INJECTION WELL PLUGGING PLAN
40 CFR 146.92(b)

FRONT RANGE STORAGE COMPLEX

Facility Information

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Front Range 1-1

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Well surface location: 31375 Great Wester Drive, Windsor, CO 80550
Lat: 40.454962 Long: -104.859761 NAD 83 (2011)

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List of Acronyms and Abbreviations

BOP = blowout preventer	ND = nipple down
CICR = Cast Iron Cement Retainer	NU BOP = nipple up blowout preventer
CO_2 = carbon dioxide	PISC = Post-Injection Site Care
CSS = Carbon Storage Solutions, LLC	ppg = pounds per gallon
cu ft/ft = cubic feet per foot	psig = pound-force per square inch, gauge
cu ft/sx = cubic feet per sack	RIH = run in hole
DTS = distributed temperature sensor	RU = rig up
ft = feet	TIH = trip in hole
ft above MSL = feet elevation referenced to the North American Datum of 1983	UIC = Underground Injection Control
lb/ft = pounds per foot	USDW = Underground Source of Drinking Water
MI = move-in	US EPA = United States Environmental Protection Agency
MIT = mechanical integrity test	

F.1. Summary

Carbon Storage Solutions, LLC (CSS) will plug and abandon Front Range 1-1 in accordance with 40 CFR 146.92. After serving as an injection well, Front Range 1-1 will be re-purposed as a monitoring well for the post-injection site care (PISC) period. Well plugging and abandonment of Front Range 1-1 will occur after completion of its duty as a monitoring well during PISC.

The essential steps for plugging and abandonment are:

1. Prior to well plugging, CSS will flush the well with a buffer fluid, determine bottomhole reservoir pressure, and perform a final external mechanical integrity test per 40 CFR 146.92(a).
2. CSS will prepare, maintain, and comply with this Injection Well Plugging Plan upon its acceptance of the United States Environmental Protection Agency (US EPA) Underground Injection Control (UIC) Program Director. This plan is submitted as part of the permit application and includes information on the following:
    a. Planned tests or measures to determine bottom-hole reservoir pressure.
    b. Planned external mechanical integrity tests (MITs).
    c. Detailed information on the plugs including:
        i. Type and number of plugs to be used.
        ii. Placement of each plug including elevations for the top and bottom.
        iii. Type, grade, and quantity of material to be used in plugging. The material must be compatible with the carbon dioxide stream.
        iv. Method of placement of the plugs.
3. CSS will notify the US EPA UIC Program Director in writing 60 days before plugging (or a shorter notice period per the US EPA UIC Program Director approval). An updated plan will accompany the notification, with any amendments to the plan approved by the US EPA UIC Program Director and incorporated into the permit subject to permit modification requirements of 40 CFR 144.39 or 144.41 (as appropriate).
4. Within 60 days after plugging, CSS will submit a plugging report to the US EPA UIC Program Director. The report will be certified as accurate by CSS and the person who performed the plug operation (if other than CSS). CSS shall retain the well plugging report for 10 years following site closure.

The intention of the plugging plan is to ensure the prevention of any fluid or gas migration from the injection zone, to prevent any additional crossflow as a result of the well penetrating formations above and below the target zone, to resist the corrosive aspects of carbon dioxide mixed with water, and to protect underground sources of drinking water (USDWs). Any revisions to the plan due to new information collected during logging and testing will be made after construction, logging, and testing of the well has been completed. The final injection well plugging plan will be provided to the US EPA UIC Program Director.

To prepare the well for plugging, it will first be flushed with a kill weight brine fluid, without exceeding formation fracture pressure. Prior to plugging, bottom hole pressure measurements will be made, and the well will be logged and pressure tested to ensure mechanical integrity inside and outside of the casing. If mechanical integrity is determined to be lost, repairs will be made prior to continuation of plugging activities. Internal tubing will be removed as part of abandonment.

Squeeze cements, casing circulations, and balanced plugs will be used to plug the well. Cement used for the squeeze cementing of the injection interval and the subsequent 6 lifts (bottom roughly 3,540 feet) will be carbon dioxide (CO_2) resistant cement. After abandoning the bottom interval of the well, the 7-inch casing will be perforated and cement will be circulated to surface in the annular space between the 7-inch casing and the 9 5/8-inch casing. Subsequently, the rest of the 7-inch casing will be cemented to surface.

F.2. Planned Tests or Measures to Determine Bottom-Hole Reservoir Pressure

CSS will record downhole pressure throughout the operating lifetime of the well. The same pressure gauge used to measure and record Front Range 1-1 downhole pressure will be used to determine the bottomhole reservoir pressure prior to plugging and abandonment in fulfillment of 40 CFR 146.92(b)(1). Kill fluid density and reservoir pressure can be determined from these measurements. See Sections E.6 and E.11 of the Testing and Monitoring Plan and Section E.I.1.4 of the Quality Assurance and Surveillance Plan for more detail.

F.3. Planned External Mechanical Integrity Test(s)

CSS will conduct at least one of the tests listed in Table F.3-1 to verify external mechanical integrity prior to plugging the injection well as required by 40 CFR 146.92(a) and 146.92(b)(2).

Table F.3-1. Potential MITs

Test Description	Location
Temperature Log	Along wellbore using distributed temperature sensor (DTS) or wireline logging
Noise Log	Wireline logging
Oxygen Activation Log	Wireline logging

F.4. Information on Plugs

This section provides information on how the requirements of 40 CFR 146.92(b)(3), (4), (5), and (6) will be met. CSS will use the materials and methods noted in Table F.4-1 and illustrated in Figure F.5-1 to plug the injection well. Plugs #1 and #2 will have multiple lifts as illustrated in Figure F.5-1. The volume and depth of the plug or plugs are based upon the geology and downhole conditions of the well as assessed during construction. The cement(s) formulated for plugging will be compatible with and resistant to the carbon dioxide stream. The cement formulation and required certification documents will be submitted to the agency with the well plugging plan. The owner or operator will report the wet density and will retain duplicate samples of the cement used for each plug.

Table F.4-1. Preliminary Plugging Details

Plug Information	Squeeze Cement	Plug #1 (Lifts 1-6)	Casing Cement	Plug #2 (Lifts 8 – 19)
Diameter of boring in which plug will be placed, inches	6.184	6.184	8.835	6.184
Depth to bottom of tubing or drill pipe, feet	9,746	9,746	9,398	9,746
Sacks of cement to be used	60	576	831	1,053
Slurry volume to be pumped, cubic feet	75	757	954	1,208
Slurry weight, pounds per gallon	15	15	15.8	15.8
Calculated top of plug, feet	9,370	6,030	0	0
Bottom of plug, feet	9,660	9,370	5,990	5,990
Calculated top of plug, Elevation ft above MSL	-4,618	-1,278	4,752	4,752
Bottom of plug, Elevation ft above MSL	-4,908	-4,618	-1,238	-1,238
Type of cement or other material	CORROSACEM (CO_2 Resistant)	CORROSACEM (CO_2 Resistant)	HALCEM	HALCEM
Method of emplacement (e.g., balance method, retainer method, or two-plug method)	Squeeze Cement	Balanced Plug	Retainer	Balanced Plug

ft above MSL = feet above mean sea level elevation referenced to the North American Datum of 1983

F.5. Narrative Description of Plugging Procedures

F.5.1. Notifications, Permits, and Inspections

In compliance with 40 CFR 146.92(c), CSS will notify the regulatory agency at least 60 days before plugging the well and provide an updated Injection Well Plugging Plan, if applicable.

F.5.2. Plugging Procedures

1. In compliance with 40 CFR 146.92(c), notify the regulatory agency at least 60 days before plugging the well and provide an updated plugging plan, if applicable.
2. Move-in (MI) rig onto Front Range 1-1 and rig up (RU). All CO_2 pipelines will be marked and noted with rig supervisor prior to MI.
3. Conduct and document a safety meeting.
4. Record bottom hole pressure from down hole gauge and calculate kill fluid density.
5. Open up all valves on the vertical run of the tree and check pressures.
6. Test the pump and line to 5,000 pound-force per square inch, gauge (psig). Fill tubing with kill weight brine (10.1 pounds per gallon (ppg) or as determined by bottom hole pressure measurement). Bleeding off occasionally may be necessary to remove all air from the system. Test casing annulus to 500 psig and monitor as in annual MIT. Monitor tubing and casing pressure for 1 hour. If both casing and tubing are dead then nipple up blowout preventers (NU BOPs). Monitor casing and tubing pressures.
   - If the well is not dead or the pressure cannot be bled off of the tubing, RU slickline and set plug in lower profile nipple below packer, bleed off pressure.
7. After the well is dead, nipple down (ND) tree NU BOPs, and perform a function test. Blowout preventors (BOPs) should have appropriately sized single pipe rams on top and blind rams in the bottom ram for tubing. Test pipe rams and blind rams to 500 psig low, 5,000 psig high. Test annular preventer to 500 psig low and 5,000 psig high. Test all pressure valves, lines, BOPs choke and kill lines, and choke manifold to 500 psig low and 500psig high. NOTE: Make sure casing valve is open during all BOP tests. After testing BOPs pick up tubing string and unlatch seal assembly from seal bore.
8. Pull out of hole with tubing standing back, spooling Tubing Encapsulated Conductor & Fiber Lines.
9. Confirm the well's mechanical integrity by performing one of the permitted external mechanical integrity tests presented in Table F.3-1.
10. Trip in hole (TIH) to 50 feet (ft) above top of packer.
11. Pump squeeze cement into injection zone perforations, leaving approximately 200 ft of CO_2 Resistant Cement above top of packer.
12. The lower section of the well will be plugged using CO_2 resistant cement from total depth around 9,370 ft to a depth of approximately 6,030 ft, which corresponds to roughly

3,630 ft above the top of the Lyons Sandstone. This will be accomplished by placing plugs in approximately 500 ft incremental lifts. Using a density of 15.0 ppg slurry with a yield of 1.316 cubic feet per sack (cu ft/sx), approximately 576 sacks of cement will be required. Actual cement volume will depend upon actual weight of the casing within the plugged zone as well as the length of plug set as determined during the plugging operation. It is anticipated that at least one squeeze job and six plugs of roughly 500 ft in length will be necessary. No more than two plugs will be set before cement is allowed to set and plugs verified by setting work string weight down onto the plug. (Calculations: Assume 29 pounds per foot (lb/ft) casing for this interval 3,630 ft x 0.2086 cubic feet per foot (cu ft/ft) / 1.316 cu ft/sx = 576 sacks.).

13. The annular section from 6,020 feet to surface will be plugged using standard Class G cement. Using a density of 15.8 ppg slurry with a yield of 1.148 cu ft/sx, approximately 831 sacks of cement will be required. This will be performed by Pulling Out Of Hole with tubing standing back. RU Wireline, Run In Hole (RIH) with wireline and shoot squeeze perforations in the 7-inch casing above the top of cement from 6,000 to 6,020 ft. RIH with Cast Iron Cement Retainer (CICR) and set above the squeeze perforations at approximately 5,990 ft. TIH with the tubing and sting into CICR. Pump 831 sacks of cement to surface. (Calculations: Assume 29 lb/ft internal casing and 40 lb/ft external casing. Interval 6,020 ft x 0.1585 cu ft/ft / 1.148 cu ft/sx = 831 sacks).
14. Place tubing just above the CICR, circulate well to ensure it is balanced. Mix and spot 500 ft balanced plug in 7 -inch casing (approximately 95 sacks Class G mixed at 15.8 ppg with yield 1.147 cu ft/sx). Pull out of plug and reverse circulate tubing. Repeat this operation placing plugs in approximately 500 ft incremental lifts until a total of 12 plugs have been set. If plugs are well balanced, then the reverse circulation step can be omitted until after each third plug. Lay down work string while pulling from well. If rig is working daylights only then pull 10 stands and rack back in derrick and reverse tubing before shutting down for night. After waiting overnight, trip back in hole and tag plug and continue. After all plugs have been set pull tubing from well and shut in for 12 hours. Total of approximately 1,053 sacks total cement used in plugs above 6,030 ft. (Calculations assume 29 lb/ft casing and no excess because this section is inside the intermediate casing 5,790 ft x 0.2086 cu ft/ft / 1.147 cu ft/sx = 1,053 sacks).
15. Top off well with cement from surface. ND BOPs and cut all casing strings below plow line (minimum 3 feet below ground level or per local policies/standards). Clean cellar to where a plate can be welded with well name onto lowest casing string at a depth of roughly 3 ft, or as per permitting agency directive.
16. The procedures described above are subject to modification during execution as necessary to ensure the plugging operation protects worker safety and is effective to protect USDWs, and any significant modifications due to unforeseen circumstances will be described in the Plugging report. The completed plugging forms will be submitted with charts and all lab information to the regulatory agency as required by the permit. The plugging report shall be certified as accurate by CSS and the plugging contractor and shall be submitted within 60 days after plugging is completed.