CONSTRUCTION DETAILS
40 CFR 146.82(a)(11-12), 40 CFR 146.86(b), 40 CFR 186.86(c), 40 CFR 146.88(e)

Brown 4 Geologic Sequestration Project

Facility Information

Facility name: Brown 4 Geologic Sequestration Project
Lambda-Brown 4-1 & Lambda-Brown 4-2

Facility contact: Claimed as PBI [redacted]

Well location: Lambda-Brown 4-1: Brown, Manistee County, Michigan
44.3361397, -86.1393888, NAD 27

Lambda-Brown 4-2: Brown, Manistee County, Michigan
44.3418411, -86.1342111, NAD 27

Introduction

Lambda requires two CO_2 injection wells for the Brown 4 Geologic Sequestration Project (GSP). Both wells will be constructed with components that are compatible with the injectate and formation fluids encountered. The well design reflects the necessary requirements to uphold the integrity of the seal, prevent any escape of CO_2 from the target reservoir, and maintain wellbore integrity over the entire life cycle of the project. Casing points will be verified using drilling data to ensure protection of shallow formations. Cement design and placement procedures will meet required standards to ensure isolation of the injection zone and protection of the USDW using cementing materials that are compatible with the injectate, formation fluids, and subsurface pressure and temperature conditions. The proposed depths listed in Table 1 are based on correlations to existing well logs in the reef. The final formation tops and casing point set depths will be reported in the well completion report.

The Brown 4 reef has been depleted from its original pressure of 2,428 psig to its current pressure of 9 psig. Lambda intends to set the long string of casing below the base of the seal (A2 Evaporite) to ensure cement circulation across the confining zones and up to the surface. This completion strategy is appropriate due to the extremely low bottom hole pressure in the reservoir and a common practice in low pressure reefs in the Niagaran Reef Trend. Figure 1 shows the location of the proposed injection and monitoring wells for the project.

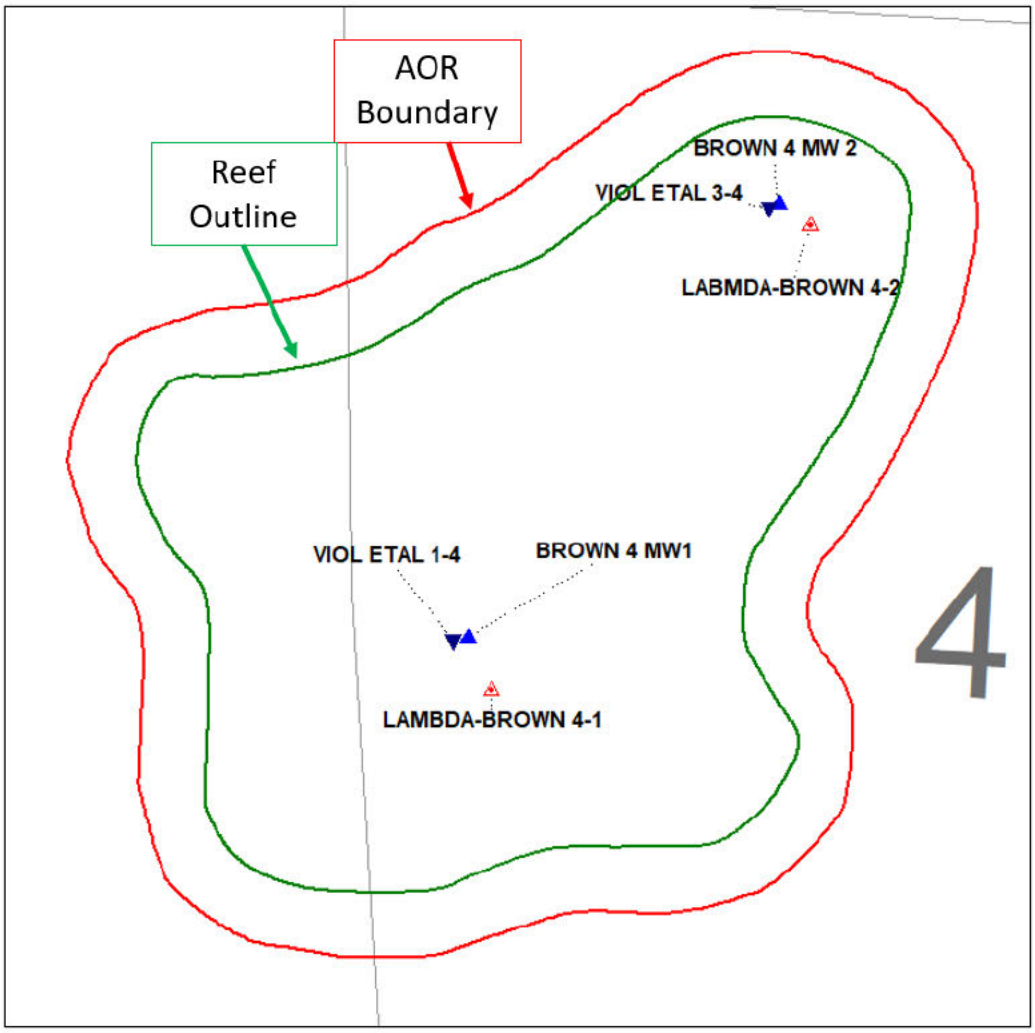

Figure 1: Map showing the location of all wells associated with the Brown 4 GSP.

Table 1. Open hole diameters and anticipated drilling intervals in the Lambda-Brown 4-2 well

Name	**Depth Interval** (Feet)	**Open Hole Diameter** (Inches)	**Comment**
Conductor	0 - 96	20	Driven
Surface	96 - 914	17.5	100’ Below Glacial Drift
Intermediate	914 – 3,130	12.25	50’ Below Bass Island Formation
Long-string	3,130 – 4,315	8.5	15’ into Reef
Open Hole	4,315 – 4,716	6	Open Hole Completion

Injection Well Construction Details

Casing and Cementing

The casing specifications outlined in Table 2 are sufficient to meet the requirements of 40 CFR 146.86(b)(1)(iv). They also allow for the safe operation at bottomhole injection conditions that will not exceed the proposed maximum operating pressure of 2,428 psig. To ensure successful placement and isolation, cementing and casing best practices will be employed as per American Petroleum Institute (API) Specification 10A. Industry standard procedures for designing and placing primary cement in the casing annuli will be utilized to guarantee the mechanical integrity of both cement and casing.

The presence of circulated cement at the surface will serve as a key indicator of effective cement placement. Cement evaluation logging will be carried out to validate cement placement and isolation for every casing section.

Lambda will be installing three strings of casing within each injection well. The casing set points are set to abide by state regulations and to protect the USDW and surrounding formations. The surface casing extends through the base of the USDW per 40 CFR 146.86(b)(2). The intermediate casing string extends 50' below the base of the Bass Island Dolomite formation. The long string extends to the injection zone per 40 CFR 146.86(b)(3). The midstream pipeline system that will transport CO_2 to the well requires a dry, non-corrosive CO_2 stream. Under these conditions, API L-80 casing would be allowable for the injectors. However, as an extra precaution, Lambda will be using CO_2 resistant chrome casing for the section of the well in contact with the CO_2 stream.

To ensure that surface, intermediate, and long string casings are properly cemented, Lambda will pump 300% excess of cement until returns are seen at the surface. Lambda will also utilize a Fidelis™ cement staging tool in the 7" casing at the top of the chrome tubulars to ensure returns to surface. The Class A cement to be utilized for all casing strings is recommended by the API Specification 10A for wells up to 6,000 feet deep. In evaluating the compatibility and fit for purpose of the well construction plan, Lambda utilized a report prepared for the API summarizing the learnings and best practices for CO_2 injection wells. The report documents core analysis from 30-year-old CO_2 injection wells with analogous cement and found "the cement retained its capacity to prevent significant transport of fluid (CO_2) through the cement matrix"[i]. However, as an extra precaution, the cement behind the chrome pipe in the long string will be CO_2 Resistant WellLock® to provide an additional layer of protection. The properties of this resin-based cement can withstand pH environments of 2.5 and below. Integrity of the cement used for each section will be verified before moving forward to the next phase of well construction (Table 3). Of note, the resin properties of the WellLock® cement require an ultrasonic cement bond log due to its unique nature. Conventional cement bond logs will verify integrity of cement above the cement staging tool, where Class A cement is used.

Table 2. Casing specifications for proposed injection wells

Name	Depth Interval (feet)	Outside Diameter (inches)	Inside Diameter (inches)	Weight (lb/ft)	Grade (API)	Design Coupling (Short or Long Threaded)	Thermal Conductivity @ 77°F (BTU/ft.hr.°F)	Burst Strength (psi)	Collapse Strength (psi)
Conductor	96	20	19.124	94	J-55	ST&C	31	2,100	520
Surface	0 - 914	13.375	12.615	54.5	J-55	ST&C	31	2,740	1,130
Intermediate	0 - 3,130	9.625	8.835	40	J-55	LT&C	31	3,950	2,570
Long-string	0 – 4,075	7	6.276	26	L-80	LT&C	31	7,250	5,410
Long-string	4,075 – 4,315	7	6.276	26	25CR-80	STD	16	7,240	5,410

Table 3: Cementing details for proposed injection wells

Casing String	Cement Type	Amount of Cement	Depth
Conductor	N/A	Driven	0’ – 96’
Surface	Class A	1,995 sxs	0’ – 914’
Intermediate String	Class A	1,575 sxs	0’ – 3,130’
Long String	Class A CO_2 Resistant WellLock®	655 sxs 11.2 bbls	0’ – 4,075’ 4,075’ – 4,315’

Tubing and Packer

The information provided in Table 4 and Table 5 describes the completion equipment to be utilized and meets the requirements of 40 CFR 146.86(c). The tubing and packer materials are compatible with the expected injection fluid and meet API Specification 5CT. All well construction materials meet or exceed the API Specifications and are compatible with the non-corrosive CO_2 stream planned for injection (Table 6).

Table 4. Tubing specifications for proposed injection wells

Name	Depth Interval (feet)	Outside Diameter (inches)	Inside Diameter (inches)	Weight (lb/ft)	Grade (API)	Design Coupling (Short or Long Thread)	Burst strength (psi)	Collapse strength (psi)
Injection tubing	0 - 4,290	4.5	3.958	12.6	JFE-13CR-80	STD	8,430	7,500

Table 5. Packer specifications for proposed injection wells

Packer Type and Material	Packer Setting Depth (feet)	Length (inches)	Nominal Casing Weight (lb/ft)	Packer Main Body Outer Diameter (inches)	Packer Inner Diameter (inches)
41XX Low Alloy Steel	4,290	86.25	23 - 29	6.0	2.853

Tensile Rating (psi)	Burst Rating (psi)	Collapse Rating (psi)	Max. Casing Inner Diameter (inches)	Min. Casing Inner Diameter (inches)
80,000	9,350	8,840	6.366	6.184

Table 6: Material specifications for proposed injection wells

Component	API Specified Materials of Construction	Materials Planned in Lambda Wells
Upstream Metering & Piping	• 316 SS	• 316 SS
Christmas Tree	• 316 SS • Nickel • Monel	• 316 SS • Nickel • Monel
Valve Packing and Seals	• Teflon • Nylon	• Teflon • Nylon
Wellhead	• 316 SS • Nickel • Monel	• 316 SS • Nickel • Monel
Tubing Hanger	• 316 SS • Incoloy	• 316 SS • Incoloy
Tubing	• Fiberglass lined carbon steel • Internally plastic-coated carbon steel • Corrosion resistant alloys	• JFE-13CR-80
Tubing Joint Seals	• Fiberglass seal ring • Internally plastic-coated threads and collars	• Premium connections with metal-to-metal seals.
On/Off tool, Profile Nipple	• 316 SS • Nickel plated wetted parts	• 316 SS
Packers	• Internally coated hardened rubber of 80-90 durometer strength • Nickel plated wetted parts	• Hydrogenated nitrile rubber • 41XX low alloy steel
Cements and Cement Additives	• Acid resistant cements containing latex, pozzolan, alumina and other additives	• Acid resistant cements containing latex, pozzolan, alumina and other additives

Injection Well Construction Diagram

The proposed wellbore diagram and wellhead design for the CO_2 injection well are shown in Figure 2 and Figure 3.

Monitoring Wells Diagrams

The diagrams below show the current and proposed wellbore configurations for the Viol 1-4 and Viol 3-4 (Figure 4 and Figure 5). These wells will be plugged back and perforated in the Bass Island Dolomite formation to serve as above-confining-zone monitoring wells. This work will be done prior to the commencement of injection.

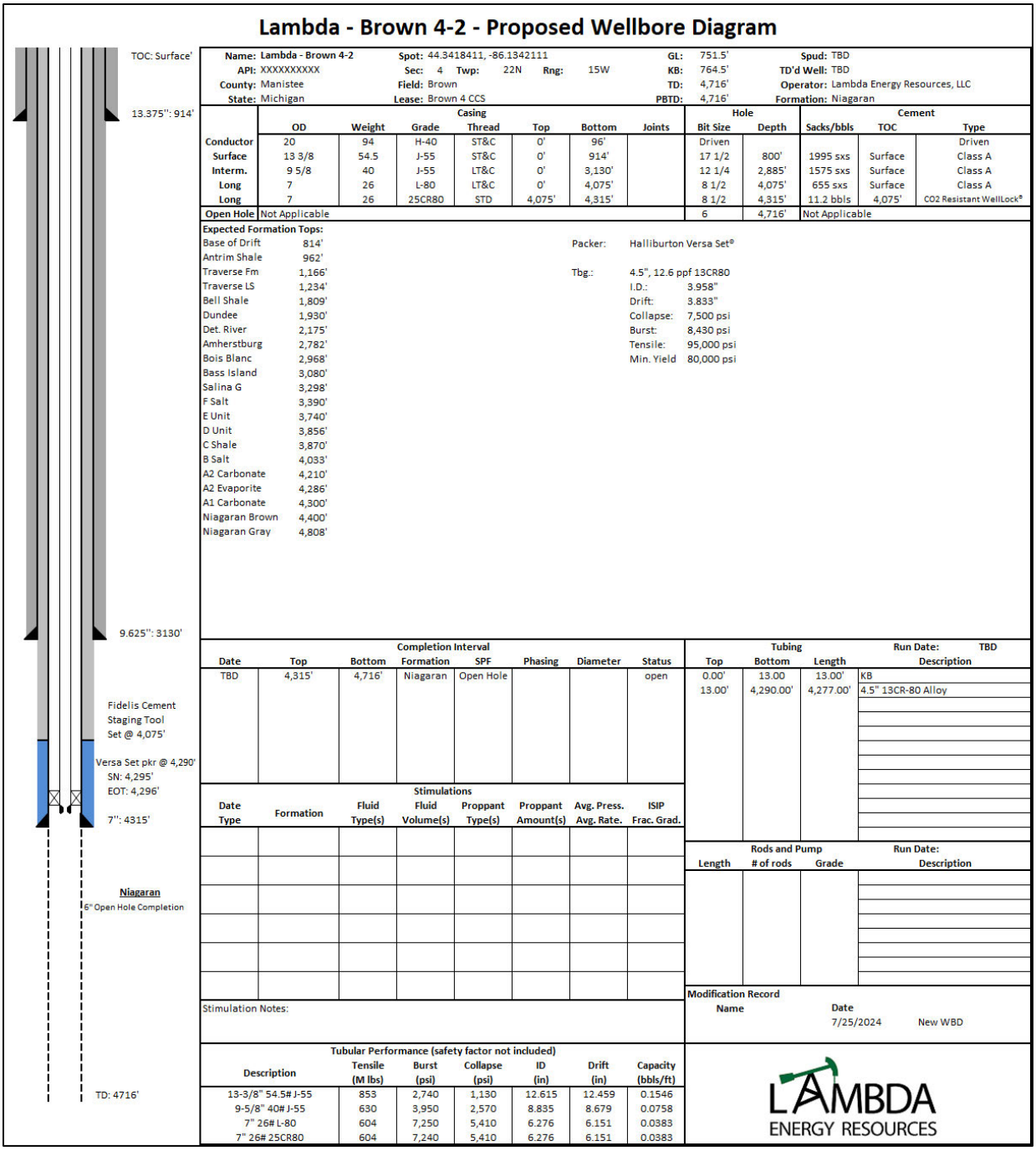

Figure 2: Proposed wellbore diagram for the Lambda-Brown 4-2 CO_2 injection well.

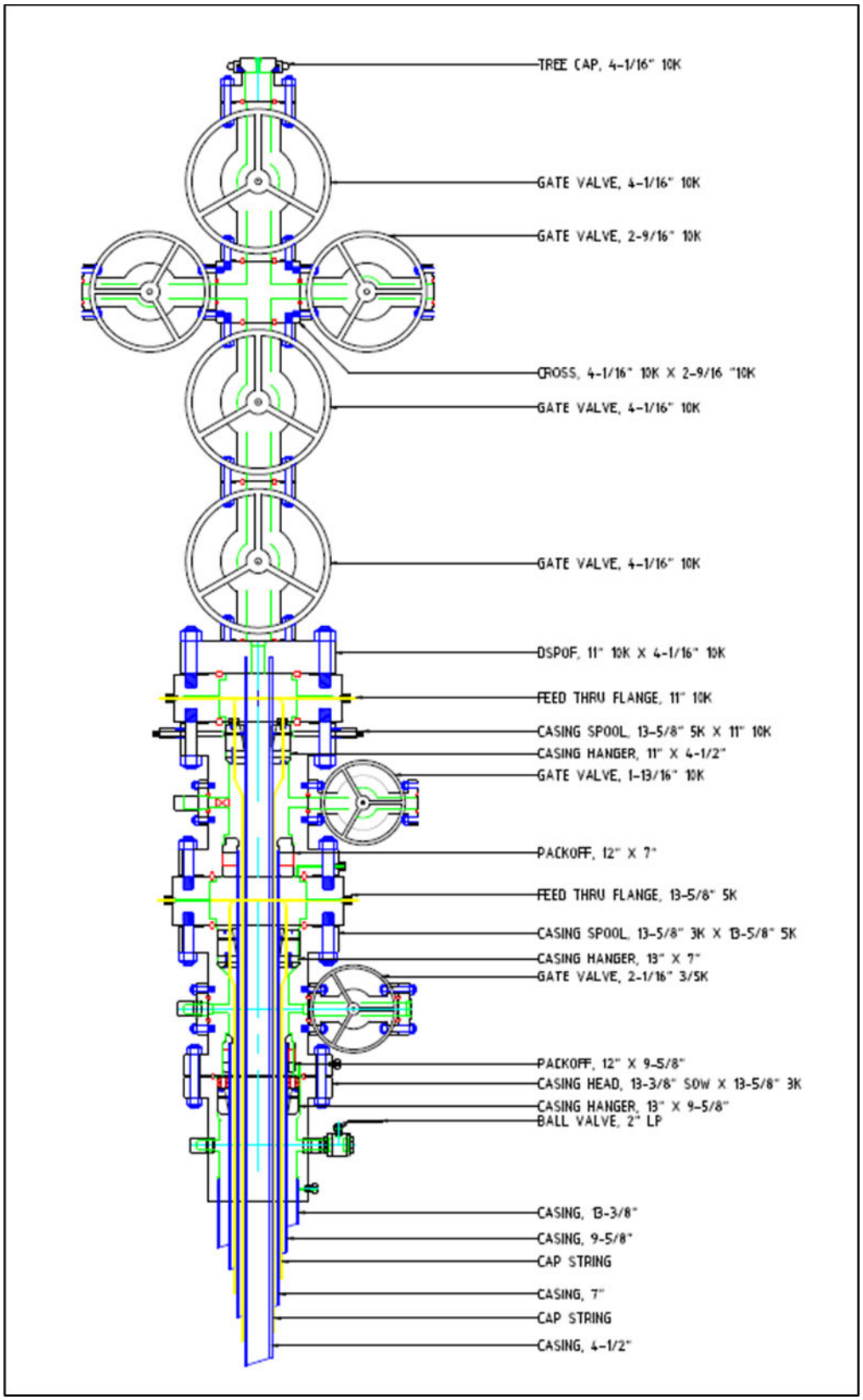

Figure 3: Proposed wellhead design for the Lambda-Brown 4-2 CO_2 injection well.

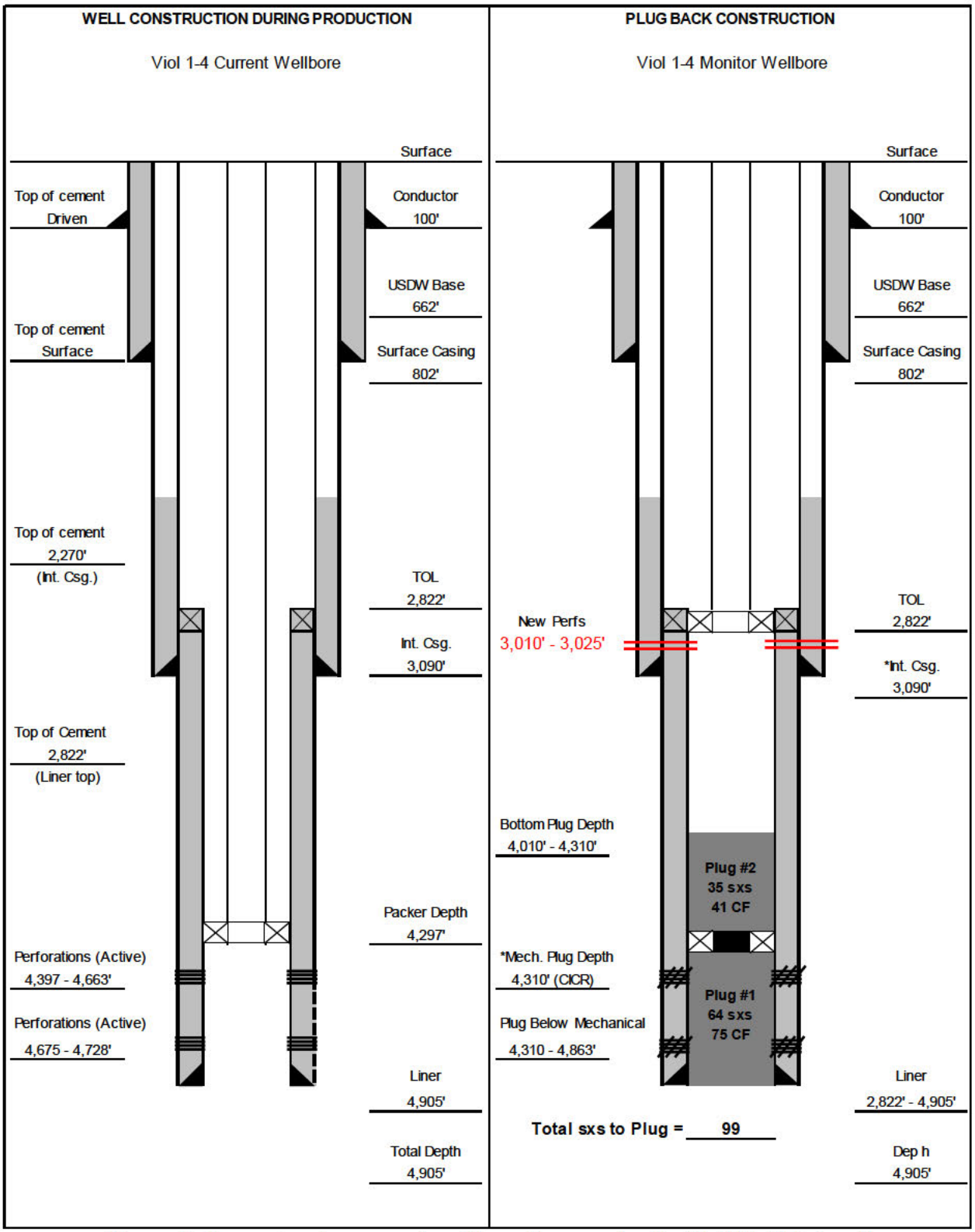

Figure 4: Current and proposed wellbore diagram for the Viol Et Al 1-4 well.

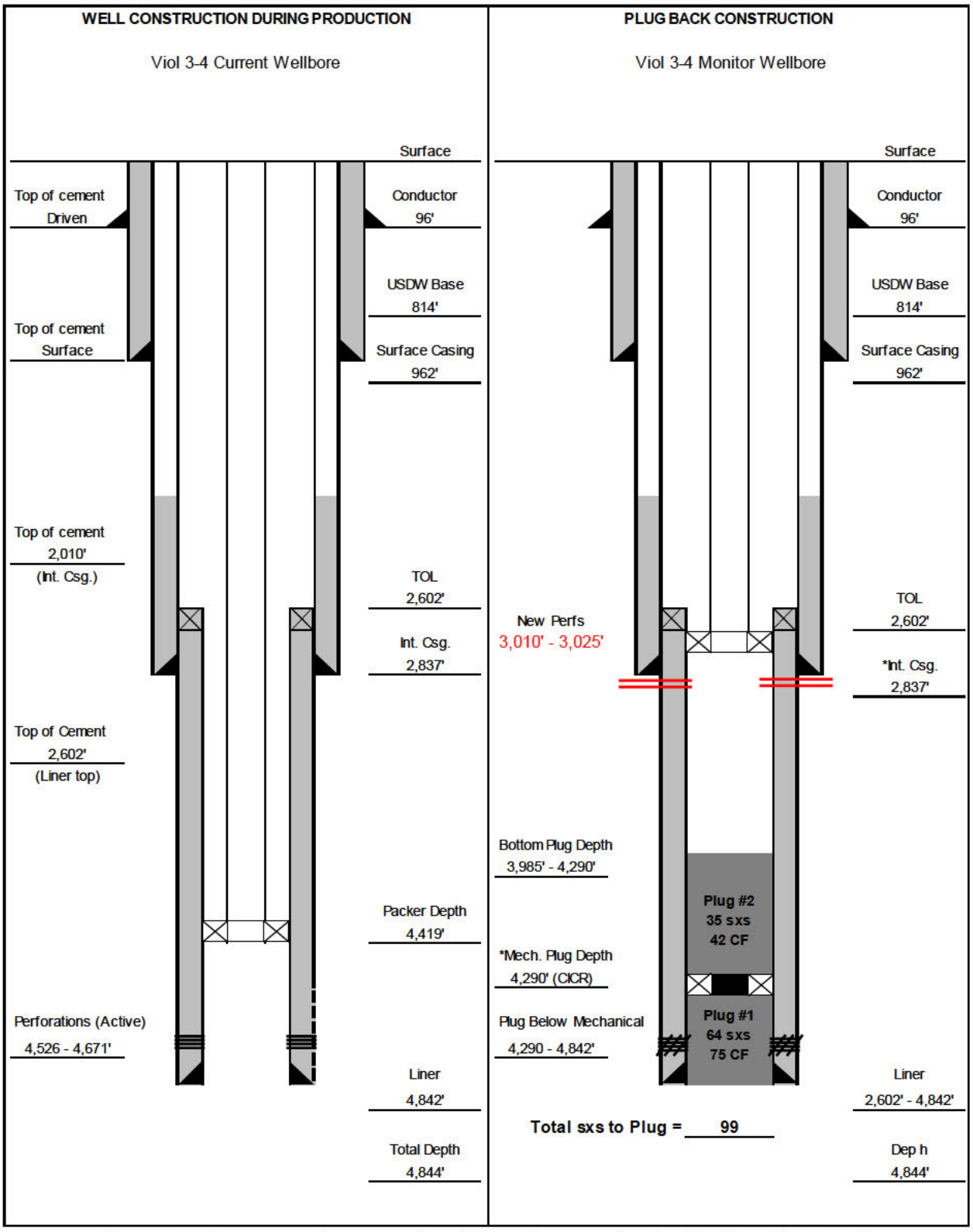

Figure 5: Current and proposed wellbore diagram for the Viol Et Al 3-4 well.

[i] https://www.api.org/~/media/files/ehs/climate-change/summary-carbon-dioxide-enhanced-oil-recovery-well-tech.ashx