394
Protection Casing	0 – 4,000	5-1/2	15.5	J-55	LT&C	4,040/4,810	248/217

Well Drilling Program

The following sections contain the proposed step-by-step program for drilling and completing the proposed CO_2 Injection Well. The CO_2 Injection Well will be used for baseline monitoring and characterization, injection of the CO_2 fluid during the active experiment, and post-injection monitoring of the intervals of interest.

DRILLING PROCEDURE

CONDUCTOR HOLE

1. Prepare surface pad location and install well cellar.
2. Mobilize drilling rig. Perform safety audit during rig-up to ensure that equipment setup complies with project requirements.
3. Notify Arizona Oil and Gas Conservation Commission at least 48 hours prior to spudding the well.
4. Drill mouse and rat holes.
5. Drill 17-1/2” conductor hole to +/-40 feet. Install 13-3/8” casing and grout annular space from set depth to surface with concrete.
6. Wait on concrete to cure for 12 hours.

SURFACE HOLE

7. Rig up mud logging unit and test equipment. Collect and save 10-foot samples from 40 feet to total depth. A set of samples is required to be submitted to the Oil and Gas Administrator, Arizona Geological Survey, within 30 days of completion of the well. Samples should be: 1) washed and dried, 2) place approximately 3 tablespoons of sample in an envelope identifying the well, the well location, the Arizona Oil and Gas Conservation Commission’s Permit Number, and the depth of the sample. Samples to be shipped to:

    Oil and Gas Administrator
    Arizona Geological Survey
    416 West Congress, Suite 100
    Tucson, AZ 85701

8. Pick up 12-1/4 inch bit and the bottomhole assembly (BHA). Drill a 12-1/4 inch surface hole to +/-965 feet (below base of Schnebly Hill) using freshwater spud mud, as detailed in the Drilling Fluids Program section below. Take deviation surveys every 500 feet and at total depth. The recommended maximum allowable deviation from vertical is 3 degrees with a maximum recommended deviation of no more that 2 degrees per 100 feet (to minimize dogleg severity) at any point in the borehole. If the maximum recommended deviation is exceeded, an evaluation will be made to determine whether remedial action is necessary. After reaching surface casing setting depth, the drilling fluid will be circulated and conditioned to ensure correct fluid properties for the open hole logging and testing.

9. Run open-hole formation evaluation logs per the requirements of the Well Logging, Coring, and Testing Program (See Attachment I above).

   If the logging procedure is extended and/or hole becomes sticky or unstable during logging, a conditioning/cleanup trip will be made with the drill string to circulate and condition the drilling fluid. The drilling string will be removed from the well and the logging program will be completed as planned.

10. Notify Arizona Oil and Gas Conservation Commission at least 48 hours prior to setting and cementing the surface casing.

11. Lower the 12-1/4" drilling assembly in the well to the total depth. The drilling fluid will be circulated and conditioned to ensure correct fluid properties for the casing installation and cementing. Remove the drilling assembly from the well.

12. Run 9-5/8 inch surface casing to +/-965 feet. See the Well Casing Specifications section above for a detailed description of the casing and casing equipment.

    Reduce mud levels in surface circulating system and have additional tanks on hand to recover any excess mud or cement that may be circulated to the surface.

    Designate a qualified person to observe the circulating system and monitor drilling fluid at all times during the cementing procedure. An accurate accounting of volumes will be critical information in the event that circulation is lost.

13. Rig up circulating equipment and perform a pressure test on the lines. Circulate and condition the drilling fluid to ensure correct fluid properties for the cementing procedure. Reciprocate the casing continuously during the circulation of the drilling fluid.

14. Cement the casing in place. Details of the cement blends proposed are located in the Well Construction Cementing Program section below.

    Be prepared to divert cement and cement-contaminated drilling fluid returns away from circulating system and into appropriate containment. Use sugar to retard the premature setting of the cement, if necessary.

15. If no cement returns are observed at surface, contact wireline service provider and schedule a temperature survey to determine the top of the cement.

16. Center the casing in the rotary table of the drilling rig after completing the cementing procedure and before the cement hardens.

17. Cement the annular space that does not contain cement, if required. Fill the annulus space by pumping cement through small tubing that has been run into the annulus to the top of cement.

18. After waiting on cement to harden for a minimum of 12 hours, cut off the surface and conductor pipe and install a 9-5/8 inch SOW (slip-on for welding) x 11-inch 3,000-psi casing head flange. Perform a pressure test on the casing head after installation. Digitally record the test and maintain a copy of the test results on location. Transfer the original test data to the Sandia Office for inclusion in the CO_2 Injection Well Report.

PROTECTION HOLE

19. Install 11-inch 3,000 psi double ram blow out preventer, 11-inch 3,000 psi annular preventer, and auxiliary well control equipment on the 11-inch, 3,000 psi casing head flange. Perform a pressure test on the equipment to the lesser of the manufacturer's full working pressure rating of the system, 70 percent of the minimum internal yield pressure of any casing subject to test, or one psi per foot of the last casing string depth. Annular or bag-type preventers shall be tested to the lesser of 1,000 psi or 50 percent of the full working pressure on installation. The blowout preventer and related equipment will be tested, as follows: a) after each string of casing is set in the well, b) not less than once every 14 days, and c) following any repairs that required the disconnection of any pressure seal assembly (note, only the repaired or replaced component need be tested unless alteration or repair occurs at a normal full blowout preventer test period).

20. Pick up an 8-1/2 inch bit, BHA, and trip in the hole to the top of cement with the drill pipe. Include drilling stabilizers above the second and third drill collars. Close pipe rams and perform a pressure test on the surface casing for at least 30 minutes. The surface casing will be pressure tested for at least 30 minutes to 70 percent of the internal yield pressure of the casing or one pound per square inch (psi) per foot of setting depth (whichever is less). A successful test is a drop of no more than 10 percent of the test pressure over the 30-minute time period. Digitally record the test and maintain a copy of the test results on location. Transfer the original test data to the Sandia Office for inclusion in the CO_2 Injection Well Report.

21. Convert the drilling fluid in the well to a salt-based drilling fluid. Details of the drilling fluid characteristics are located in the Drilling Fluids Program section below.

22. Drill out casing float equipment and 10 feet of new hole.

23. Perform a pressure test on the casing seat and formation to pressure leak-off point or to an 11.0 pounds per gallon equivalent drilling fluid density.

24. Drill an 8-1/2 inch hole from surface casing point to the core point in the Martin Formation. Alternatively, sidewall coring may be done as part of the wireline activities in Item #26. Take deviation surveys every 500 feet and at core point. The recommended maximum allowable deviation from vertical is 3 degrees with a maximum recommended deviation of no more that 2 degrees per 100 feet (to

minimize dogleg severity) at any point in the borehole. If the maximum recommended deviation is exceeded, an evaluation will be made to determine whether remedial action is necessary. Details of the coring program are described above in Appendix I. Monitor the well path as drilling proceeds.

25. Drill and retrieve the core (Martin proposed injection interval), unless sidewall coring is done instead.

26. Pick up the drilling assembly and lower into the well. Drill the cored interval (if taken) and continue drilling to the proposed total depth (+/-4,000 feet true vertical depth) into the Pre-Cambrian basement. Take deviation surveys every 500 feet and at total depth. The recommended maximum allowable deviation from vertical is 3 degrees with a maximum recommended deviation of no more that 2 degrees per 100 feet (to minimize dogleg severity) at any point in the borehole. If the maximum recommended deviation is exceeded, an evaluation will be made to determine whether remedial action is necessary.

27. After reaching total depth, circulate and condition the drilling fluid to ensure correct fluid properties for the wireline logging procedure. Make a short trip by pulling up into the 9-5/8-inch surface casing with the drill bit and BHA. Lower the drilling assembly back to bottom and check for solids fill. Resume circulating and conditioning drilling fluid and wellbore for open hole logging. Remove drilling assembly from well for open hole logging.

    Measure the drill string on the trip out to confirm well depth.

28. Rig up wireline equipment and run the open-hole logging and sampling suite. See Appendix I for Well Logging, Coring and Testing details.

    If the logging procedure is extended and/or hole becomes sticky or unstable during logging, a conditioning/cleanup trip will be made with the drill string to circulate and condition the drilling fluid. The drilling string will be removed from the well and the logging program will be completed as planned.

29. After completing all wireline logging and sampling, go into the hole with bit, drill collars, and drill pipe to bottom. Check and note presence of any fill at the bottom of the hole. Circulate hole clean, condition the drilling fluid for running of the protection casing. Note, a high viscosity pill may be required to keep the bottom portion of the hole open.

30. Pull out of the hole with the drilling assembly. Lay down drill pipe and drilling assembly.

    Notify Arizona Oil and Gas Conservation Commission and USEPA of upcoming cement job at least 48 hours ahead of anticipated activities.

31. Rig up casing handling and make-up equipment. Run the 5-1/2 inch protection casing. Details of the casing program are described in the Well Casing Specifications section above. Set a differential shoe and a differential collar between the second and third joint.

    Ensure that all dimensions of cementing equipment and casing are visually inspected, measured, and drifted before running in the hole.

API Modified thread lubricant or equivalent will be used unless premium threads and/or corrosion resistant casing are used.

Have a casing swedge available, on the rig floor, with circulating hoses ready, in the event the casing must be washed to bottom or in the event that well control procedures are required.

32. Once the casing is on bottom, rig up and circulate the hole for a minimum of 150% of the open hole volume to clear the floats and cool the formation sufficiently for cementing. Add water and chemicals to the drilling fluid to adjust the characteristics of the fluid to improve drilling mud removal from the annulus during the cementing procedure.

    Reciprocate the pipe slowly, but continuously, in ±20-foot strokes during the circulating and cementing operations. If the movement of the pipe begins to indicate that sticking is occurring, lower the pipe to planned setting depth and discontinue pipe movement.

    Reduce mud levels in surface circulating system and have additional tanks on hand to recover any excess mud or cement that may be circulated to the surface.

    Designate a qualified person to observe the circulating system and monitor drilling fluid at all times during the cementing procedure. An accurate accounting of volumes will be critical information in the event that circulation is lost.

33. Mix and pump the cement. Details of the cementing program are described in the Well Construction Cementing Program section below. Displace the cement with drilling mud, 2% KCl, or fresh water.

34. Lift the BOP stack and hang off the 5-1/2" casing in tension (same hook load as when originally cemented in place). Nipple up the 7-1/16-inch 3,000 psi x 11-inch 3,000 psi tubing spool and perform a pressure test on the seals to the manufacturer's specifications. Isolate the well by installing a 7-1/16-inch 3,000 psi tapped flange with valve on the tubing spool.

35. Rig down the drilling rig and release rig from location. Remove and clean location of all drilling equipment.

COMPLETION PROCEDURE

PROTECTION CASING AND CEMENT EVALUATION

1. Mobilize a workover rig to location and rig up the equipment (note that the drilling rig may be used for completion operations, depending on availability and scheduling). Perform safety audit during rig-up to ensure that equipment setup complies with project requirements.
2. Install 7-1/16" 3,000 psi dual blow out preventer on well and pressure test.
3. Pick up a 4-3/4-inch cement bit and two casing scrapers, trip into the hole with a workstring to tag the top of cement in the casing.

4. Verify tagged depth and dress off cement as needed. Circulate the fluid in the wellbore to remove any solids. Displace the wellbore with filtered 2% KCl or other suitable completion fluid. Pull the workstring, scrapers, and bit.
5. Rig up wireline equipment and lubricator to the top of the annular BOP. Perform a 2,000-psig pressure test on the lubricator. Run cement evaluation/casing inspection/caliper logs, differential temperature survey, and gyroscopic survey as detailed in Attachment I, Well Logging, Coring and Testing. Run cement bond log initially under zero pressure. A repeat run at elevated pressure may be necessary to remove effects from potential micro-annulus. Run cement evaluation/casing inspection logs to surface or approximately 500 feet above the top of calculated annular cement. Rig down wireline equipment.
6. Perform a pressure test on the casing to 70 percent of the manufacturer's rated internal yield pressure or one psi per foot of casing depth, which ever is less, for at least 30 minutes. Note: Arizona Oil and Gas Conservation Commission and/or USEPA may witness casing pressure test. A successful test is a drop of no more than 10 percent of the test pressure over the 30-minute time period. Digitally record the test and maintain a copy of the test results on location. The original copy of the pressure test record **MUST** be sent in to the Sandia Office and made part of the CO_2 Injection Well report. Keep a copy of the pressure test record at the CO_2 Injection Well site with other important records.

WELL COMPLETION – CO_2 INJECTION PILOT

7. Run any pre-experiment baseline testing that requires the well to be clear of completion equipment (such as the baseline VSP).
8. Rig up wireline unit and set up perforating charges. Run in hole and correlate perforation gun(s) on depth. Perforate the Martin Formation (or alternate Naco Formation) injection interval as determined from the open-hole logs. It is recommended that the well be perforated **underbalanced**, to aid in perforation tunnel clean up.
9. Produce formation fluid from the Martin Formation by swabbing or backlift. This will also aid in developing the well. Monitor formation fluid properties at surface (chlorides, pH, temperature, specific gravity, etc.). Continue flowing the well until parameters stabilize, indicating that formation fluids are being recovered. Collect samples periodically for laboratory analysis. Once clean and stable formation brine is established, divert returns to a "fresh" frac tank(s). The stored formation fluids will be used for injection testing of the injection interval.
10. Pick up completion packer and tubing. Attach any downhole monitoring equipment and control lines. Run the completion assembly into the well. Once on bottom, circulate the well with clean formation brine.
11. Space out tubing string and set the packer +/-10 feet above the uppermost perforation in the Martin Formation injection interval.
12. Land the tubing into the wellhead.
13. Install wellhead equipment and control lines.

14. Allow well to equilibrate and perform annulus pressure test. The pressure test will be run at equal to the lesser of the maximum authorized injection pressure or 1,000 psi (no testing pressure will be less than 300 psi). A successful test is a drop of no more than 10 percent of the test pressure over the 30-minute time period. Digitally record the test and maintain a copy of the test results on location. *Note: Arizona Oil and Gas Conservation Commission & USEPA may witness annulus pressure test.* The original copy of the pressure test record **MUST** be sent in to the Sandia Office and made part of the well report. Keep a copy of the pressure test record at the well site with other important records.
15. Rig down the workover rig and move out associated equipment.

GENERAL NOTES

All depths referenced are approximate and are based on the expected log depth from rig Kelly bushing of 15 feet above ground level.

Actual depths may vary based on lithology and evaluation of local formations.

DRILLING FLUIDS PROGRAM

Surface Hole

Depth (Feet)	Mud Type	Weight (Lb./gal)	Viscosity (Funnel-sec.)	Fluid Loss (cc/30 min)
40-300	Freshwater Gel	8.4 – 9.0	40 - 60	control
300-965	Freshwater Gel	8.4 – 9.0	50 - 60	<10

Notes:

1. Should lost circulation and excessive drilling mud losses occur, materials designed for that problem will be used to remedy the problem on an "as needed" basis.
2. High-viscosity sweeps will be used as needed to assist in hole cleaning.

Protection Hole

Depth (Feet)	Mud Type	Weight (Lb./gal)	Viscosity (Funnel-sec.)	Fluid Loss (cc/30 min)
965-2,300	Saltwater Gel	9.5 - 10.5	35-42	<10
2,300-4,000	Saltwater Gel	9.5 - 10.5	35-42	≤5

Notes:

1. Should lost circulation and/or excessive drilling mud losses occur, materials designed for that problem will be used to remedy the problem on an "as needed" basis.
2. High-viscosity sweeps will be used as needed to assist in hole cleaning.