Underground Injection Control
Carbon Sequestration
Class VI Permit Application

CONSTRUCTION DETAILS
40 CFR 146.86
Section 5.0

NexGen Carbon Oklahoma, LLC
Vanguard CCS Hub

June 2025

5.0 CONSTRUCTION DETAILS

VANGUARD CCS HUB

INSTRUCTIONS

This template provides a suggested outline and recommendations for the construction details summary for a Class VI well. Permit applicants are not required to use this template. This document does not substitute for promulgated provisions or regulations, nor is it a regulation itself, and it does not impose legally-binding requirements on the U.S. Environmental Protection Agency (EPA), states, or the regulated community.

Note that references to EPA's Class VI Rule in the code of federal regulations (CFR) are provided in this template. States with Class VI primacy have requirements that are at least as stringent as EPA's. If your Class VI well is in a primacy state, consult your permitting authority about any additional requirements for what must be included in the plan.

In this template, instructions or suggestions appear in ***blue text***. These are provided to assist with site- and project-specific plan development. These are recommendations and are not required elements of the federal Class VI Rule.

Please delete the ***blue text*** and replace the yellow highlighted text before submitting your document. Similarly, please adjust the example text and tables throughout as necessary (e.g., by adding or removing rows or columns). Appropriate figures, references, etc. should also be included to support the text of the plan.

For more information, see EPA's Class VI guidance documents at https://www.epa.gov/uic/class-vi-guidance-documents. It is the responsibility of the owner or operator to maintain records of previous revisions to this plan.

Facility Information

Facility name: Vanguard CCS Hub
Vanguard I-1
Vanguard I-2
Vanguard I-3
Vanguard I-4
Vanguard I-5
Vanguard I-6
Vanguard I-8
Vanguard I-9
Vanguard I-10
Vanguard I-12

Plan revision number: 0
Plan revision date: 6/24/2025

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Well locations: Osage County, Oklahoma

Vanguard I-1: Lat 36.633288°N, Lon -96.571029°W (NAD 83)
Vanguard I-2: Lat 36.660083°N, Lon -96.534652°W (NAD 83)
Vanguard I-3: Lat 36.664329°N, Lon -96.586951°W (NAD 83)
Vanguard I-4: Lat 36.710244°N, Lon -96.542370°W (NAD 83)
Vanguard I-5: Lat 36.744047°N, Lon -96.533843°W (NAD 83)
Vanguard I-6: Lat 36.724157°N, Lon -96.489526°W (NAD 83)
Vanguard I-8: Lat 36.823356°N, Lon -96.620496°W (NAD 83)
Vanguard I-9: Lat 36.849167°N, Lon -96.592912°W (NAD 83)
Vanguard I-10: Lat 36.893849°N, Lon -96.578026°W (NAD 83)
Vanguard I-12: Lat 36.785641°N, Lon -96.594085°W (NAD 83)

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Acronyms and Abbreviations

25CR	25 chromium
A	
AoR	area of review
API	American Petroleum Institute
B	
BBL	barrel
C	
C	Celsius
CO_2	carbon dioxide
CRA	corrosion resistant alloys
D	
DAC	Direct attach copper
DAT	Digital audio tape
DF	design factor
DTS	Distributed Temperature Sensing
E	
ECD	equivalent circulating density
EPA	Environmental Protection Agency
F	
F	Fahrenheit
ft	foot or feet
H	
H_2S	hydrogen sulfide
I	
in	inch or inches
K	
KIPS	equivalent of 1,000 pounds of force
ksi	thousand pounds per square inch
L	
lbm/ft	pounds per foot
M	

Mta	million tons per annum (year)
O	
OBM	oil based mud
OEM	Original equipment manufacturer
P	
ppf	Pounds per foot
PPG	pounds per gallon
psi	pounds per square inch
psi/ft	pounds per square inch per foot
S	
SCADA	Supervisory Control and Data Acquisition
SWD	Salt Water Disposal
T	
TEC	Tubing encapsulated cable
TOC	top of cement
U	
UCZ	Upper confining zone
USDW	underground source of drinking water
V	
VAM	A threaded and coupled connection for tubing and casing string types, providing gas-tight sealing under severe conditions
W	
w/m	watts per meter
WBD	Wellbore diagram
WBM	water based mud

5.0 CONSTRUCTION DETAILS

The design and operations of the injection and monitoring wells consider the injection volume, rate, chemical composition, and physical properties of the injectate fluid, metallurgical evaluations, as well as the potentially corrosive nature of the injectate fluid and its interaction with wellbore components. The design of the injection wells is optimized to permanently sequester CO_2 and prevent the movement of CO_2 and subsurface fluids into USDWs.

The expected composition of the entire injectate stream is shown in *Section 7* and will consist of greater than 95% CO_2 and less than 1,500ppm water content. Future samples and laboratory testing will validate the injectate stream composition upon confirmation of the final source.

The upper Arbuckle Group carbonate is the primary injection target for the injectors with the Lower Mississippian Limestone unit and Woodford Shale providing the primary upper confining zone (UCZ), with the lower 40% of the Arbuckle group providing the lower confining seal, due to lower permeability.

The ten (10) injection wells, ten (10) above-zone monitoring wells, and seven (7) in-zone monitoring wells planned at the Vanguard CCS Hub will be constructed in accordance with 40 CFR 146.82(a)(9), (11), and (12) and 40 CFR 146.86. The designs incorporate corrosion and CO2-resistant materials (CRA) and ensures compatibility with downhole tools, fiber optic cable, gauges, and workover equipment allowing for effective operation and maintenance. The wellbore cement design, and products used, to cement the well are designed to create good, reliable bonding between the casing and formations while withstanding the potentially corrosive nature of the injectate. The casings are designed with a sufficient cement sheath to protect the wellbore from developing any channeling out of the injection interval and to maintain the CO_2 below the UCZ (the Woodford Formation and the Lower Miss. Limestone).

This section also includes the design and construction plans for the monitoring wells to support the injection and monitoring processes outlined in the application. The plan includes drilling ten (10) above-zone monitoring wells, designated: Vanguard AZM-1, Vanguard AZM-2, Vanguard AZM-3, Vanguard AZM-4, Vanguard AZM-5, Vanguard AZM-6, Vanguard AZM-8, Vanguard AZM-9, Vanguard AZM-10, Vanguard AZM-12 and seven (7) in-zone monitoring wells, labeled Vanguard IZM-1 through Vanguard IZM-7. These monitoring wells are being permitted for construction through all applicable federal, state and local regulatory entities.

The specific construction details for the Vanguard I-1 injection well, the Vanguard AZM-1 above-zone monitoring well, and the Vanguard IZM-1 in-zone monitoring well, are described in this section in detail. All other injection, above-zone and in-zone well details will follow the same procedures. The AZM wells will be equipped with DTS fiber optic cable to provide continuous downhole temperature and allow for indirect CO_2 monitoring when required. The IZM wells will be equipped with both DTS and behind casing quartz pressure gauges to provide continuous downhole temperature and pressure readings throughout the wellbore and allow for indirect CO_2 monitoring when required. The tables in *Section 5.1, 5.2*, and *5.3* specify well design parameters for each individual injector, in-zone monitoring and above-zone monitoring well, respectively.

Bottomhole assemblies and drill string analysis will be performed to prevent excessive wellbore deviation. Deviation surveys will be taken while drilling, and the well will be corrected for direction and/or inclination if required. All downhole equipment will be operated within OEM specifications to prevent damage to the bottomhole assembly (BHA) and drill string. If drilling equipment is lost downhole, fishing services are available for recovery. A loss circulation response plan will be implemented in collaboration with the drilling fluid services provider, and materials will be made available on-site. Cement modeling will be conducted prior to the final design proposal, and the cement provider will adhere to all regulatory requirements, API specifications, and recommended practices.

5.1 Proposed Stimulation Program [40 CFR 146.82(s)(9)]

Vanguard injection wells may require a stimulation program over selected intervals after well perforation, depending on downhole conditions. Currently they are not anticipated to require stimulation, however if stimulation is required, the zones will be chosen based on well log, core, and formation testing evaluations. Core testing will be performed for fluid compatibility and reactivity. Additional data will be used to design stimulation procedures submitted to EPA Region 6 for approval. Arbuckle SWD wells have historically responded well to acid stimulations. Any downhole-injected chemicals will comply with state and federal regulations. See *Section 12*—Stimulation Program for details on the planned stimulation program, should it be needed.

5.2 Introduction

NexGen permit's *Section 5* outlines the engineering design specifications for the injectors, while *Section 7* details the operational strategies for the planning and operations of the proposed injection wells **Table 5.1**.

Table 5.1—Injection well design details for Vanguard I-1, Vanguard I-2, Vanguard I-3, Vanguard I-4, Vanguard I-5, Vanguard I-6, Vanguard I-8, Vanguard I-9, Vanguard I-10, Vanguard I-12

Well Name	Injection Zone Formation Name(s)	Injection Well Total Depth (ft)	Injection Zone Depths (ft)
Vanguard I-1	Upper Arbuckle	3,724	3,104-3,664
Vanguard I-2	Upper Arbuckle	3,611	3,055-3,551
Vanguard I-3	Upper Arbuckle	3,848	3,240-3,788
Vanguard I-4	Upper Arbuckle	3,589	3,092-3,529
Vanguard I-5	Upper Arbuckle	3,536	3,072-3,476
Vanguard I-6	Upper Arbuckle	3,404	2,919-3,344
Vanguard I-8	Upper Arbuckle	3,832	3,307-3,772
Vanguard I-9	Upper Arbuckle	3,901	3,308-3,841
Vanguard I-10	Upper Arbuckle	3,808	3,168-3,748
Vanguard I-12	Upper Arbuckle	3,832	3,305-3,772

*Depths are measured depth (ft)

The ten injection wells, collectively, are designed to inject approximately 3.5 million metric tons per year at an average wellhead pressure of 1,140 psi and a maximum annular pressure of 1,240 psi. The estimated Arbuckle Formation reservoir temperature is 115°F, and the fluid in the injection zone is assumed to be brine with approximately 125,000 mg/L TDS.

5.3 General Outline of Injection Well Design [40 CFR 146.82(a)(12)]

5.3.1 Mechanical Integrity Testing

Annulus Pressure Test

All annuli, except the tubing annulus, will be cemented to the surface. NexGen will ensure mechanical integrity by performing an annular pressure test after installing the tubing. The annular pressure test will demonstrate the mechanical integrity of the casing above the packer, tubing, and packer sealing element. The procedure outlines how this test will be conducted:

1. Move in and rig up the pump unit.
2. Perform fingerprint pressure up at the planned pump rate against a closed valve to ensure no leaks are present upstream of the tubing annulus.
3. Line up to pump down the tubing annulus.
4. Begin pumping down the tubing annulus at the same rate the fingerprint pressure up was performed.
5. Test pressure will be equal to or less than 80% of exposed equipment but no greater than the limited surface injection pressure or 500 psi, whichever is less.
6. All ports into the casing annulus must be closed except the one monitored by the test pressure gauge.
7. The test pressure will be monitored and recorded for a minimum duration of 30 minutes.
8. Any discernable loss (> 10%) of pressure during the testing period will be considered a failed test.

5.3.2 Injection Well Construction Details

The well design, for the ten (10) injection wells, includes a 100-ft conductor pipe (16 in), followed by 600-1,100 ft of API 9 5/8 in, 40 ppf, J-55 surface casing extending 150 ft below the base of the Vamoosa Formation (at each injection well location), identified as the lowermost possible base of the USDW.

The production casing, also referred to as the long string casing, will be a combination of API 7 in, 26ppf, L-80 and CRA 7 in, 26ppf 25CR80ksi casing with premium connections, extending approximately 60 ft into the upper Arbuckle reservoir at an average depth of 3,100 ft. The long string will be cemented to surface in two (2) stages and will secure the upper Arbuckle Group reservoir, the overlying confining layers, and the saline monitoring interval. At each stage of construction, casing will be cemented to the surface as per U.S. Environmental Protection (EPA) Class VI standards, to ensure zonal isolation.

Expected loads on the surface casing, production casing, and production tubing will be within equipment specifications. Due to the shallow depths of the wells modeled loads (downhole stresses) with design limits and equipment specification limits were not modeled at this time, but will be confirmed prior to running.

Below the long string casing shoe, the upper Arbuckle Group interval will be left open hole to allow for injection. The Arbuckle Group has been used for saltwater disposal (SWD) in Osage

County, OK since the 1950s, with an estimated 300 million barrels of produced water effectively injected and confined over the past seven (7) decades. Existing disposal wells in the area are typically open-hole completions. This historical success in high-volume water disposal, and lack of induced seismicity, supports the proposed method for containing CO_2 in the upper Arbuckle Group reservoir. The proposed designs for these wells are depicted in **(Figure 5.1)** and **Appendix 1—Wellbore Diagrams for Injection Wells.**

5.3.2.1 *Casing and Cementing (40 CFR 146.86(b)(iv))*

The casing and cement used in the construction of each of the Vanguard Injection, Above-Zone Monitoring, and In-zone monitoring wells will have sufficient structural strength and are designed for the life of the sequestration project. All well materials are compatible with all injectate and reservoir fluids they may be and meet or exceed standards developed for such materials by the American Petroleum Institute, ASTM International. The casing and cementing programs are designed to prevent the movement of fluids into or between USDWs.

Upon reaching final depths, a casing centralizer model will be completed, such that a sufficient number of centralizers are installed from the long string casing shoe to surface, to ensure the best possible cement barrier and ensure isolation and integrity. Cementing programs include lead and tail slurries in addition to a stage tool to ensure zonal coverage and that all strings are cemented to the surface, while to maximize cementing efficiency.

5.3.2.2 *Tubing and Packer*

Injectate fluid will be injected through tubing with a packer. The injection tubing will be 3-½-in 25CRW, with premium connections, installed from surface to 60 ft above the long string casing shoe isolated with a 3-½-in x 7-in CRA material retrievable packer. All tubular and packer materials will meet or exceed standards developed for such materials by the American Petroleum Institute, ASTM International, and will be compatible with all fluids with which the materials may be expected to come into contact. The expected composition of the entire injectate steam is shown in *Section 7* and will consist of greater than 95% CO_2 and less than 150 ppm water content. Future samples and laboratory testing will validate the injectate stream composition, upon confirmation of the final source.

5.3.2.3 *Injection Well Monitoring Devices*

The tubing and casing annulus pressures will be continuously monitored at surface and downhole to ensure that well integrity is maintained. A SCADA system will measure and record downhole temperatures and pressures in the injection interval and assist in monitoring the CO_2 plume's size. The monitoring system consists of running a fiber optic cable (purple line on **Figure 5.1**) as the production casing is run in the hole. The cable will then be cemented into place. See permit *Section 8* for additional information regarding monitoring plan.

5.3.3 Injection Well Construction Procedure

The following is an outline procedure describing the steps to construct the injector Vanguard I-1:

1) Move in, rig up drilling rig.
2) Drill 20 in conductor hole to 100 ft.
3) RIH 100 ft of 16 in, 64lb./ft, H40 casing.
4) Cement conductor casing from 100 ft to surface, using Class A cement (150sx + excess).
5) Drill 12-¼ in hole with freshwater spud mud to approximately 754 ft.
6) Run open hole logs from 754 ft to 100 ft.
7) RIH 754 ft of 9 5/8 in, J-55, 40lb./ft, casing.
8) Cement surface casing from 754 ft to surface using 14.5ppg, Class A cement (245sx + excess).
9) Install blowout preventor and pressure test.
10) Drill 8-1/2 in. hole from 754 ft to approximately 3,104 ft.
11) Run open hole logs from 3,104 ft to 754 ft.
12) Run cased hole logs from 754 ft to surface.
13) Run 283 ft of 7 in. 26 lb./ft, 25Cr80ksi, premium connection, casing followed by 2,821 ft, 7 in 26 lb/ft) L80, premium connection, casing complete with DTS fiber optic cable to casing point. Install DV tool at approx. 1650ft. Ensure final centralizer program is followed.
14) Cement the 7-in. casing in two (2) stages as follows:
    a. Stage 1:
        i. Pump 1,171ft of class G, 11.8ppg, lead slurry
        ii. Followed by 283ft of 14.5ppg EverCrete or equivalent, tail slurry
    b. Stage 2:
        i. Pump 1,650ft of Class G, 11.8ppg, to surface

15) WOC. RIH w. 6 1/8 in bit and drill out DV tool at 1,650 ft and float shoe at 3,104 ft.
16) Drill 6 1/8 in open hole to TD of approximately 3,724 ft.
17) Run open hole logs from 3,724 to 3,104 ft.
18) Run cased hole logs with baseline VDL/CBL, USIT, and temperature log from 3,104 ft to 754 ft
19) Nipple down BOP's and install wellhead.
20) Rig down, move out drilling rig.
21) Move in and rig up a completion rig.
22) RIH with work string and clean to TD to ensure open hole is free and clear.
23) Pick up and pressure test into the hole 3-½-in., 9.2ppf, 25CRW, VAMTop (or equivalent) injection tubing string with a 7"x3 ½" CRA retrievable packer complete with tubing and annular bottom hole pressure gauges on TEC, and 2jts of tail pipe.
24) Set packer at approximately 2,979 ft.
25) Land tubing bottom at approximately 3,044 ft and install injection tree. Complete annular MIT
26) Rig down the completion rig.

Table 5.2—Open hole diameters and intervals Vanguard Injection wells

	Surface Hole									
Well[1]	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	0-754	0-686	0-916	0-776	0-765	0-568	0-1,117	0-1,054	0-984	0-1,058
Open Hole Diameter (inches)	12 1/4									
Comment	Landed 150 ft below base Vamoosa Formation									

	Long String									
Well	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	3,104	3,055	3,240	3,092	3,072	2,919	3,307	3,308	3,168	3,305
Open Hole Diameter (inches)	8 1/2									
Comment	Landed approx. 60ft into top Arbuckle									

	Open Hole Injection Interval									
Well	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth Interval (ft TVD)	3,104 - 3,724	3,055 - 3,611	3,240 - 3,848	3,092 - 3,589	3,072 - 3,536	2,919 - 3,404	3,307 - 3,832	3,308 - 3,901	3,168 - 3,808	3,305- 3,832
Open Hole Diameter (inches)	6 1/8									
Comment										

[1] Note: Well name nomenclature has been shortened for brevity (e.g., from Vanguard I-1 to I-1).

Table 5.3— Casing Specifications for Vanguard Injection wells

	Surface Casing									
Well	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	0-754	0-686	0-916	0-776	0-765	0-568	0-1,117	0-1,054	0-984	0-1,058
Outside Diameter (inches)	9 5/8									
Inside Diameter (inches)	8.835									
Weight (ppf)	40									
Grade (API)	J-55									
Design Coupling	LT&C									
Burst Strength (psi)	3,950									
Collapse Strength (psi)	2,570									

	Long String									
Well	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	0-2,821	0-2,728	0-2,950	0-2,817	0-2,806	0-2,644	0-3,038	0-3,054	0-2,914	0-3,071
Outside Diameter (inches)	7									
Inside Diameter (inches)	6.276									
Weight (ppf)	26									
Grade (API)	L-80									
Design Coupling	VAM or equivalent									
Thermal Conductivity (BTU/(h*ft*F)	16.178									
Burst Strength (psi)	7,240									
Collapse Strength (psi)	5,410									

	Long String - CRA

Well	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	2,821-3,104	2,728-3,055	2,950-3,240	2,817-3,092	2,806-3,072	2,644-2,919	3,038-3,307	3,054-3,308	2,914-3,168	3,071-3,305
Outside Diameter (inches)	7									
Inside Diameter (inches)	6.276									
Weight (ppf)	26									
Grade (API)	25Cr-80ksi									
Design Coupling	VAM or equivalent									
Thermal Conductivity (BTU/(h*ft*F)	8.089									
Burst Strength (psi)	7,450									
Collapse Strength (psi)	5,410									

Table 5.4 Tubing Specifications for Vanguard Injection wells

	Tubing									
Well	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	3,044	2,995	3,180	3,032	3,012	2,859	3,247	3,248	3,108	3,245
Outside Diameter (inches)	3 1/2									
Inside Diameter (inches)	2.992									
Weight (ppf)	9.2									
Grade (API)	25CRW									
Design Coupling	VAM or equivalent									
Burst Strength (psi)	10,450									
Collapse Strength (psi)	10,540									

Table 5.5 Packer Specifications for Vanguard Injection wells

Well	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Packer Type and Material	Premium packer with V0 rating (CRA)									
Packer Setting Depth (ft TVD)	2,979	2,930	3,115	2,967	2,947	2,794	3,182	3,183	3,043	3,180

Length	under review
Nominal Casing Weight (ppf)	26
Packer Main Body Outer Diameter (inches)	7
Packer Inner Diameter (inches)	under review

Table 5.6 Cement Specifications for Vanguard Injection wells

	Surface Casing									
	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	0-754	0-686	0-916	0-776	0-765	0-568	0-1,117	0-1,054	0-984	0-1,058
OH Diameter (in)	12 1/4									
Csg Diameter (in)	9 5/8									
Capacity (cf/ft)	0.3132									
% excess for washout	15%									
Cement Class	A									
Slurry Weight (lb/gal)	14.5									
Cement Yield (cf/sk)	1.39									
Volume (cf)	334	320	403	355	348	278	466	452	417	452

	Long String - Stage 2									
	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	0 - 1,650									
OH Diameter (in)	8 1/2									
Csg Diameter (in)	7									
Capacity (cf/ft)	0.1268									
% excess for washout	15%									
Cement Class	G									
Slurry Weight (lb/gal)	12.6									
Cement Yield (cf/sk)	2.26									
Volume (cf)	271									

	Long String - Stage 1 - Tail									
	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	2,821-3,104	2,728-3,055	2,950-3,240	2,817-3,092	2,806-3,072	2,644-2,919	3,038-3,307	3,054-3,308	2,914-3,168	3,071-3,305
OH Diameter (in)	8 1/2									
Csg Diameter (in)	7									
Capacity (cf/ft)	0.1268									
% excess for washout	15%									
Cement Class	Evercrete or equivalent									
Slurry Weight (lb/gal)	14.5									
Cement Yield (cf/sk)	1.22									
Volume (cf)	67	73	37	67	67	67	67	67	67	61

	Long String - Stage 1 - Lead									
	I-1	I-2	I-3	I-4	I-5	I-6	I-8	I-9	I-10	I-12
Depth (ft TVD)	1,650-2,821	1,650-2,728	1,650-2,950	1,650-2,817	1,650-2,806	1,650-2,644	1,650-3,038	1,650-3,054	1,650-2,914	1,650-3,071
OH Diameter (in)	8 1/2									
Csg Diameter (in)	7									
Capacity (cf/ft)	0.1268									
% excess for washout	15%									
Cement Class	G									
Slurry Weight (lb/gal)	12.6									
Cement Yield (cf/sk)	2.26									
Volume (cf)	203	192	215	203	192	181	237	237	215	237

5.3.4 Injection Well Construction Diagrams

PROPOSED WELL BORE SCHEMATIC
VANGUARD I -1 Injector

Status: Permit **START DATE:**

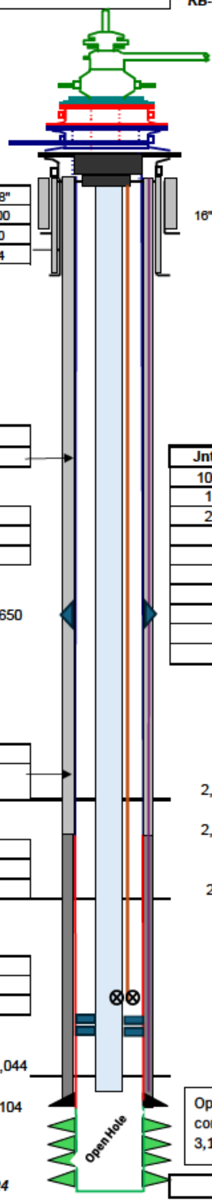
WELL NAME:	Vanguard I-1
	UWI (API No):
COUNTY:	Osage
STATE:	OK
LSD:	20-T25N-R7E

KB: 1,046 ft
GL: 1,034 ft
KB-GL: 12 ft
GL-THF:
KB-THF: 12.00

Surface Latitude: *36.633237*
Surface Longitude: *-96.57072646*

20" OH to 100 ft with 16", 64ppf, H40 conductor set at 100ft
12 1/4" OH to 754 ft
8 1/2" OH to 3104 ft
6 1/8" OH to 3724 ft. Complete well in Arbuckle formation - openhole

UCZ - Top Lwr Miss
Top of 25CR Csg & Acid Resist Cement ~ 100ft above top UCZ
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 7" casing
TEC cable for quartz bottom hole pressure gauges



Surface Casing

CASING SIZE	9 5/8"
CASING WEIGHT J-55	40.00
CEMENT (sks) Class A	240
LANDED DEPTH (ft)	754

Production Casing

SIZE (in)	7"
WEIGHT (ppf) - L80	26.00

Stage 2

CEMENT (sks) Class G	120
Top (ft)	0
Bottom (ft)	1650

DV Tool (ft) 1,650

Tubing String

Jnts	Description	Length	From	TO
100	3 1/2" VAMTop, 9.2#/ft, 25CRW tbg	3008.00	-	2,979
1	3 1/2" x 7" CRA material Retrievable Packer	5.00	2,979	2,984
2	3 1/2" VAMTop, 9.2#/ft, 25CRW tbg	60.00	2,984	3,044
	KB Difference	12.00	-	-
	Bottom Landed @	3085.00		

ft of perfs

Production Casing

SIZE	7"
WEIGHT (ppf) 25Cr80ksi Prem. Conn.	26.00

2,684 Top Miss - Perm (ft TVD)
2,821 Minimum TOC (Acid Resist) (ft)
2,921 Top Lwr Miss - UCZ (ft TVD)

Stage 1 - Lead

CEMENT (sks) Class G	90
Top (ft)	1650
Bottom (ft)	2821

Stage 1 - Tail

CEMENT (sks) Acid Resist	55
Top (ft)	2821
Bottom (ft)	3104

Top Arbuckle (ft TVD) 3,044
Csg. Pt. (ft TVD) 3,104
PBTD:
TD: *3724*

Openhole completion from 3,104 - 3,724ft

PERFORATIONS

FROM	FORMATION	TO	STATUS
3,104	Arbuckle	3,664	

Total O/H	620 ft

Figure 5.1 is the well bore diagram (WBD) for Vanguard I-1. The WBD's for all injection wells can be found in Appendix 1.

5.1.3 General Outline of Injection Well Design and Completion Schematic

5.4 Above-Zone Monitoring Wells

NexGen plans to drill and complete ten (10) above-zone monitoring wells, designated as Vanguard AZM-1, Vanguard AZM-2, Vanguard AZM-3, Vanguard AZM-4, Vanguard AZM-5, Vanguard AZM-6, Vanguard AZM-8, Vanguard AZM-9, Vanguard AZM-10 and Vanguard AZM-12, to monitor the lowermost permeable interval above the upper confining layer (Top Lower Mississippian). These monitoring wells will be located approximately 250 ft laterally east of the injection wells and will track any potential CO_2 migration from the confining zone into the first permeable zone above the UCZ. These wells will consist of corrosion-resistant materials for construction. The final well locations may be adjusted based on the results of hydrogeologic testing. NexGen intends to place these wells updip from the injection wells, targeting the areas most likely to experience a potential leak. The proposed designs for these wells are depicted in **Figure 5.2 and Appendix 2—Wellbore Diagrams for Above-Zone Monitoring Wells**

The above-zone monitoring wells are designed to be completed in the Top Mississippian Lime which is the first permeable zone above the confining layer, at an average depth of ~2,700 ft TVD.

The well design includes a 100-ft conductor pipe (16in), followed by 600-1,100 ft of API 7", 23ppf, J-55 surface casing extending 150 ft below the base of the Vamoosa Formation (at each location), identified as the lowermost possible base of the USDW.

The long string casing will consist of a combination of API 4 ½in, 11.6 ppf, L-80 and CRA 4 ½", 11.6 ppf 25CRW80ksi casing with premium connections, and will be landed 100 ft above the top of the Top Lower Mississippian upper confining layer, at an average depth of 2,820 ft. The long string will be cemented to surface in two (2) stages and will secure the upper Arbuckle reservoir, the overlying confining layers, and the saline monitoring interval. At each stage of construction, casing will be cemented to the surface as per U.S. Environmental Protection (EPA) Class VI standards, to ensure zonal isolation.

The above-zone monitoring wells are currently not planned to be perforated as all testing will be performed via indirect methods through casing with the casing pressures being monitored continuously at surface and downhole temperatures via DTS fiber optic cable. This will ensure that well integrity is maintained. If required, the casing is designed to allow for standard wireline perforating operations and equipment. A SCADA system will measure and record downhole temperatures in the Top Mississippian interval and in conjunction with

PNL (or equivalent) logging assist in monitoring the CO2 plume's size. The monitoring system consists of running a DTS fiber optic cable (purple line on **Figure 5.3**) as the production casing is run in the hole. The cable will then be cemented into place. See permit *Section 8* for additional information regarding monitoring plan.

The following is an outline procedure describing the steps to construct the Vanguard AZM-1 (Above-Zone Monitoring Well #1):

1) Move in, rig up drilling rig.
2) Drill 20 in conductor hole to 100 ft.
3) RIH 100 ft of 16 in, 64lb./ft, H40 casing.
4) Cement conductor casing from 100 ft to surface, using Class A cement (150sx + excess).
5) Drill 8 ½ in surface casing hole with freshwater spud mud to approximately 150 ft below base Vamoosa Formation.
6) Run open hole logs from surface casing depth TD (SCTD) to 100 ft.
7) RIH 7", J-55, 23lb./ft, surface casing to SCTD.
8) Cement surface casing from SCTD to surface using 14.5ppg, Class A cement (100sx + excess).
9) Install blowout preventor and pressure test.
10) Drill 6 1/8" hole to approximately 100 ft above Top Lower Mississippian formation (TD).
11) Run open hole logs from TD to surface casing shoe.
12) Run cased hole logs from surface casing shoe to surface.
13) Run 237 ft of 4 ½ in 11.6 lb./ft, 25Cr80ksi, premium connection, casing followed by 932 ft, 4 ½ in 11.6 lb./ft, L80, premium connection, casing complete with DTS fiber optic cable secured to the outside of the casing to casing point. Install DV tool at approx. 1,650ft. Ensure final centralizer program is followed.
14) Cement the 4 ½ in casing in two (2) stages as follows:
    a. Stage 1:
        i. Pump 932 ft of class G, 11.8ppg, lead slurry
        ii. Followed by 237 ft of 14.5ppg EverCrete or equivalent, tail slurry
    b. Stage 2:
        i. Pump 1,650 ft of Class G, 11.8ppg, to surface
15) WOC. RIH w. 3 ¾ in bit and drill out DV tool and clean to TD.
16) Run cased hole logs with baseline VDL/CBL, USIT, and temperature log from TD to surface casing shoe.
17) Nipple down BOP's and install wellhead.
18) Rig down, move out drilling rig.

Table 5.7 Open hole diameters and intervals for Vanguard AZM-1 to AZM-12

	Surface Hole									
Well	AZM-1	AZM-2	AZM-3	AZM-4	AZM-5	AZM-6	AZM-8	AZM-9	AZM-10	AZM-12
Depth (ft TVD)	0-751	0-682	0-912	0-773	0-759	0-567	0-1,118	0-1,053	0-983	0-1059
Open Hole Diameter (inches)	8 1/2"									
Comment	Landed 150ft below base Vamoosa Formation									

	Long String									
Well	AZM-1	AZM-2	AZM-3	AZM-4	AZM-5	AZM-6	AZM-8	AZM-9	AZM-10	AZM-12
Depth (ft TVD)	2,819	2,726	2,947	2,813	2,800	2,643	3,039	3,054	2,913	3,068
Open Hole Diameter (inches)	6 1/8"									
Comment	Landed approx. 100ft above Top Lwr Miss. UCZ									

Table 5.8 Casing Specifications for Vanguard AZM-1 to AZM-12

	Surface Casing									
Well	AZM-1	AZM-2	AZM-3	AZM-4	AZM-5	AZM-6	AZM-8	AZM-9	AZM-10	AZM-12
Depth (ft TVD)	0-751	0-682	0-912	0-773	0-759	0-567	0-1,118	0-1,053	0-983	0-1,059
Outside Diameter (inches)	7									
Inside Diameter (inches)	6.366									
Weight (ppf)	23									

Grade (API)	J-55
Design Coupling	LT&C
Burst Strength (psi)	4,360
Collapse Strength (psi)	3,270

	Long String									
Well	AZM-1	AZM-2	AZM-3	AZM-4	AZM-5	AZM-6	AZM-8	AZM-9	AZM-10	AZM-12
Depth (ft TVD)	0-2,582	0-2,525	0-2,707	0-2,615	0-2,579	0-2,436	0-2,784	0-2,787	0-2,629	0-2,836
Outside Diameter (inches)	4 1/2"									
Inside Diameter (inches)	4									
Weight (ppf)	11.6									
Grade (API)	L-80									
Design Coupling	VAM or equivalent									
Thermal Conductivity (BTU/(h*ft*F)	?									
Burst Strength (psi)	7,780									
Collapse Strength (psi)	6,350									

	Long String - CRA									
Well	AZM-1	AZM-2	AZM-3	AZM-4	AZM-5	AZM-6	AZM-8	AZM-9	AZM-10	AZM-12
Depth (ft TVD)	2,582-2,819	2,525-2,726	2,707-2,947	2,615-2,813	2,579-2,800	2,436-2,643	2,784-3,039	2,787-3,054	2,629-2,913	2,836-3,068
Outside Diameter (inches)	4 1/2"									

Inside Diameter (inches)	4
Weight (ppf)	11.6
Grade (API)	L-80
Design Coupling	VAM or equivalent
Thermal Conductivity (BTU/(h*ft*F)	?
Burst Strength (psi)	8,000
Collapse Strength (psi)	6,350

Table 5.9 Cement Specifications for Vanguard AZM-1 to AZM-12

	Surface Casing									
	AZM-1	AZM-2	AZM-3	AZM-4	AZM-5	AZM-6	AZM-8	AZM-9	AZM-10	AZM-12
Depth (ft TVD)	0-754	0-686	0-916	0-776	0-765	0-568	0-1,117	0-1,054	0-984	0-1,058
OH Diameter (in)	8 1/2									
Csg Diameter (in)	7									
Capacity (cf/ft)	0.1268									
% excess for washout	15%									
Cement Class	A									
Slurry Weight (lb/gal)	14.5									
Cement Yield (cf/sk)	1.39									
Volume (cf)	139	132	167	146	139	111	139	188	174	181

	Long String - Stage 2									
	AZM-1	AZM-2	AZM-3	AZM-4	AZM-5	AZM-6	AZM-8	AZM-9	AZM-10	AZM-12
Depth (ft TVD)	0 - 1,650									
OH Diameter (in)	6 1/8									
Csg Diameter (in)	4 1/2									
Capacity (cf/ft)	0.0942									

% excess for washout	15%
Cement Class	G
Slurry Weight (lb/gal)	12.6
Cement Yield (cf/sk)	2.26
Volume (cf)	203

	Long String - Stage 1 - Tail									
	AZM-1	AZM-2	AZM-3	AZM-4	AZM-5	AZM-6	AZM-8	AZM-9	AZM-10	AZM-12
Depth (ft TVD)	2,582-2,819	2,525-2,726	2,707-2,947	2,615-2,813	2,579-2,800	2,436-2,643	2,784-3,039	2,787-3,054	2,629-2,913	2,836-3,068
OH Diameter (in)	6 1/8									
Csg Diameter (in)	4 1/2									
Capacity (cf/ft)	0.0942									
% excess for washout	15%									
Cement Class	Evercrete or equivalent									
Slurry Weight (lb/gal)	14.5									
Cement Yield (cf/sk)	1.22									
Volume (cf)	49	43	49	43	43	43	49	49	49	43

	Long String - Stage 1 - Lead									
	AZM-1	AZM-2	AZM-3	AZM-4	AZM-5	AZM-6	AZM-8	AZM-9	AZM-10	AZM-12
Depth (ft TVD)	1,650-2,582	1,650-2,525	1,650-2,707	1,650-2,615	1,650-2,579	1,650-2,436	1,650-2,784	1,650-2,787	1,650-2,629	1,650-2,836
OH Diameter (in)	6 1/8									
Csg Diameter (in)	0.0942									
Capacity (cf/ft)	0.1268									

% excess for washout	15%									
Cement Class	G									
Slurry Weight (lb/gal)	12.6									
Cement Yield (cf/sk)	2.26									
Volume (cf)	125	113	136	124	125	113	147	147	125	147

5.4.1 Above-Zone Monitoring Well Construction Diagrams

Below **(Figure 5.2)** is the well bore diagram (WBD) for Vanguard AZM-1. The WBD's for all injection wells can be found in **Appendix 3—Wellbore Diagrams for In-Zone Monitoring Wells**

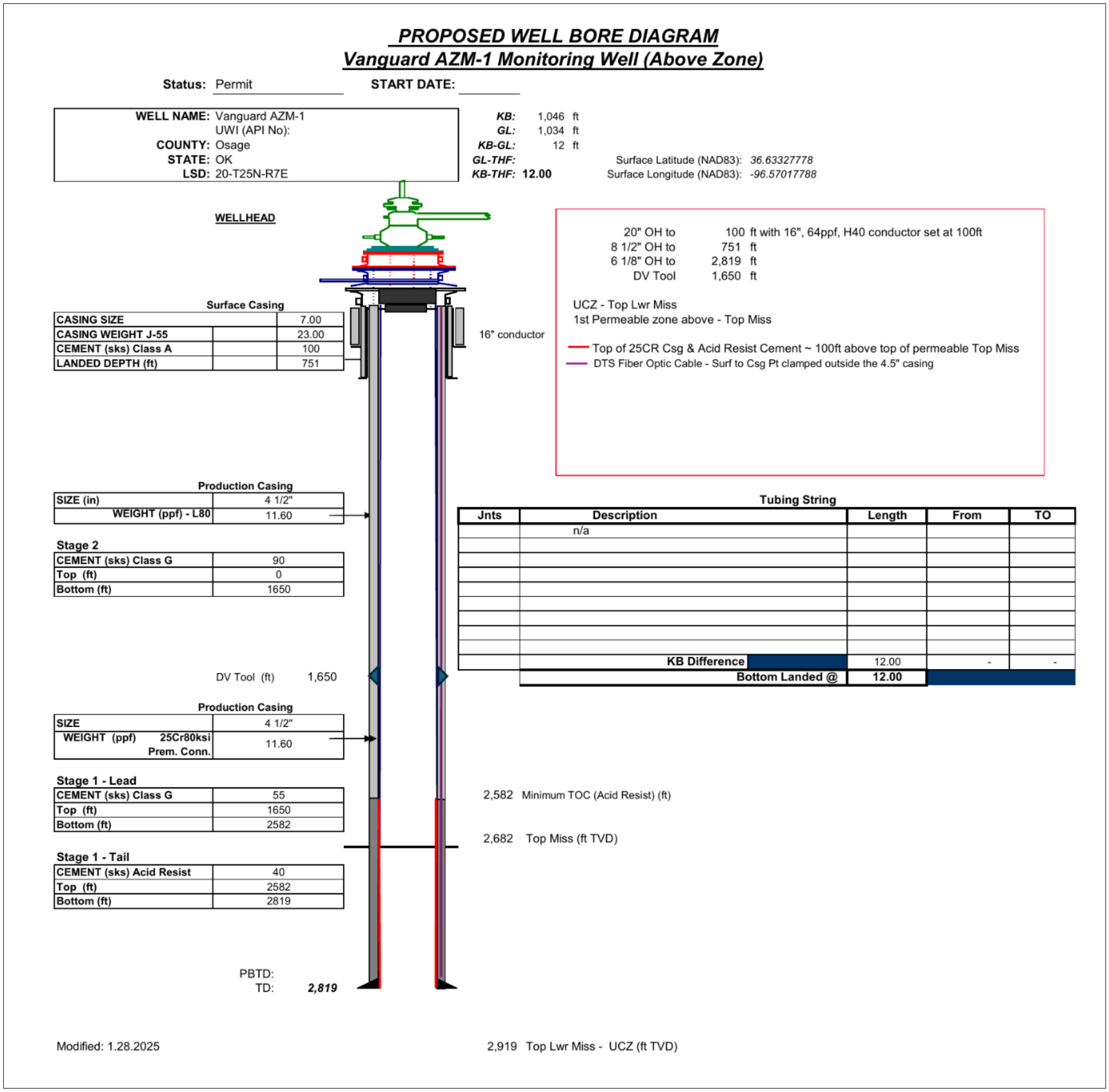


Figure 5.2 Vanguard AZM-1 (above-zone monitoring well) WBD

5.5 In-Zone Monitoring Wells

NexGen plans to drill and complete seven (7) in-zone monitoring wells, identified as Vanguard IZM-1 through Vanguard IZM-7, to monitor the injection zone within the upper Arbuckle Group and the interval above the confining zone in the upper Mississippian Formation. The wells will be completed with fiber optic cables for continuous monitoring purposes. These IZM wells will be strategically positioned near the edges of the estimated CO_2 plume around the 12 injection wells to detect any signs of CO_2 within the injection zone or migration beyond the Upper Confining

Zone. The proposed designs for IZM 1-7 are shown in **Appendix 3—Wellbore Diagrams for In-Zone Monitoring Wells** For more information on fiber optic cables, see *Section 8* of the permit application.

The in-zone monitoring wells are designed to be completed at an average depth of ~3,570 ft TVD, within the upper 60% of the Arbuckle Group injection zone.

The well design includes a 100 ft conductor pipe (16 in.), followed by 600–1,100 ft of API 7 in., 23 lbm/ft, J-55 surface casing extending 150 ft below the base of the Vamoosa Formation (at each location), identified as the lowermost possible base of the USDW.

The long string casing will consist of API 4 ½ in., 11.6 lbm/ft, L-80 casing landed approximately 100 ft above the Top Basement at an average depth of 3,900 ft. The long string will be cemented to surface in two (2) stages and will secure the upper Arbuckle reservoir, the overlying confining layers, and the saline monitoring interval. At each stage of construction, casing will be cemented to the surface as per U.S. Environmental Protection (EPA) Class VI standards, to ensure zonal isolation.

The in-zone monitoring wells are currently not planned to be perforated as all testing will be performed via indirect methods through casing with the casing pressures being monitored continuously at surface and downhole to ensure that well integrity is maintained. If required, the casing is designed to allow for standard wireline perforating operations and equipment. A SCADA system will measure and record downhole temperatures and pressures at the top of the injection interval, and at TD, and assist in monitoring the CO_2 plume's size. The monitoring system consists of running a fiber optic cable (purple line on **Figure 5.3**) as the casing is run in the hole. The cable will then be cemented into place. See permit *Section 8* for additional information regarding monitoring plan.

The following is an outline procedure describing the steps to construct the Vanguard IZM-1 (In-Zone Monitoring Well #1):

1) Move in, rig up drilling rig.
2) Drill 20in conductor hole to 100 ft.
3) RIH 100 ft of 16 in, 64lb./ft, H40 casing.
4) Cement conductor casing from 100 ft to surface, using Class A cement (150sx + excess).
5) Drill 8 ½in surface casing hole with freshwater spud mud to approximately 150 ft below base Vamoosa Formation.
6) Run open hole logs from surface casing depth TD (SCTD) to 100 ft.
7) RIH 7", J-55, 23lb./ft, surface casing to SCTD.
8) Cement surface casing from SCTD to surface using 14.5ppg, Class A cement (100sx + excess).
9) Install blowout preventor and pressure test.
10) Drill 6 1/8" hole to approximately 100 ft above Top Basement formation (TD).
11) Run open hole logs from TD to surface casing shoe.
12) Run cased hole logs from surface casing shoe to surface.
13) Run 4 ½" 11.6 lb./ft, L80, premium connection, casing complete with DTS fiber optic cable secured to the outside of the casing, to TD. Install and run 2 sets of cemented

perforated behind casing bottomhole gauges, run on TEC, landed at Top Arbuckle and immediately above float shoe. Install DV tool at approx. 1,650 ft. Ensure the final centralizer program is followed.

14) Cement the 4 ½ in casing in two (2) stages as follows:
    a. Stage 1:
        i. Pump 1,208 ft of class G, 11.8ppg, lead slurry
        ii. Followed by 1,226 ft of 14.5ppg EverCrete or equivalent, tail slurry
    b. Stage 2:
        i. Pump 1,650 ft of Class G, 11.8ppg, to surface

15) WOC. RIH w. 3 ¾in bit and drill out DV tool and clean to TD.
16) Run cased hole logs with baseline VDL/CBL, USIT, and temperature log from TD to surface casing shoe.
17) Nipple down BOP's and install wellhead.
18) Rig down, move out drilling rig.

Table 5.10 Open hole diameters and intervals for Vanguard IZM-1 to IZM-7

	Surface Hole						
Well	IZM-1	IZM-2	IZM-3	IZM-4	IZM-5	IZM-6	IZM-7
Depth (ft TVD)	0-760	0-273	0-945	0-577	0-1,218	0-1,014	0-1,025
Open Hole Diameter (inches)	8 1/2						
Comment	Landed 150ft below base Vamoosa Formation						
Long String							
	IZM-1	IZM-2	IZM-3	IZM-4	IZM-5	IZM-6	IZM-7
Depth (ft TVD)	4,085	3,287	3,926	3,592	4,239	4,055	4,053
Open Hole Diameter (inches)	6 1/8						
Comment	Landed approx. 100ft above Basement						

Table 5.11 Casing specifications for Vanguard IZM-1 to IZM-7

	Long String						
Well	IZM-1	IZM-2	IZM-3	IZM-4	IZM-5	IZM-6	IZM-7
Depth (ft TVD)	4,085	3,287	3,926	3,592	4,239	4,055	4,053
Outside Diameter (inches)	4 1/2"						
Inside Diameter (inches)	4						
Weight (ppf)	11.6						
Grade (API)	L-80						
Design Coupling	VAM or equivalent						
Thermal Conductivity (BTU/(h*ft*F)	?						
Burst Strength (psi)	7,780						

Collapse Strength (psi)	6,350

	Long String - CRA						
Well	IZM-1	IZM-2	IZM-3	IZM-4	IZM-5	IZM-6	IZM-7
Depth (ft TVD)							
Outside Diameter (inches)	7						
Inside Diameter (inches)	6.276						
Weight (ppf)	26						
Grade (API)	25Cr-80ksi						
Design Coupling	VAM or equivalent						
Thermal Conductivity (BTU/(h*ft*F)	8.089						
Burst Strength (psi)	7,450						

Table 5.12 Cement specifications for Vanguard IZM-1 to IZM-7

	Surface Casing						
	IZM-1	IZM-2	IZM-3	IZM-4	IZM-5	IZM-6	IZM-7
Depth (ft TVD)	0-760	0-273	0-945	0-577	0-1,218	0-1,014	0-1,025
OH Diameter (in)	8 1/2						
Csg Diameter (in)	7						
Capacity (cf/ft)	0.1268						
% excess for washout	15%						
Cement Class	A						
Slurry Weight (lb/gal)	14.5						
Cement Yield (cf/sk)	1.39						
Volume (cf)	139	70	167	111	209	174	181

	Long String - Stage 2						
	IZM-1	IZM-2	IZM-3	IZM-4	IZM-5	IZM-6	IZM-7
Depth (ft TVD)	0 - 1,650						
OH Diameter (in)	6 1/8						
Csg Diameter (in)	4 1/2						
Capacity (cf/ft)	0.0942						
% excess for washout	15%						
Cement Class	G						
Slurry Weight (lb/gal)	12.6						
Cement Yield (cf/sk)	2.26						
Volume (cf)	203						

	Long String - Stage 1 - Lead						
	IZM-1	IZM-2	IZM-3	IZM-4	IZM-5	IZM-6	IZM-7
Depth (ft TVD)	1,650-2,858	1,650-2,431	1,650-2,837	1,650-2,645	1,650-3,139	1,650-2,929	1,650-2,906
OH Diameter (in)	6 1/8						
Csg Diameter (in)	4 1/2						
Capacity (cf/ft)	0.0942						
% excess for washout	15%						
Cement Class	G						
Slurry Weight (lb/gal)	12.6						
Cement Yield (cf/sk)	2.26						
Volume (cf)	159	113	147	136	181	158	158

	Long String - Stage 1 - Tail (Evercrete or equiv)						
	IZM-1	IZM-2	IZM-3	IZM-4	IZM-5	IZM-6	IZM-7
Depth (ft TVD)	2,858-4,085	2,431-3,287	2,837-3,926	2,645-3,592	3,139-4,239	2,929-4,055	2,906-4,053
OH Diameter (in)	6 1/8						
Csg Diameter (in)	4 1/2						
Capacity (cf/ft)	0.0942						
% excess for washout	15%						
Cement Class	Evercrete or equivalent						
Slurry Weight (lb/gal)	14.5						
Cement Yield (cf/sk)	1.22						
Volume (cf)	153	116	141	122	141	140	147

5.5.1 In-zone Monitoring Well Construction Diagram

Below (**Figure 5.3**) is the well bore diagram (WBD) for Vanguard IZM-1. The WBD's for all in-zone monitoring wells can be found in **Appendix 3—Wellbore Diagrams for In-Zone Monitoring Wells**

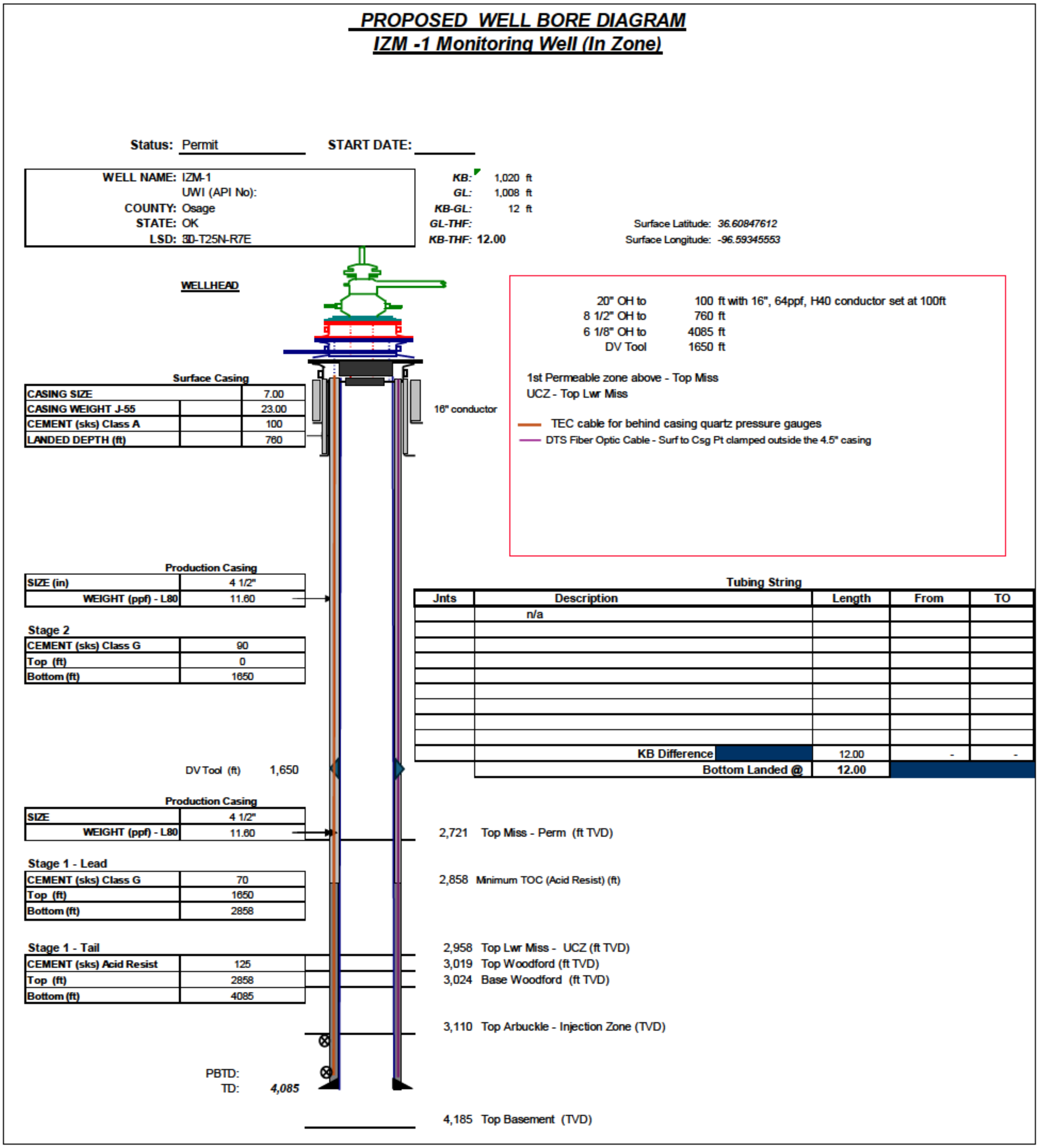


Figure 5.3 Vanguard IZM-1 (in-zone monitoring well) WBD

5.6 Near Surface Monitoring Wells

NexGen plans to drill and complete ten (10) groundwater and shallow seismic monitoring wells labeled Vanguard GWM-1 through Vanguard GWM-10. These wells will be located 150 ft due east of the AZM wells. These wells are further detailed in permit *Section 8.9* and illustrated in 5-4. Each GWM well will have a 6-inch hole diameter drilled to an average of 400 ft TVD. They will include the following components: two (2) 1.4-inch PVC cementation pipes, one (1) 0.6-inch seismic sensor line, one (1) 1.85-inch water probe sensor, and one (1) 2-inch PVC casing. The water quality probe will be installed within a slotted screen at a depth determined by logging data, as shown in **Figure 5.4**. A seismometer will be cemented at the bottom of the well to optimize coupling with the bedrock. NexGen will use services provided by Baker Hughes or an equivalent provider.

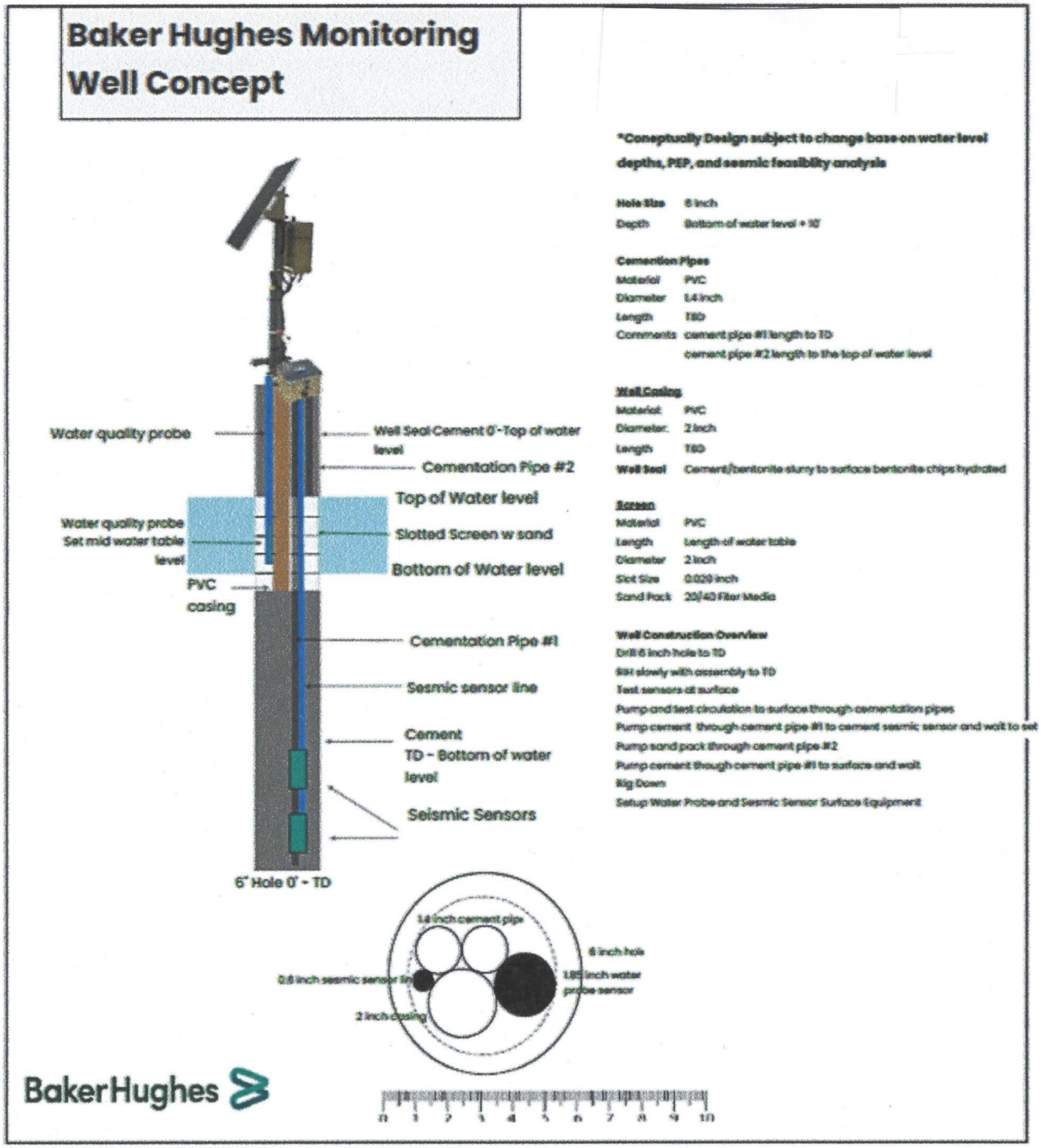


Figure 5.4 Vanguard GWM-1 (groundwater and seismic monitoring well) WBD

Appendix 1—Wellbore Diagrams for Injection Wells[2]

[2] NTD: All wellbore diagrams here - https://www.dropbox.com/scl/fo/ck79k9u2v1ureuoqjzzw8/AGdW042arBVOJSKD9SHb6p8?rlkey=t9st1vkhuuk5omyv5sz6s05be&dl=0

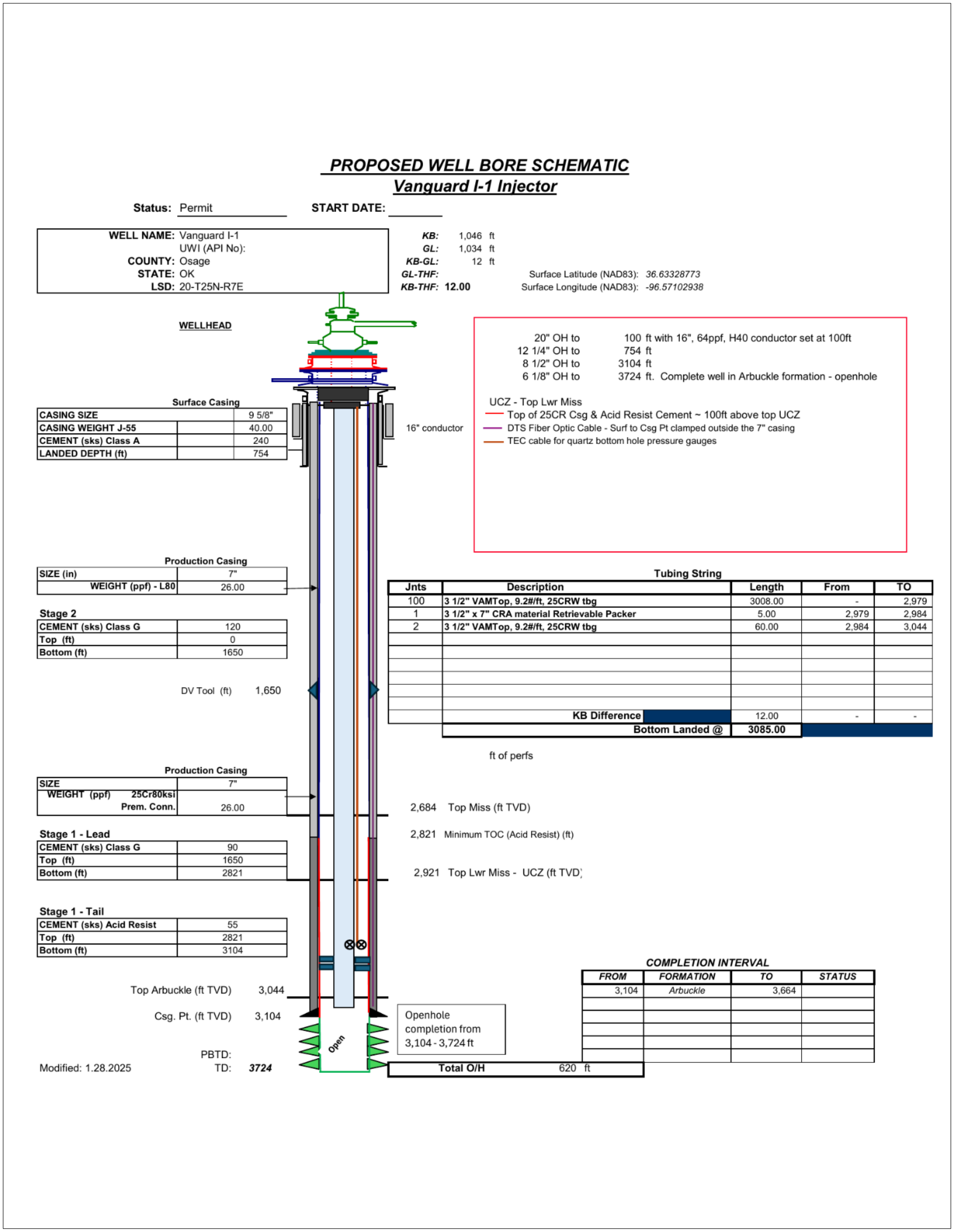


Figure 5.5—Planned well construction diagram for the Vanguard I-1 Injector.

PROPOSED WELL BORE SCHEMATIC
Vanguard I-2 Injector

Status: Permit **START DATE:**

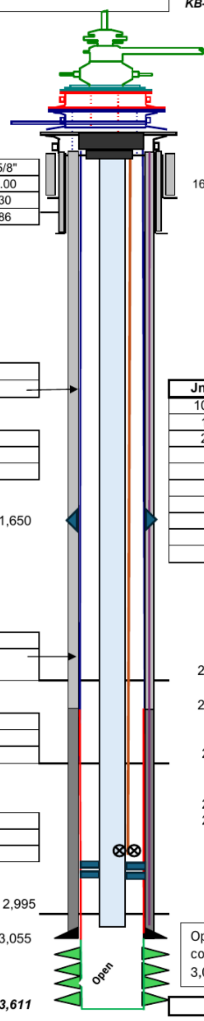
WELL NAME:	Vanguard I-2
UWI (API No):	
COUNTY:	Osage
STATE:	OK
LSD:	10-T25N-R7E

KB:	1,097	ft
GL:	1,085	ft
KB-GL:	12	ft
GL-THF:		
KB-THF:	**12.00**	

Surface Latitude (NAD83): *36.6600828*
Surface Longitude (NAD83): *-96.53465215*

20" OH to 100 ft with 16", 64ppf, H40 conductor set at 100ft
12 1/4" OH to 686 ft
8 1/2" OH to 3055 ft
6 1/8" OH to 3611 ft. Complete well in Arbuckle formation - openhole

UCZ - Top Lwr Miss
Top of 25CR Csg & Acid Resist Cement ~ 100ft above top UCZ
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 7" casing
TEC cable for quartz bottom hole pressure gauges



Surface Casing

CASING SIZE	9 5/8"
CASING WEIGHT J-55	40.00
CEMENT (sks) Class A	230
LANDED DEPTH (ft)	686

Production Casing

SIZE (in)	7"
WEIGHT (ppf) - L80	26.00

Stage 2

CEMENT (sks) Class G	120
Top (ft)	0
Bottom (ft)	1650

DV Tool (ft) 1,650

Tubing String

Jnts	Description	Length	From	TO
100	3 1/2" VAMTop, 9.2#/ft, 25CRW tbg	2930.00	-	2,930
1	3 1/2" x 7" CRA material Retrievable Packer	5.00	2,930	2,935
2	3 1/2" VAMTop, 9.2#/ft, 25CRW tbg	60.00	2,935	2,995
	KB Difference	12.00	-	-
	Bottom Landed @	**3007.00**		

Production Casing

SIZE	7"
WEIGHT (ppf) 25Cr80ksi Prem. Conn.	26.00

Stage 1 - Lead

CEMENT (sks) Class G	85
Top (ft)	1650
Bottom (ft)	2728

Stage 1 - Tail

CEMENT (sks) Acid Resist	60
Top (ft)	2728
Bottom (ft)	3055

2,627 Top Miss (ft TVD)
2,728 Minimum TOC (Acid Resist) (ft)
2,828 Top Lwr Miss - UCZ (ft TVD)
2,887 Top Woodford (ft TVD)
2,893 Base Woodford (ft TVD)

Top Arbuckle (ft TVD) 2,995
Long String Csg. Pt. (ft TVD) 3,055
PBTD:
TD: ***3,611***

Modified: 1.28.2025

Openhole completion from 3,055 - 3,611 ft

COMPLETION INTERVAL

FROM	*FORMATION*	*TO*	*STATUS*
3,055	*Arbuckle*	3,551	

Total O/H 556 ft

Figure 5.6—Planned well construction diagram for the Vanguard I-2 Injector.

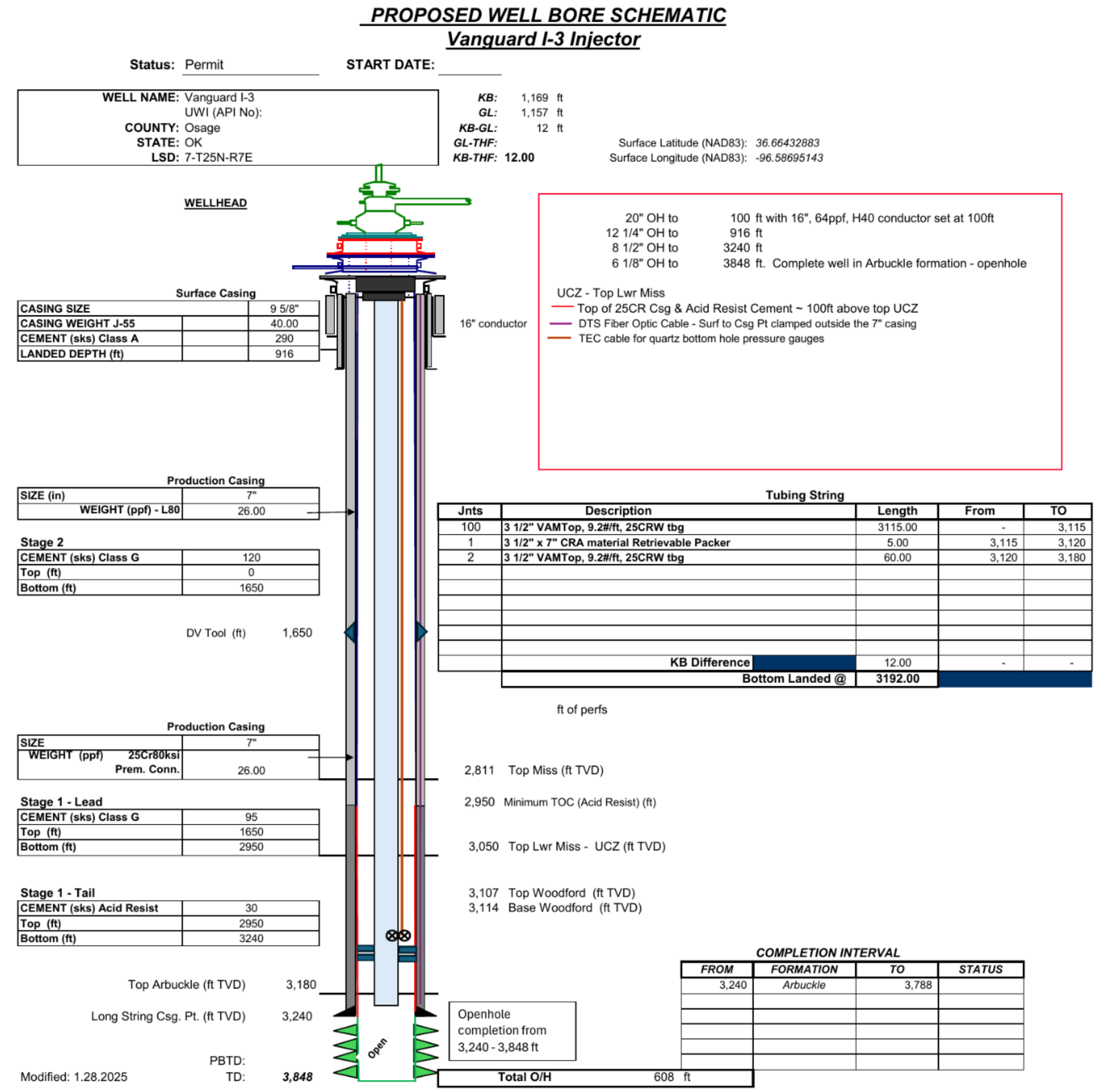


Figure 5.7—Planned well construction diagram for the Vanguard I-3 Injector.

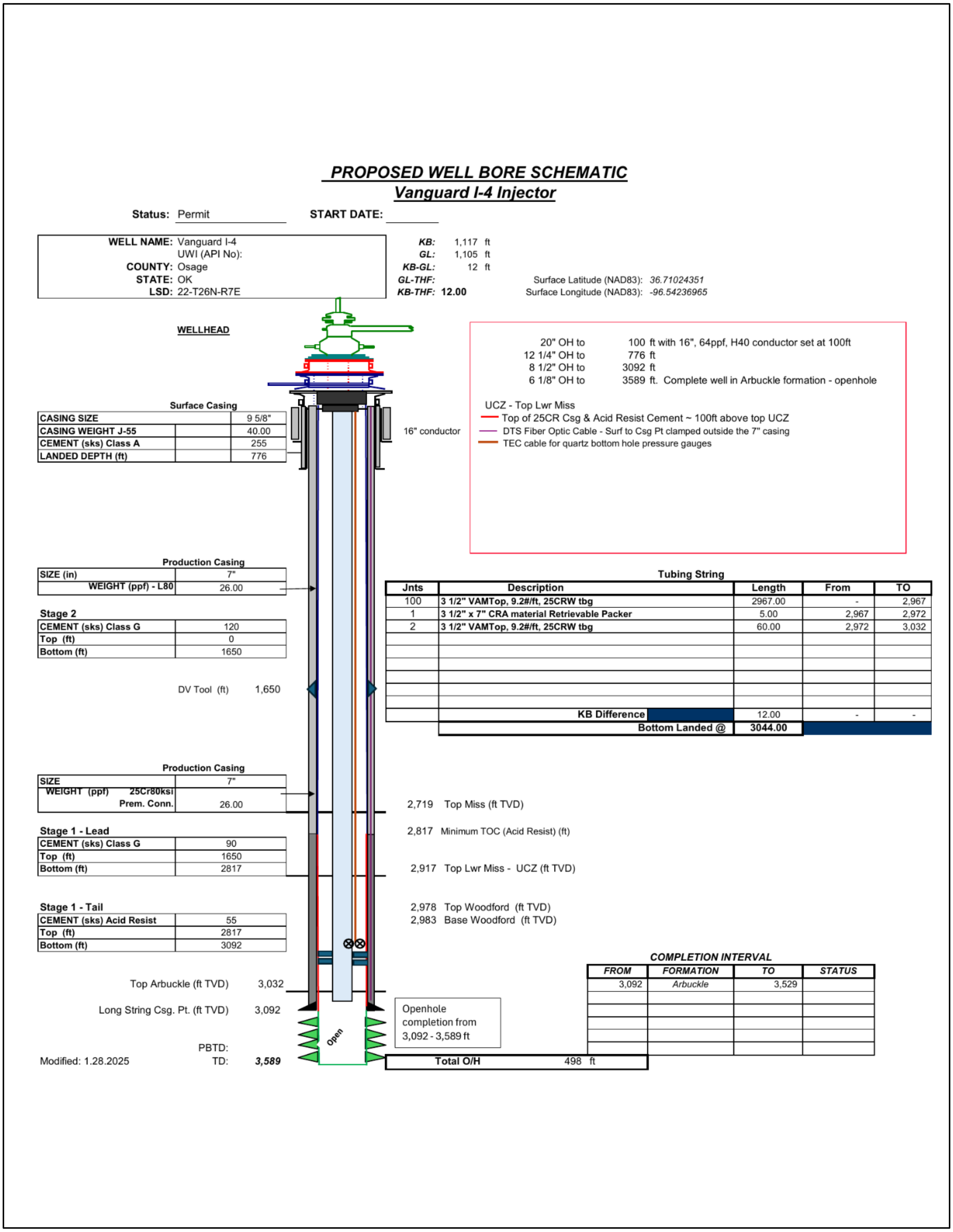


Figure 5.8—Planned well construction diagram for the Vanguard I-4 Injector.

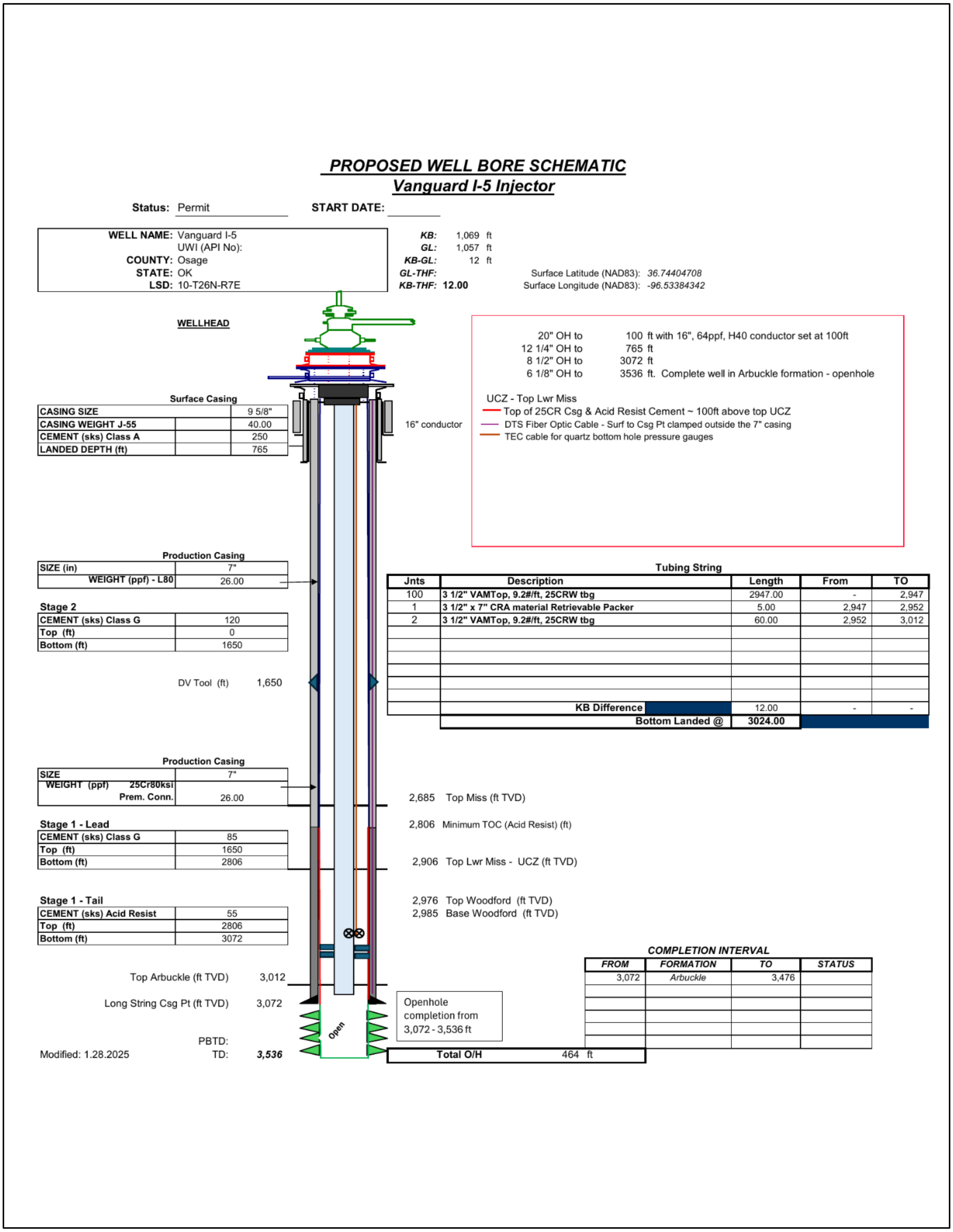
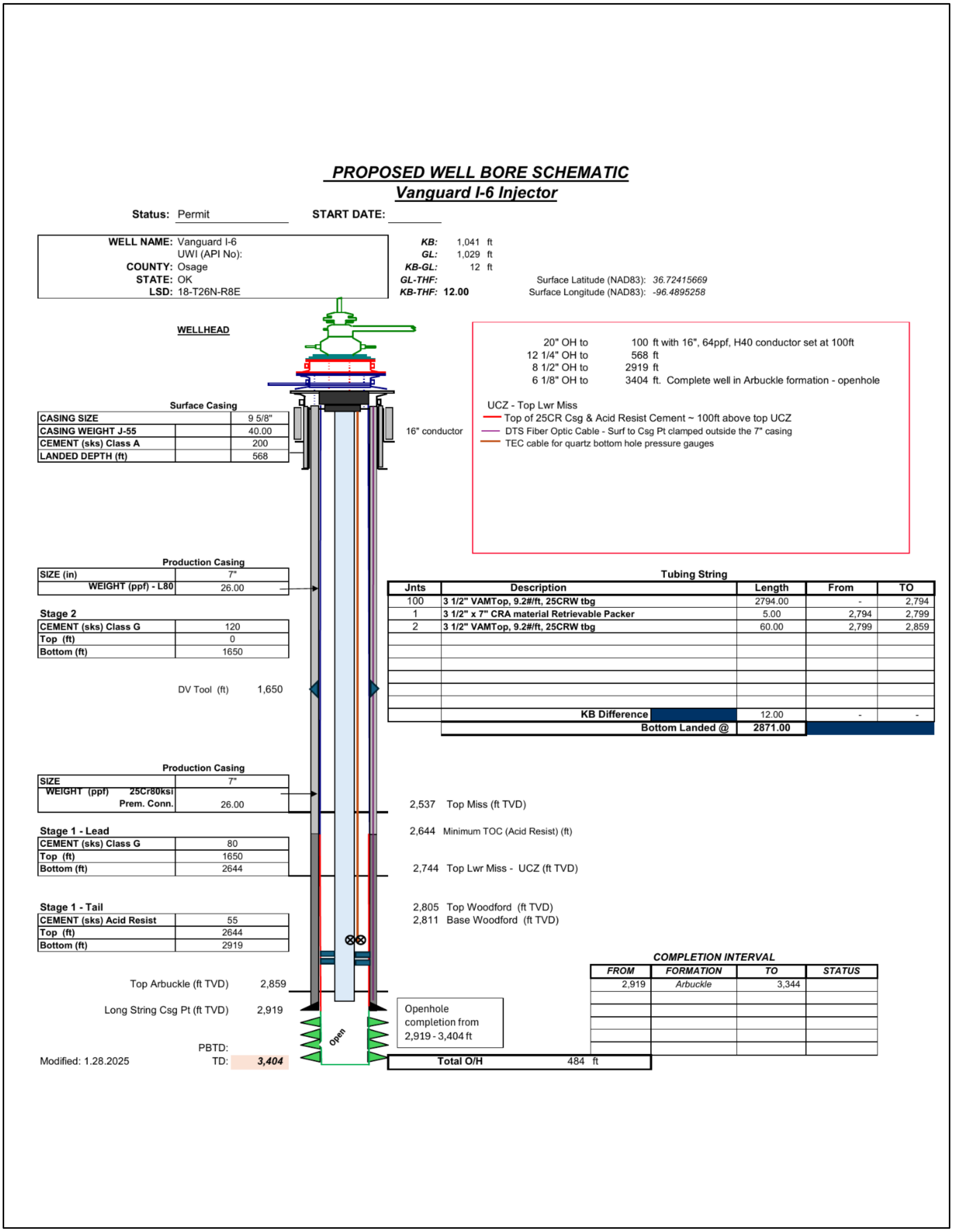


Figure 5.9—Planned well construction diagram for the Vanguard I-5 Injector.



Tubing String

Jnts	Description	Length	From	TO
100	3 1/2" VAMTop, 9.2#/ft, 25CRW tbg	2794.00	-	2,794
1	3 1/2" x 7" CRA material Retrievable Packer	5.00	2,794	2,799
2	3 1/2" VAMTop, 9.2#/ft, 25CRW tbg	60.00	2,799	2,859
	KB Difference	12.00	-	-
	Bottom Landed @	2871.00		

COMPLETION INTERVAL

FROM	FORMATION	TO	STATUS
2,919	Arbuckle	3,344	

Figure 5.10—Planned well construction diagram for the Vanguard I-6 Injector.

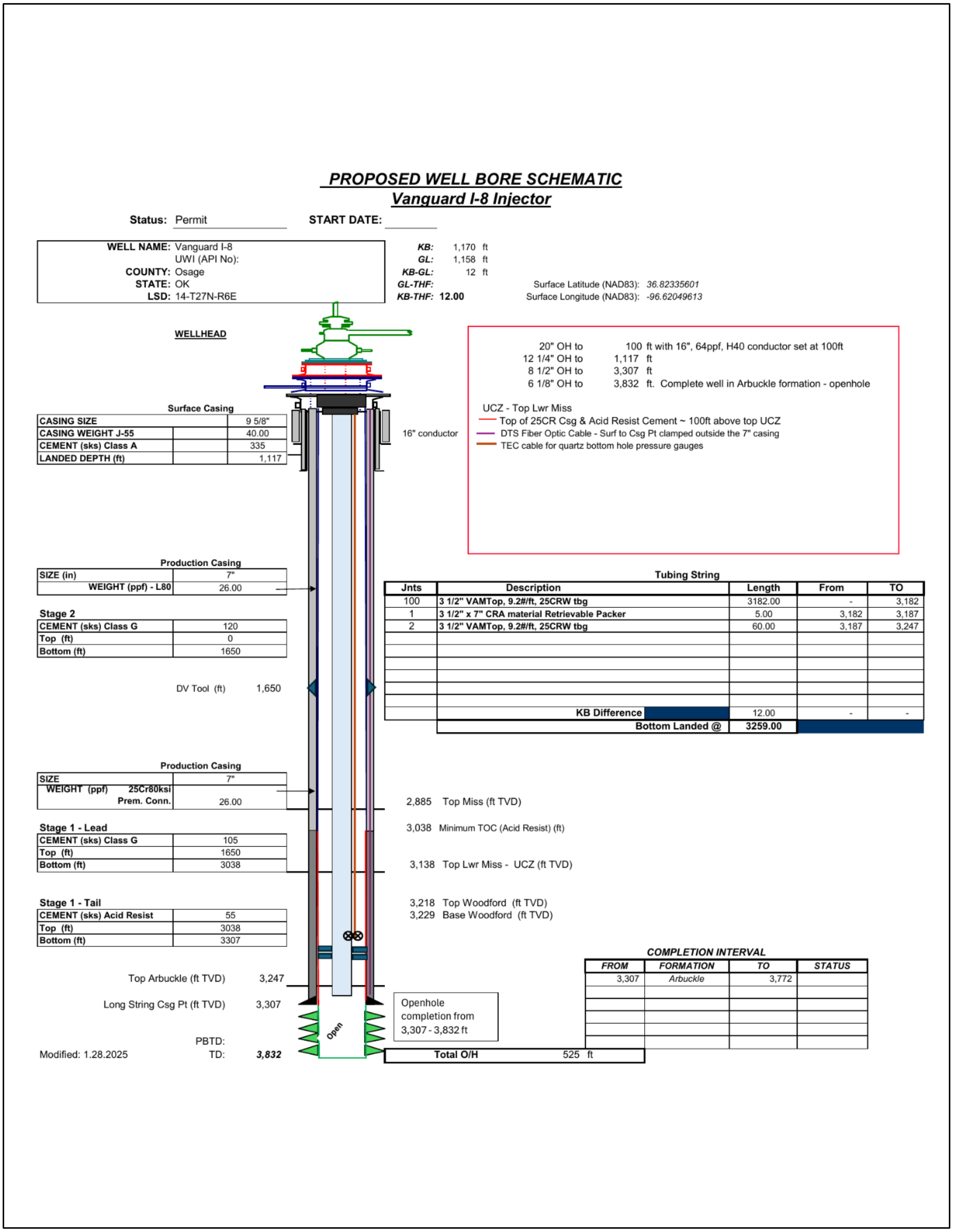


Figure 5.11—Planned well construction diagram for the Vanguard I-8 Injector.

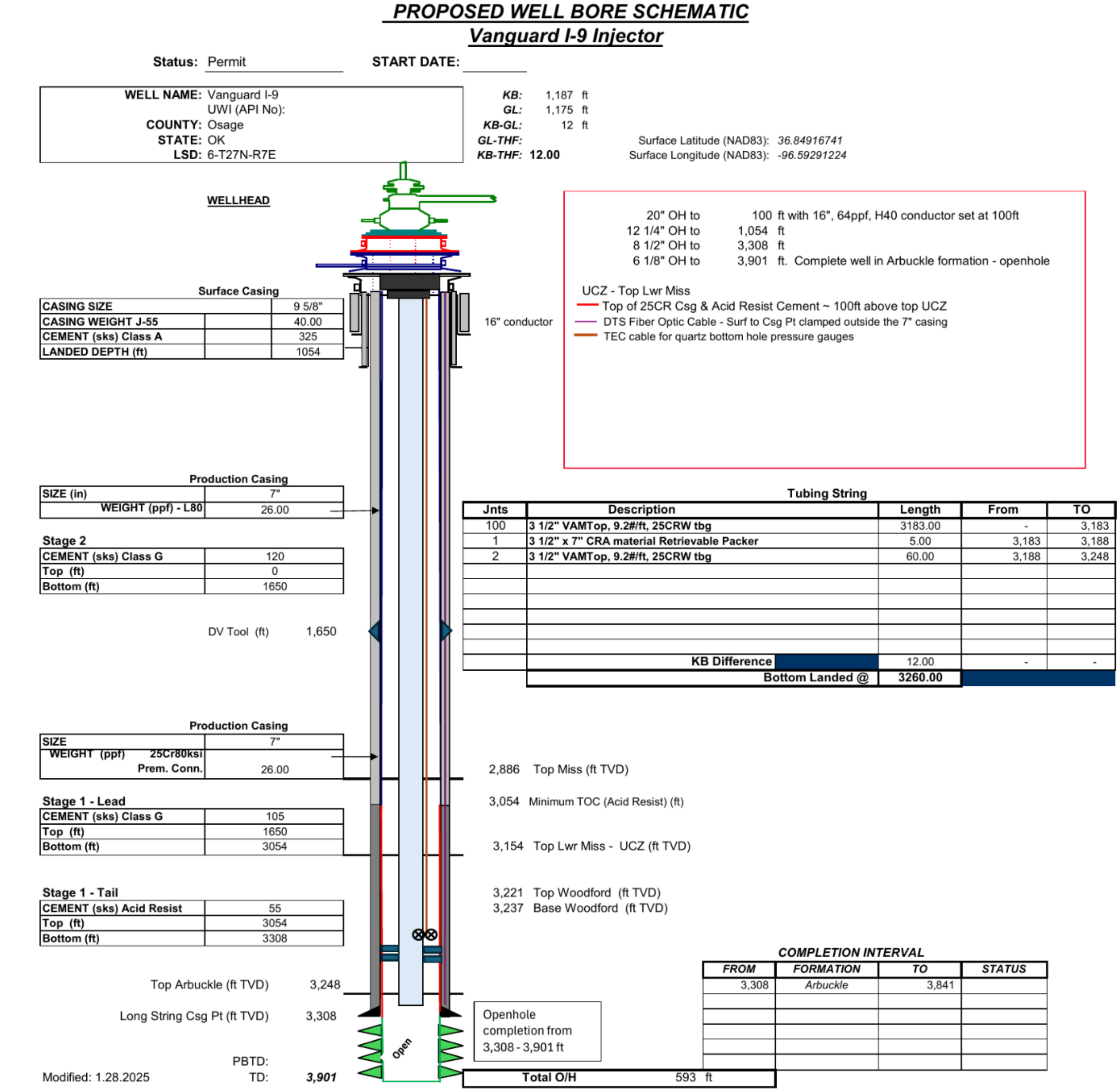


Figure 5.12—Planned well construction diagram for the Vanguard I-9 Injector.

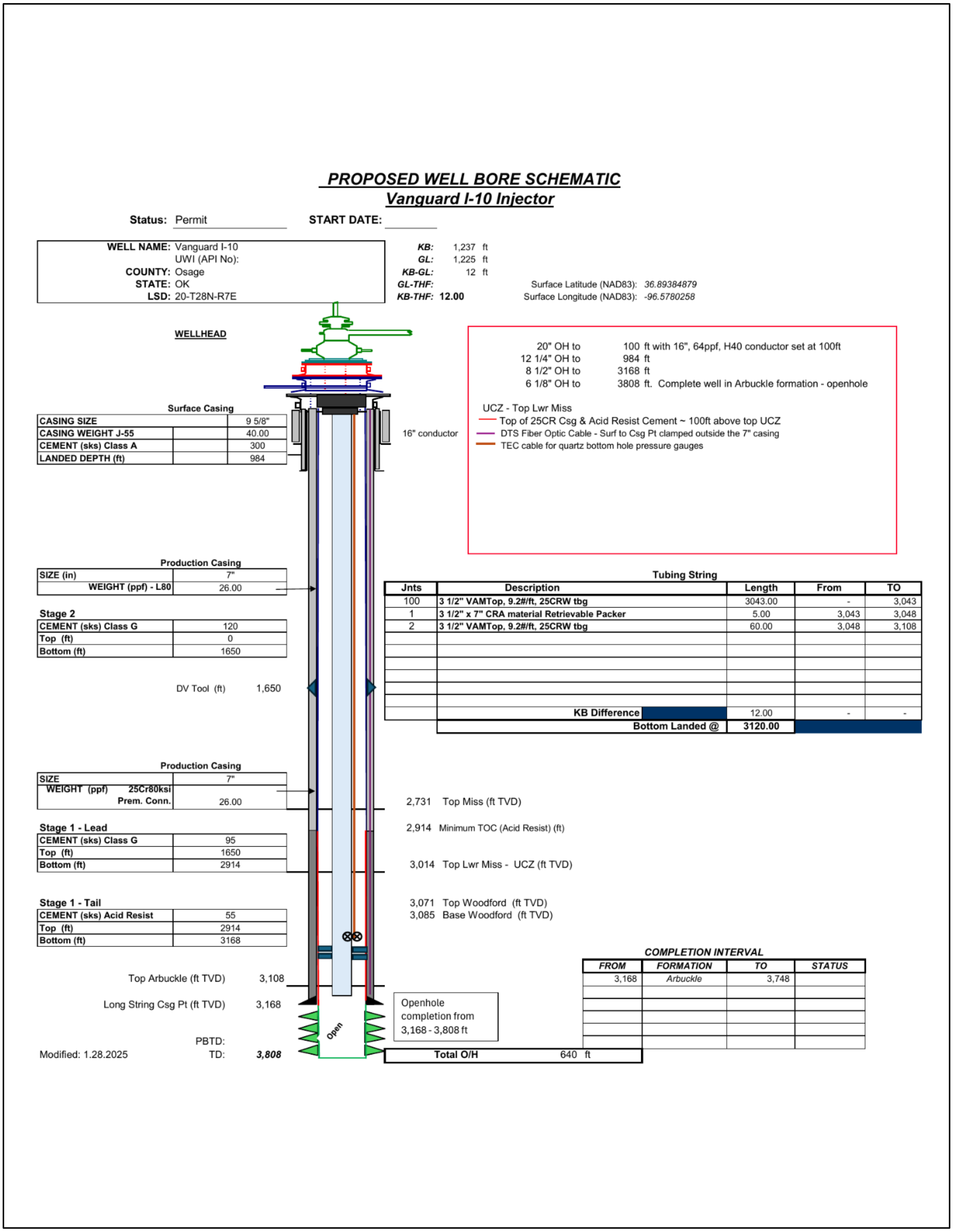


Figure 5.13—Planned well construction diagram for the Vanguard I-10 Injector.

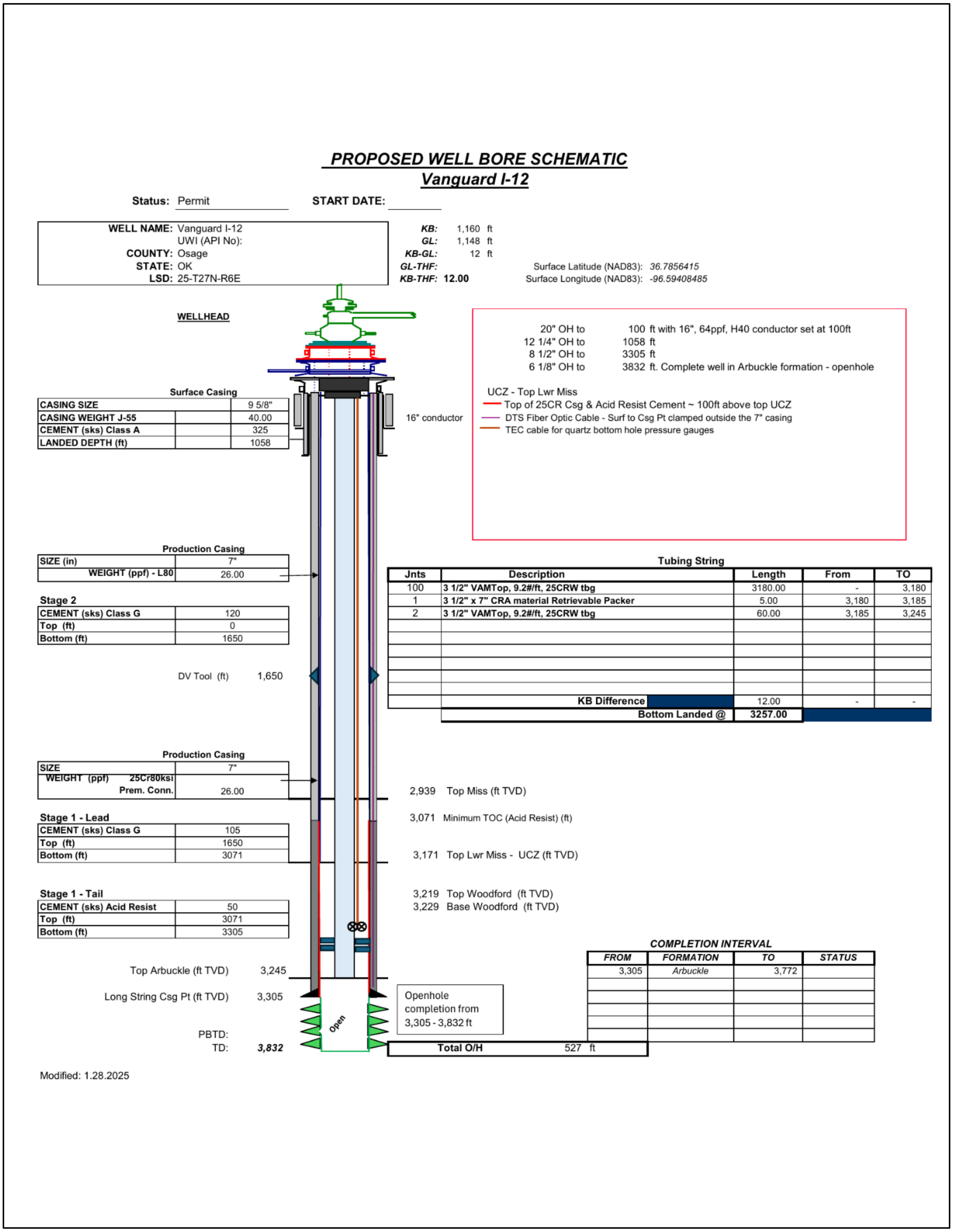


Figure 5.14—Planned well construction diagram for the Vanguard I-12 Injector.

Appendix 2—Wellbore Diagrams for Above-Zone Monitoring Wells

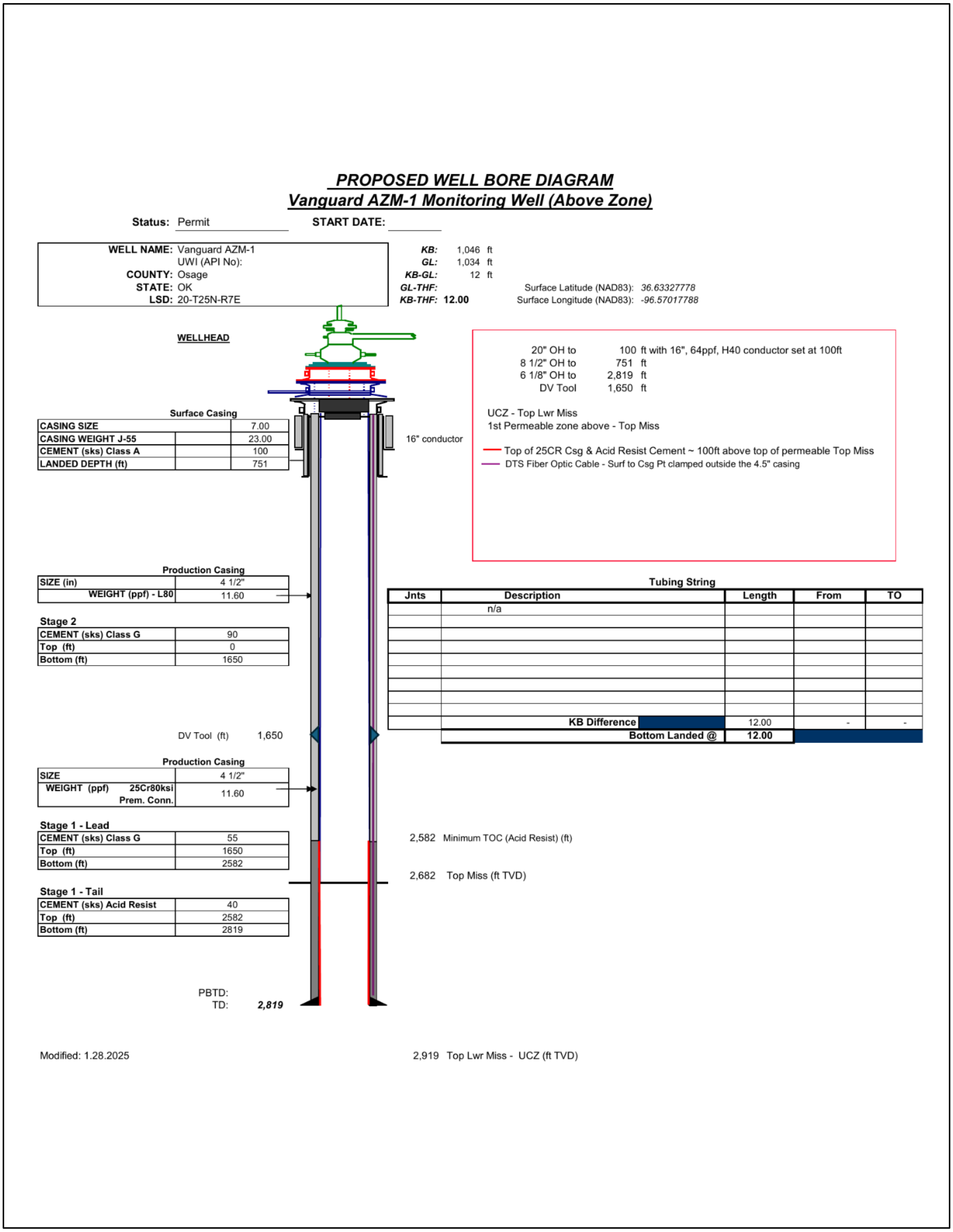


Figure 5.15—Planned well construction diagram for the Vanguard AZM-1 Monitoring Well (Above-Zone).

PROPOSED WELL BORE DIAGRAM
Vanguard AZM-2 Monitoring Well (Above Zone)

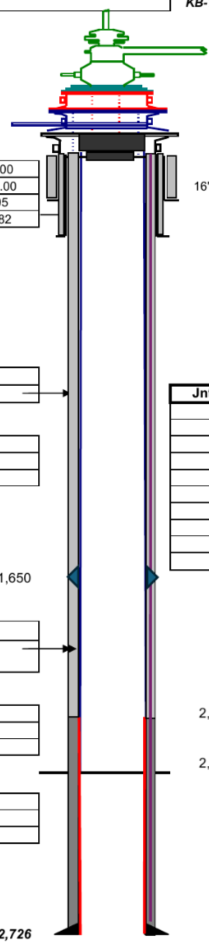
Status: Permit **START DATE:**

WELL NAME:	Vanguard AZM-2
	UWI (API No):
COUNTY:	Osage
STATE:	OK
LSD:	10-T25N-R7E

KB:	1,096	ft
GL:	1,084	ft
KB-GL:	12	ft
GL-THF:		
KB-THF:	**12.00**	

Surface Latitude (NAD83): *36.66007234*
Surface Longitude (NAD83): *-96.53379942*

WELLHEAD



20" OH to	100	ft with 16", 64ppf, H40 conductor set at 100ft
8 1/2" OH to	682	ft
6 1/8" OH to	2,726	ft
DV Tool	1,650	ft

UCZ - Top Lwr Miss
1st Permeable zone above - Top Miss

Top of 25CR Csg & Acid Resist Cement ~ 100ft above top of permeable Top Miss
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 4.5" casing

Surface Casing

CASING SIZE		7.00
CASING WEIGHT J-55		23.00
CEMENT (sks) Class A		95
LANDED DEPTH (ft)		682

Production Casing

SIZE (in)	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 2

CEMENT (sks) Class G	90
Top (ft)	0
Bottom (ft)	1650

Tubing String

Jnts	Description	Length	From	TO
	n/a			
	KB Difference	12.00	-	-
	Bottom Landed @	**12.00**		

DV Tool (ft) 1,650

Production Casing

SIZE	4 1/2"
WEIGHT (ppf) 25Cr80ksi Prem. Conn.	11.60

Stage 1 - Lead

CEMENT (sks) Class G	50
Top (ft)	1650
Bottom (ft)	2525

Stage 1 - Tail

CEMENT (sks) Acid Resist	35
Top (ft)	2525
Bottom (ft)	2726

2,525 Minimum TOC (Acid Resist) (ft)
2,625 Top Miss (ft TVD)

PBTD:
TD: ***2,726***

Modified: 1.28.2025

2,826 Top Lwr Miss - UCZ (ft TVD)

Figure 5.16—Planned well construction diagram for the Vanguard AZM-2 Monitoring Well (Above-Zone).

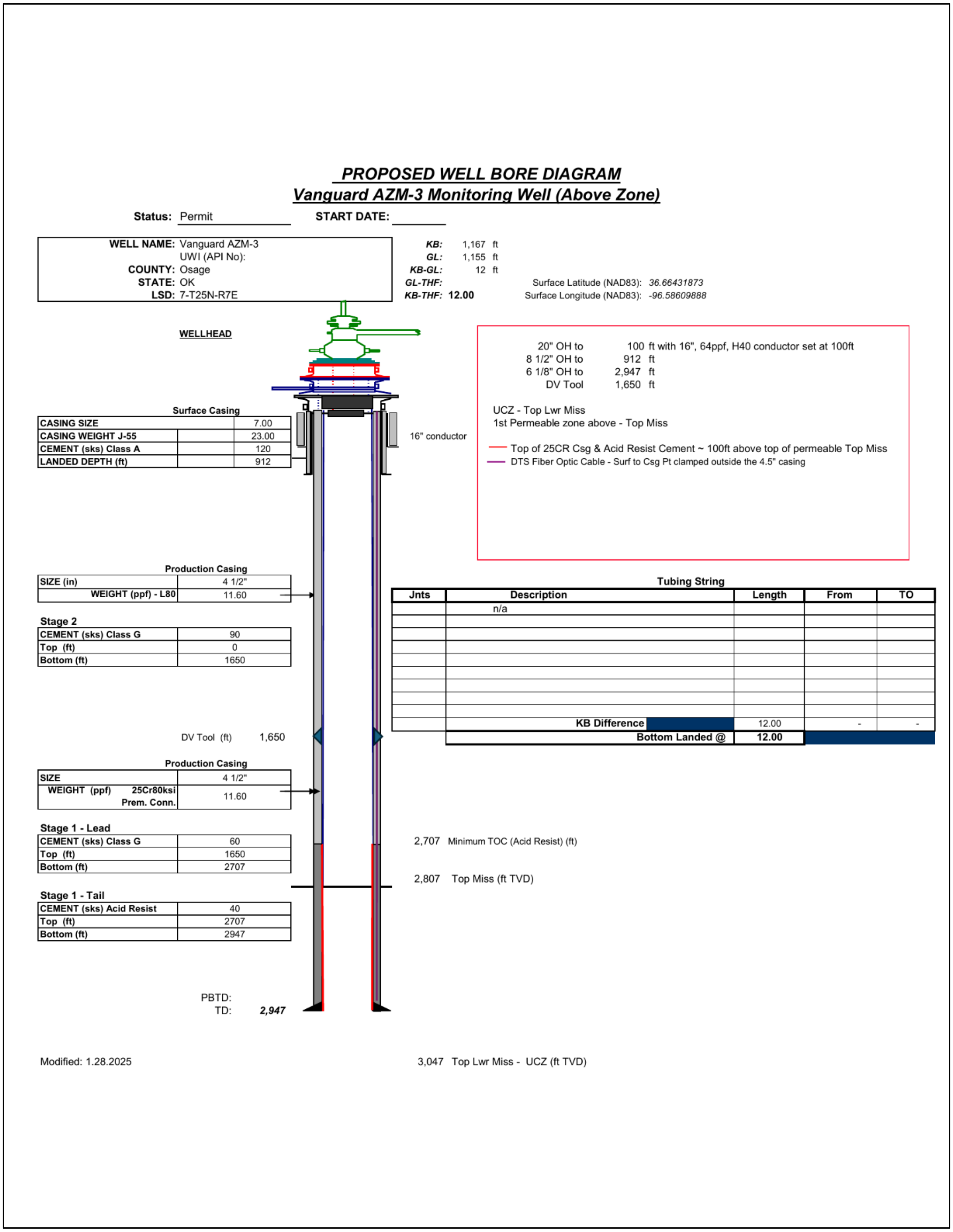


Figure 5.17—Planned well construction diagram for the Vanguard AZM-3 Monitoring Well (Above-Zone).

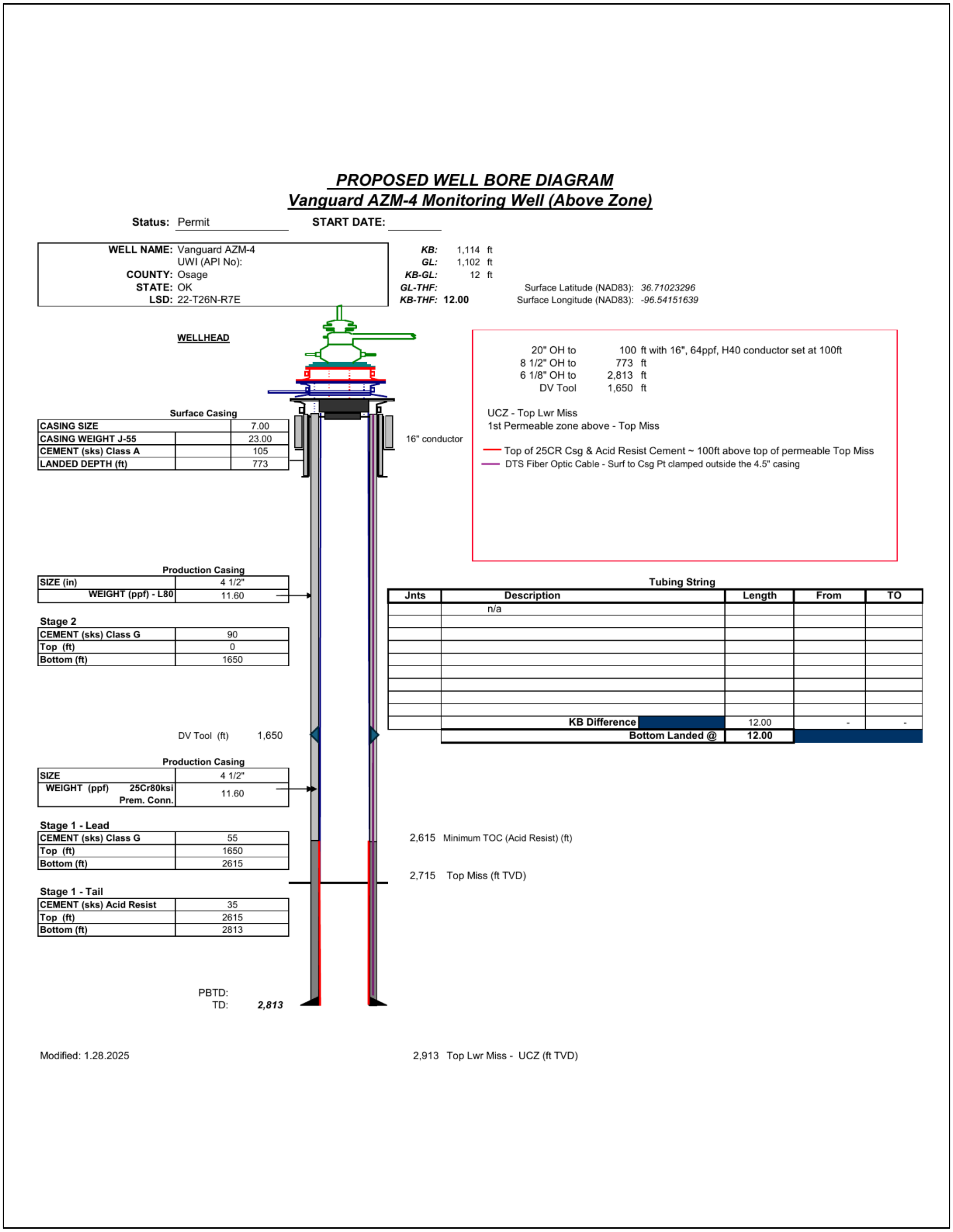


Figure 5.18—Planned well construction diagram for the Vanguard AZM-4 Monitoring Well (Above-Zone).

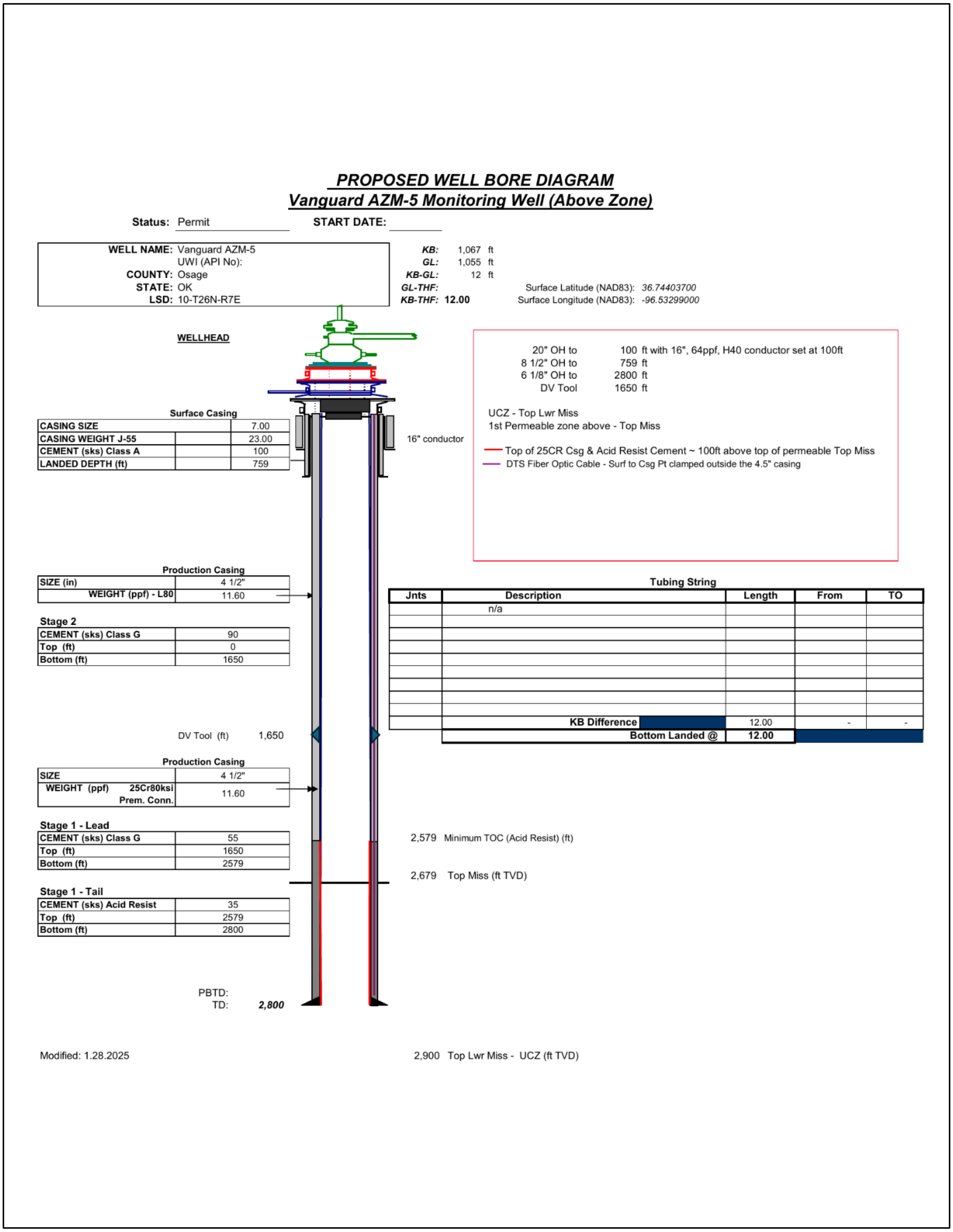


Figure 5.19—Planned well construction diagram for the Vanguard AZM-5 Monitoring Well (Above-Zone).

PROPOSED WELL BORE DIAGRAM
Vanguard AZM-6 Monitoring Well (Above Zone)

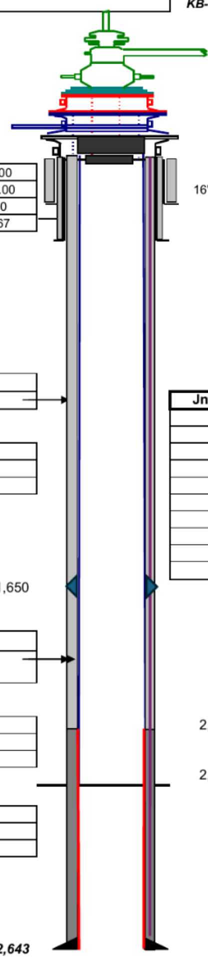
Status: Permit **START DATE:**

WELL NAME:	Vanguard AZM-6
	UWI (API No):
COUNTY:	Osage
STATE:	OK
LSD:	18-T26N-R8E

KB:	1,042	ft
GL:	1,030	ft
KB-GL:	12	ft
GL-THF:		
KB-THF:	**12.00**	

Surface Latitude (NAD83): *36.72414600*
Surface Longitude (NAD83): *-96.48867300*

WELLHEAD



20" OH to	100	ft with 16", 64ppf, H40 conductor set at 100ft
8 1/2" OH to	567	ft
6 1/8" OH to	2,643	ft
DV Tool	1,650	ft

UCZ - Top Lwr Miss
1st Permeable zone above - Top Miss

Top of 25CR Csg & Acid Resist Cement ~ 100ft above top of permeable Top Miss
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 4.5" casing

Surface Casing

CASING SIZE	7.00
CASING WEIGHT J-55	23.00
CEMENT (sks) Class A	80
LANDED DEPTH (ft)	567

Production Casing

SIZE (in)	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 2

CEMENT (sks) Class G	90
Top (ft)	0
Bottom (ft)	1650

Tubing String

Jnts	Description	Length	From	TO
	n/a			
	KB Difference	12.00	-	-
	Bottom Landed @	**12.00**		

DV Tool (ft) 1,650

Production Casing

SIZE	4 1/2"
WEIGHT (ppf) 25Cr80ksi Prem. Conn.	11.60

Stage 1 - Lead

CEMENT (sks) Class G	50
Top (ft)	1650
Bottom (ft)	2436

Stage 1 - Tail

CEMENT (sks) Acid Resist	35
Top (ft)	2436
Bottom (ft)	2643

2,436 Minimum TOC (Acid Resist) (ft)

2,536 Top Miss (ft TVD)

PBTD:
TD: ***2,643***

Modified: 1.28.2025

2,743 Top Lwr Miss - UCZ (ft TVD)

Figure 5.20—Planned well construction diagram for the Vanguard AZM-6 Monitoring Well (Above-Zone).

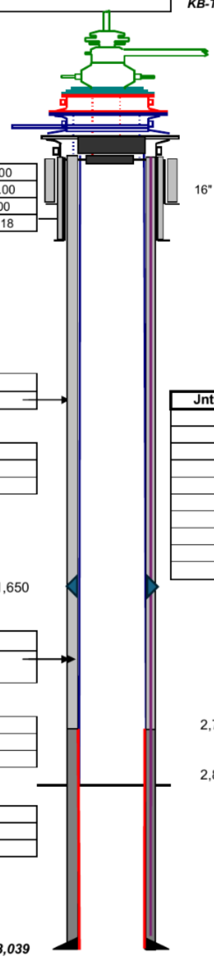
PROPOSED WELL BORE DIAGRAM
Vanguard AZM-8 Monitoring Well (Above Zone)

Status: Permit **START DATE:**

WELL NAME:	Vanguard AZM-8
	UWI (API No):
COUNTY:	Osage
STATE:	OK
LSD:	14-T27N-R6E

KB:	1,172	ft
GL:	1,160	ft
KB-GL:	12	ft
GL-THF:		
KB-THF:	**12.00**	

Surface Latitude (NAD83): *36.82334641*
Surface Longitude (NAD83): *-96.61964200*



20" OH to	100	ft with 16", 64ppf, H40 conductor set at 100ft
8 1/2" OH to	1,118	ft
6 1/8" OH to	3,039	ft
DV Tool	1,650	ft

UCZ - Top Lwr Miss
1st Permeable zone above - Top Miss

Top of 25CR Csg & Acid Resist Cement ~ 100ft above top of permeable Top Miss
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 4.5" casing

Surface Casing

CASING SIZE		7.00
CASING WEIGHT J-55		23.00
CEMENT (sks) Class A		100
LANDED DEPTH (ft)		1118

Production Casing

SIZE (in)	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 2

CEMENT (sks) Class G	90
Top (ft)	0
Bottom (ft)	1650

Production Casing

SIZE	4 1/2"
WEIGHT (ppf) 25Cr80ksi Prem. Conn.	11.60

Stage 1 - Lead

CEMENT (sks) Class G	65
Top (ft)	1650
Bottom (ft)	2784

Stage 1 - Tail

CEMENT (sks) Acid Resist	40
Top (ft)	2784
Bottom (ft)	3039

Tubing String

Jnts	Description	Length	From	TO
	n/a			
	KB Difference	12.00	-	-
	Bottom Landed @	**12.00**		

Modified: 1.28.2025

Figure 5.21—Planned well construction diagram for the Vanguard AZM-8 Monitoring Well (Above-Zone).

PROPOSED WELL BORE DIAGRAM
Vanguard AZM-9 Monitoring Well (Above Zone)

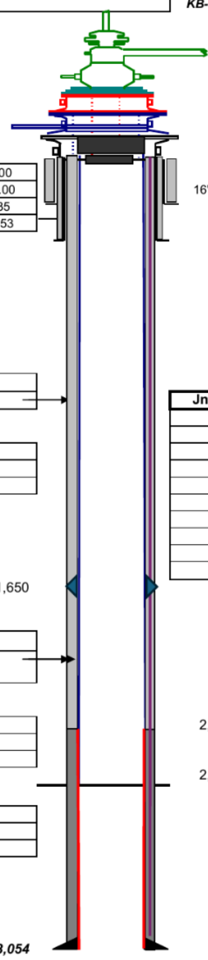
Status: Permit **START DATE:**

WELL NAME:	Vanguard AZM-9
	UWI (API No):
COUNTY:	Osage
STATE:	OK
LSD:	6-T27N-R7E

KB:	1,187	ft
GL:	1,175	ft
KB-GL:	12	ft
GL-THF:		
KB-THF:	**12.00**	

Surface Latitude (NAD83): *36.84915793*
Surface Longitude (NAD83): *-96.59205766*

WELLHEAD



WELL HISTORY

20" OH to	100	ft with 16", 64ppf, H40 conductor set at 100ft
8 1/2" OH to	1,053	ft
6 1/8" OH to	3,054	ft
DV Tool	1,650	ft

UCZ - Top Lwr Miss
1st Permeable zone above - Top Miss

Top of 25CR Csg & Acid Resist Cement ~ 100ft above top of permeable Top Miss
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 4.5" casing

Surface Casing

CASING SIZE		7.00
CASING WEIGHT J-55		23.00
CEMENT (sks) Class A		135
LANDED DEPTH (ft)		1053

Production Casing

SIZE (in)	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 2

CEMENT (sks) Class G	90
Top (ft)	0
Bottom (ft)	1650

Tubing String

Jnts	Description	Length	From	TO
	n/a			
	KB Difference	12.00	-	-
	Bottom Landed @	**12.00**		

DV Tool (ft) 1,650

Production Casing

SIZE	4 1/2"
WEIGHT (ppf) 25Cr80ksi Prem. Conn.	11.60

Stage 1 - Lead

CEMENT (sks) Class G	65
Top (ft)	1650
Bottom (ft)	2787

Stage 1 - Tail

CEMENT (sks) Acid Resist	40
Top (ft)	2787
Bottom (ft)	3054

2,787 Minimum TOC (Acid Resist) (ft)

2,887 Top Miss (ft TVD)

PBTD:
TD: ***3,054***

Modified: 1.28.2025

3,154 Top Lwr Miss - UCZ (ft TVD)

Figure 5.22—Planned well construction diagram for the Vanguard AZM-9 Monitoring Well (Above-Zone).

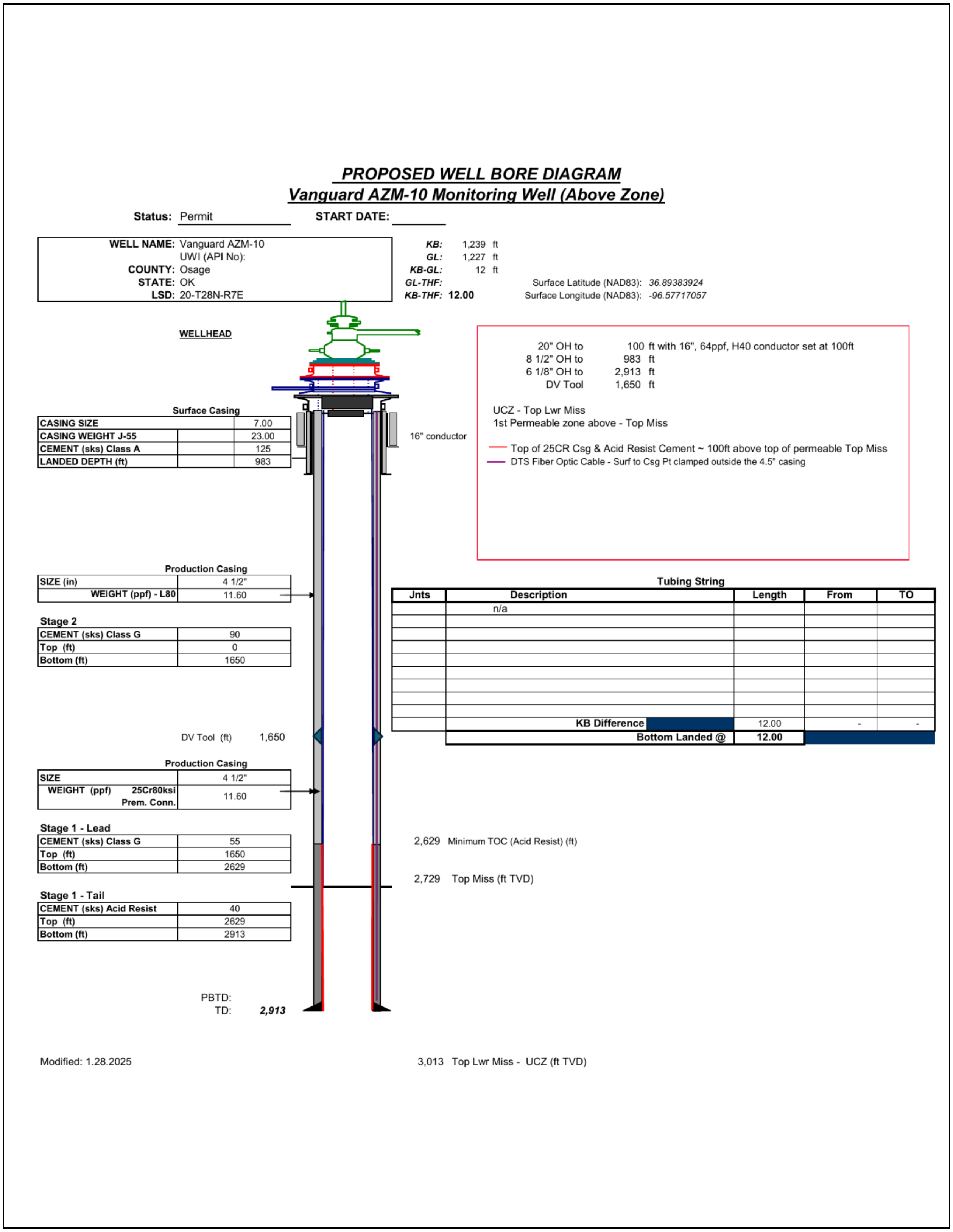


Figure 5.23—Planned well construction diagram for the Vanguard AZM-10 Monitoring Well (Above-Zone).

PROPOSED WELL BORE DIAGRAM
Vanguard AZM-12 Monitoring Well (Above Zone)

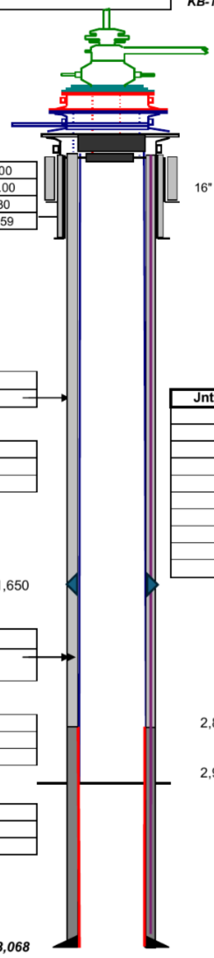
Status: Permit **START DATE:**

WELL NAME:	Vanguard AZM-12
	UWI (API No):
COUNTY:	Osage
STATE:	OK
LSD:	30-T27N-R7E

KB:	1,161	ft
GL:	1,149	ft
KB-GL:	12	ft
GL-THF:		
KB-THF:	**12.00**	

Surface Latitude (NAD83): *36.78563169*
Surface Longitude (NAD83): *-96.59323133*

WELLHEAD



20" OH to	100	ft with 16", 64ppf, H40 conductor set at 100ft
8 1/2" OH to	1,059	ft
6 1/8" OH to	3,068	ft
DV Tool	1,650	ft

UCZ - Top Lwr Miss
1st Permeable zone above - Top Miss

Top of 25CR Csg & Acid Resist Cement ~ 100ft above top of permeable Top Miss
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 4.5" casing

Surface Casing

CASING SIZE		7.00
CASING WEIGHT J-55		23.00
CEMENT (sks) Class A		130
LANDED DEPTH (ft)		1059

Production Casing

SIZE (in)	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 2

CEMENT (sks) Class G	90
Top (ft)	0
Bottom (ft)	1650

Tubing String

Jnts	Description	Length	From	TO
	n/a			
	KB Difference	12.00	-	-
	Bottom Landed @	**12.00**		

DV Tool (ft) 1,650

Production Casing

SIZE	4 1/2"
WEIGHT (ppf) 25Cr80ksi Prem. Conn.	11.60

Stage 1 - Lead

CEMENT (sks) Class G	65
Top (ft)	1650
Bottom (ft)	2836

Stage 1 - Tail

CEMENT (sks) Acid Resist	35
Top (ft)	2836
Bottom (ft)	3068

PBTD:
TD: ***3,068***

Modified: 1.28.2025

Figure 5.24—Planned well construction diagram for the Vanguard AZM-12 Monitoring Well (Above-Zone).

Appendix 3—Wellbore Diagrams for In-Zone Monitoring Wells

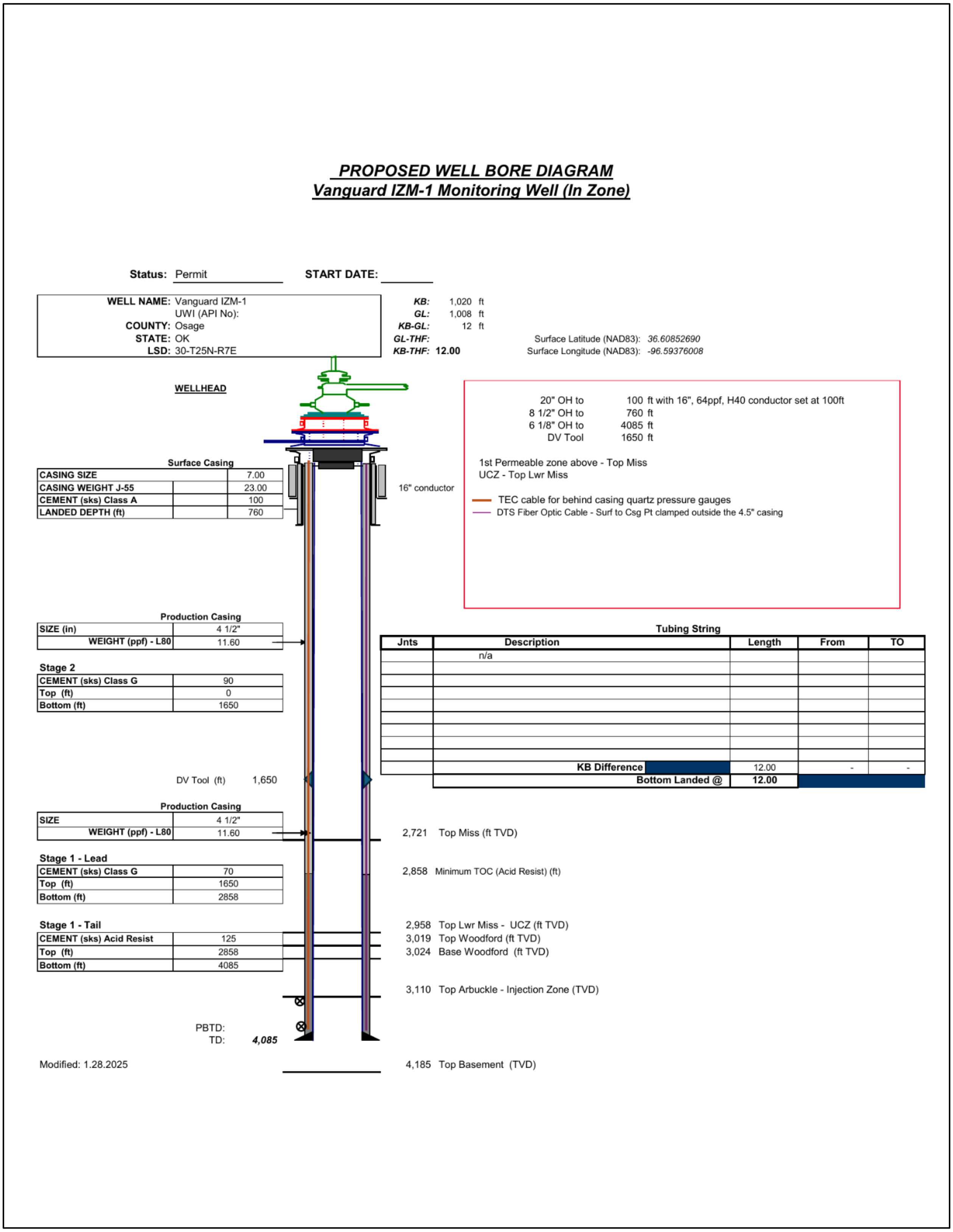


Figure 5.25—Planned well construction diagram for the Vanguard IZM-1 Monitoring Well (In-Zone).

PROPOSED WELL BORE DIAGRAM
Vanguard IZM-2 Monitoring Well (In Zone)

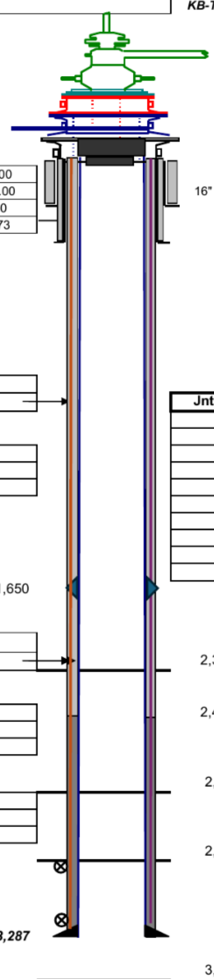
Status: Permit **START DATE:**

WELL NAME:	Vanguard IZM-2
	UWI (API No):
COUNTY:	Osage
STATE:	OK
LSD:	35-T26N-R8E

KB:	943	ft
GL:	931	ft
KB-GL:	12	ft
GL-THF:		
KB-THF:	**12.00**	

Surface Latitude(NAD83): *36.69034488*
Surface Longitude(NAD83): *-96.40709128*

WELLHEAD



20" OH to 100 ft with 16", 64ppf, H40 conductor set at 100ft
8 1/2" OH to 273 ft
6 1/8" OH to 3287 ft
DV Tool 1650 ft

1st Permeable zone above - Top Miss
UCZ - Top Lwr Miss

TEC cable for behind casing quartz pressure gauges
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 4.5" casing

Surface Casing

CASING SIZE	7.00
CASING WEIGHT J-55	23.00
CEMENT (sks) Class A	50
LANDED DEPTH (ft)	273

Production Casing

SIZE (in)	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 2

CEMENT (sks) Class G	90
Top (ft)	0
Bottom (ft)	1650

Tubing String

Jnts	Description	Length	From	TO
	n/a			
	KB Difference	12.00	-	-
	Bottom Landed @	**12.00**		

DV Tool (ft) 1,650

Production Casing

SIZE	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 1 - Lead

CEMENT (sks) Class G	50
Top (ft)	1650
Bottom (ft)	2431

Stage 1 - Tail

CEMENT (sks) Acid Resist	95
Top (ft)	2431
Bottom (ft)	3287

2,362 Top Miss (ft TVD)
2,431 Minimum TOC (Acid Resist) (ft)
2,531 Top Lwr Miss - UCZ (ft TVD)
2,589 Top Arbuckle - Injection Zone (TVD)

PBTD:
TD: ***3,287***

3,387 Top Basement (TVD)

Modified: 1.28.2025

Figure 5.26—Planned well construction diagram for the Vanguard IZM-2 Monitoring Well (In-Zone).

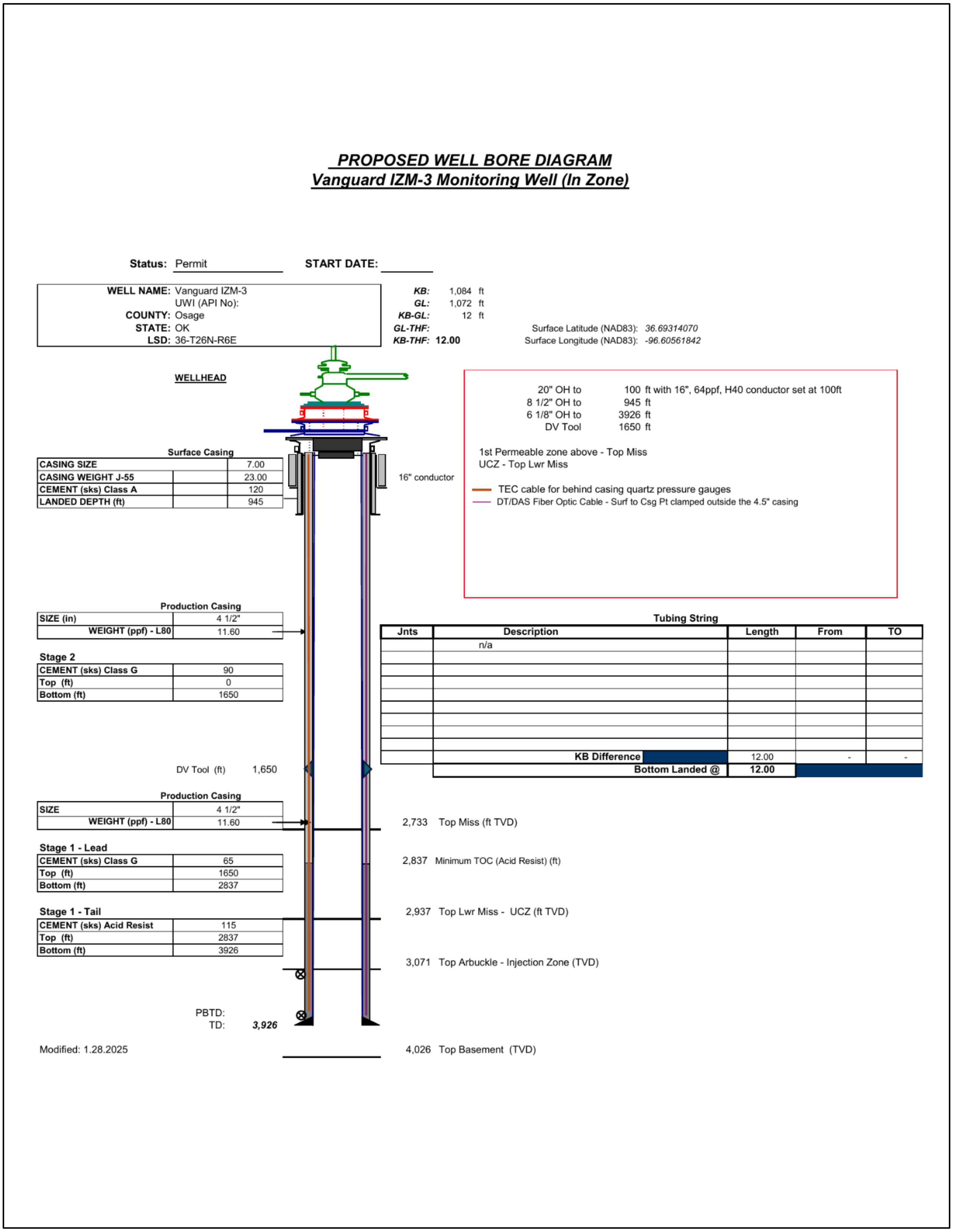


Figure 5.27—Planned well construction diagram for the Vanguard IZM-3 Monitoring Well (In-Zone).

PROPOSED WELL BORE DIAGRAM
Vanguard IZM-4 Monitoring Well (In Zone)

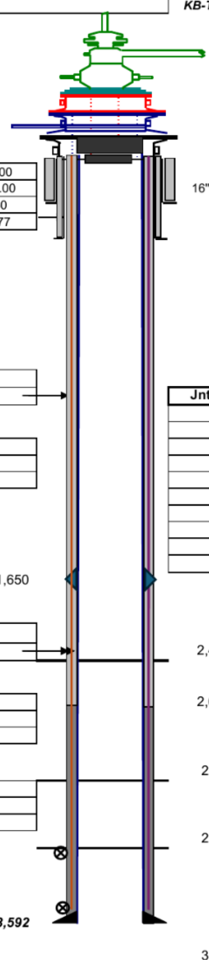
Status: Permit **START DATE:**

WELL NAME:	Vanguard IZM-4
	UWI (API No):
COUNTY:	Osage
STATE:	OK
LSD:	6-T26N-R8E

KB:	1,037	ft
GL:	1,025	ft
KB-GL:	12	ft
GL-THF:		
KB-THF:	**12.00**	

Surface Latitude (NAD83): *36.76792361*
Surface Longitude (NAD83): *-96.48675495*

WELLHEAD



20" OH to 100 ft with 16", 64ppf, H40 conductor set at 100ft
8 1/2" OH to 577 ft
6 1/8" OH to 3592 ft
DV Tool 1650 ft

1st Permeable zone above - Top Miss
UCZ - Top Lwr Miss

TEC cable for behind casing quartz pressure gauges
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 4.5" casing

Surface Casing

CASING SIZE		7.00
CASING WEIGHT J-55		23.00
CEMENT (sks) Class A		80
LANDED DEPTH (ft)		577

Production Casing

SIZE (in)	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 2

CEMENT (sks) Class G	90
Top (ft)	0
Bottom (ft)	1650

Tubing String

Jnts	Description	Length	From	TO
	n/a			
	KB Difference	12.00	-	-
	Bottom Landed @	**12.00**		

DV Tool (ft) 1,650

Production Casing

SIZE	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 1 - Lead

CEMENT (sks) Class G	60
Top (ft)	1650
Bottom (ft)	2645

Stage 1 - Tail

CEMENT (sks) Acid Resist	100
Top (ft)	2645
Bottom (ft)	3592

2,499 Top Miss (ft TVD)
2,645 Minimum TOC (Acid Resist) (ft)
2,745 Top Lwr Miss - UCZ (ft TVD)
2,860 Top Arbuckle - Injection Zone (TVD)

PBTD:
TD: ***3,592***

3,692 Top Basement (TVD)

Modified: 1.28.2025

Figure 5.28—Planned well construction diagram for the Vanguard IZM-4 Monitoring Well (In-Zone).

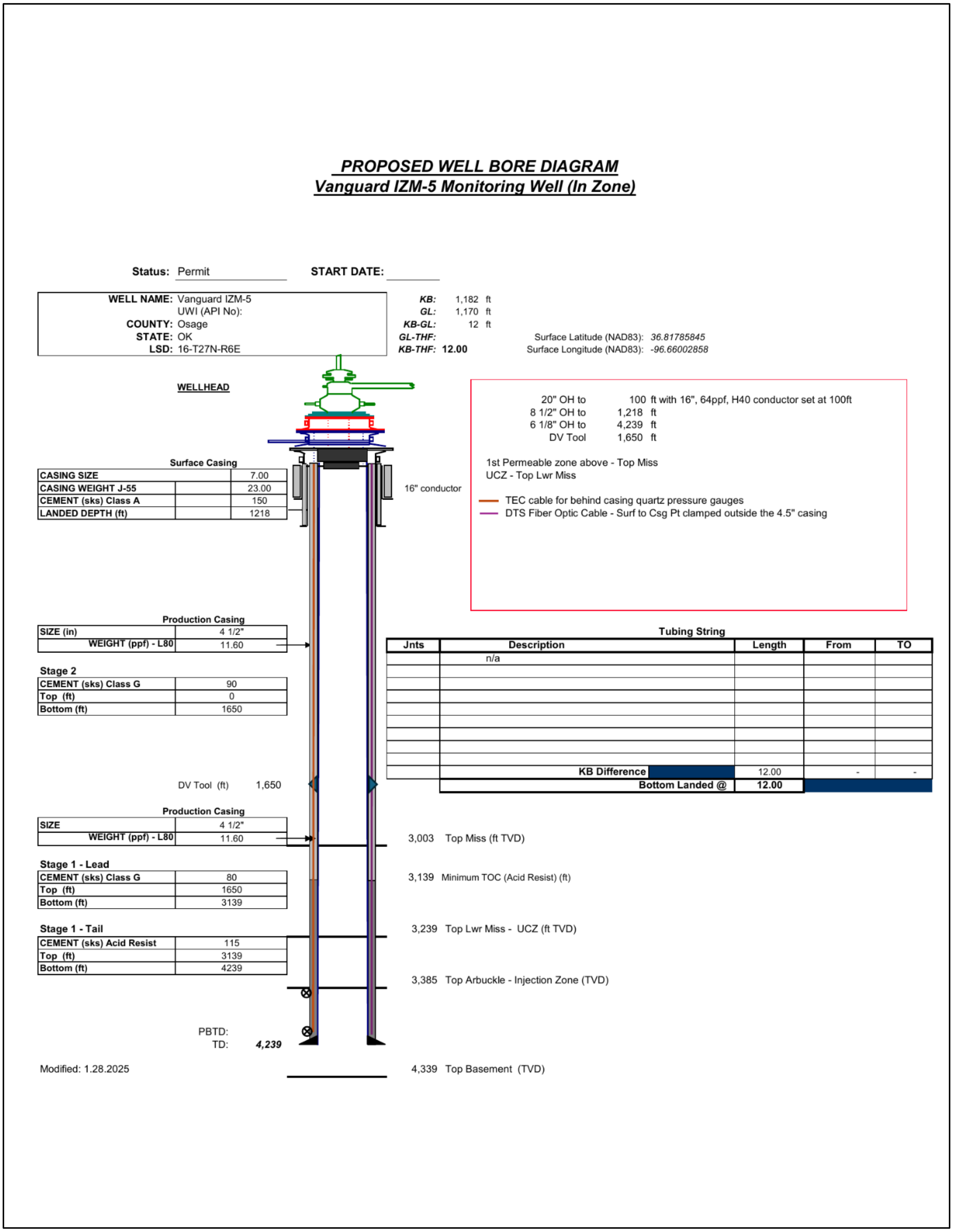


Figure 5.29—Planned well construction diagram for the Vanguard IZM-5 Monitoring Well (In-Zone).

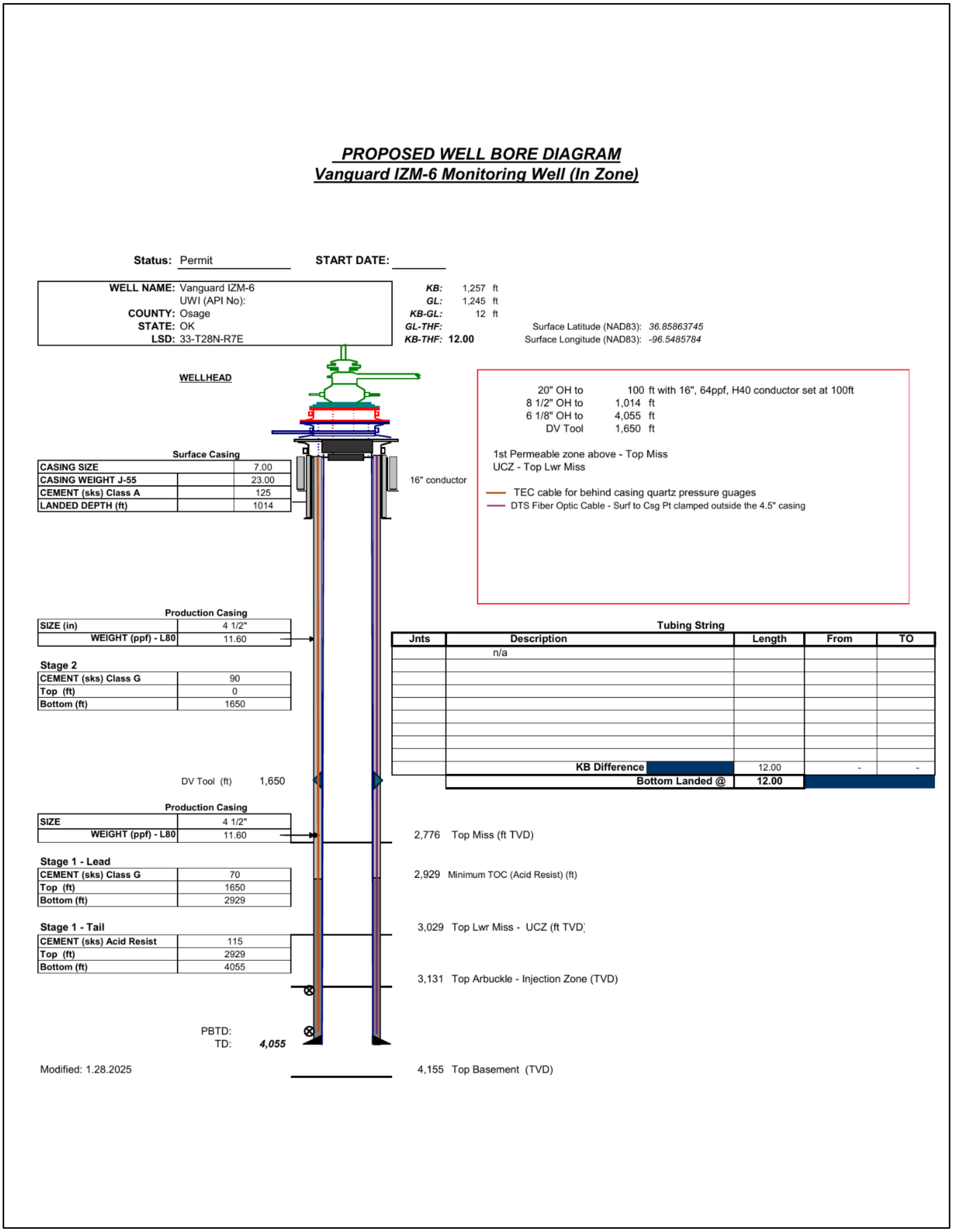


Figure 5.30—Planned well construction diagram for the Vanguard IZM-6 Monitoring Well (In-Zone).

PROPOSED WELL BORE DIAGRAM
Vanguard IZM-7 Monitoring Well (In Zone)

Status: Permit **START DATE:**

WELL NAME:	Vanguard IZM-7
	UWI (API No):
COUNTY:	Osage
STATE:	OK
LSD:	9-T28N-R7E

KB:	1,273	ft
GL:	1,261	ft
KB-GL:	12	ft
GL-THF:		
KB-THF:	**12.00**	

Surface Latitude (NAD83): *36.926075770*
Surface Longitude (NAD83): *-96.54861881*

20" OH to 100 ft with 16", 64ppf, H40 conductor set at 100ft
8 1/2" OH to 1,025 ft
6 1/8" OH to 4,053 ft
DV Tool 1,650 ft

1st Permeable zone above - Top Miss
UCZ - Top Lwr Miss

TEC cable for behind casing quartz pressure gauges
DTS Fiber Optic Cable - Surf to Csg Pt clamped outside the 4.5" casing

Surface Casing

CASING SIZE	7.00
CASING WEIGHT J-55	23.00
CEMENT (sks) Class A	130
LANDED DEPTH (ft)	1025

Production Casing

SIZE (in)	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 2

CEMENT (sks) Class G	90
Top (ft)	0
Bottom (ft)	1650

Tubing String

Jnts	Description	Length	From	TO
	n/a			
	KB Difference	12.00	-	-
	Bottom Landed @	**12.00**		

DV Tool (ft) 1,650

Production Casing

SIZE	4 1/2"
WEIGHT (ppf) - L80	11.60

Stage 1 - Lead

CEMENT (sks) Class G	70
Top (ft)	1650
Bottom (ft)	2906

Stage 1 - Tail

CEMENT (sks) Acid Resist	120
Top (ft)	2906
Bottom (ft)	4053

2,772 Top Miss - Perm (ft TVD)
2,906 Minimum TOC (Acid Resist) (ft)
3,006 Top Lwr Miss - UCZ (ft TVD)
3,105 Top Arbuckle - Injection Zone (TVD)

PBTD:
TD: ***4,053***

4,153 Top Basement (TVD)

Modified: 1.28.2025

Figure 5.31—Planned well construction diagram for the Vanguard IZM-7 Monitoring Well (In-Zone).