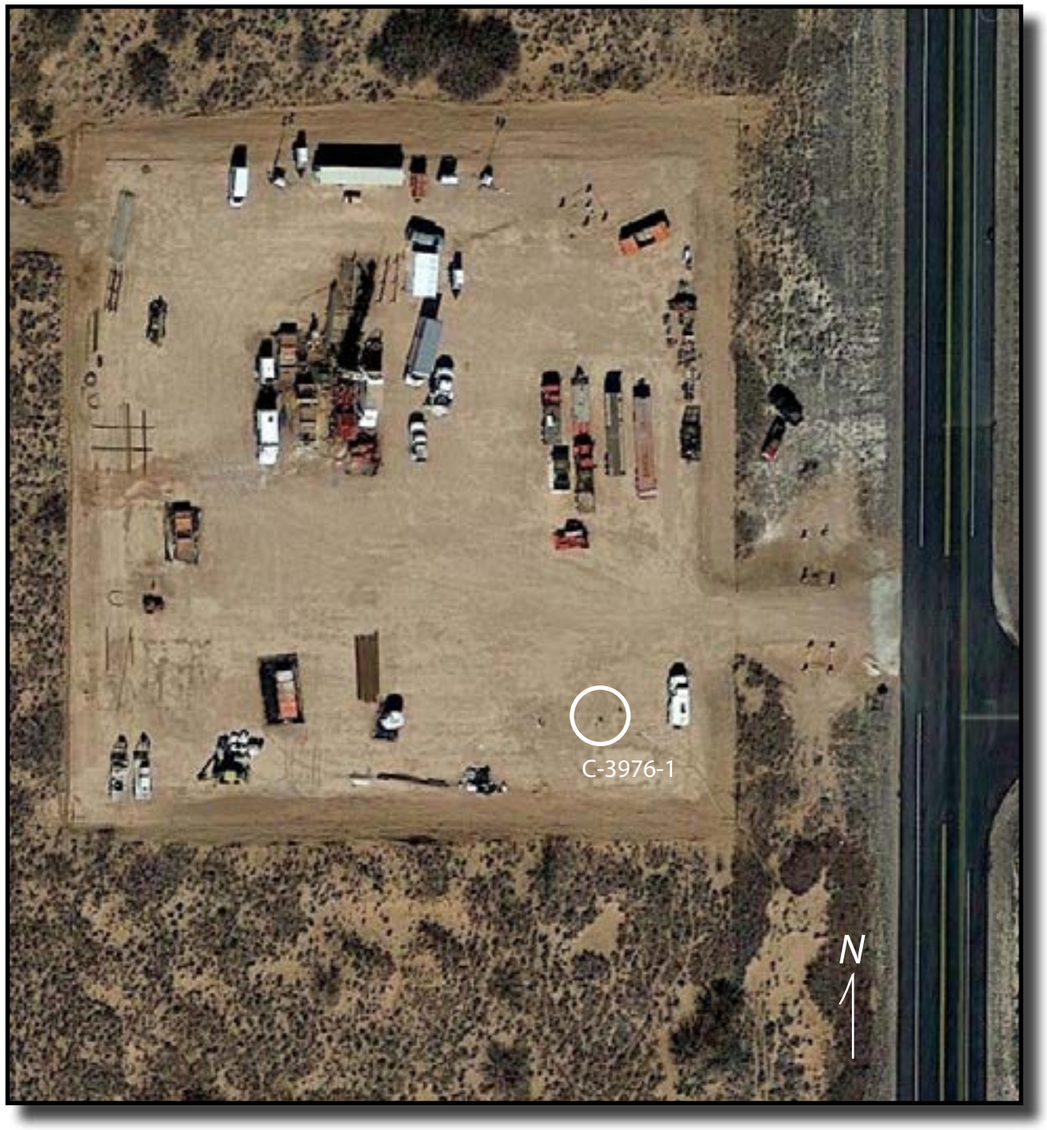


Basic Data Report for C-3976-1 (Dewey Lake 1) for Waste Isolation Pilot Plant (WIPP)

March 2019
(revised August 2019)



Drillpad for pre-shaft corehole (C-3977) and monitoring well locations at proposed location of unfiltered exhaust shaft (UES). Image from Google Earth, dated 2/1/2017. C-3976-1 is shown near the southeast corner of the drillpad.

Front cover: Stewart Brothers drilling rig on location at C-3976-1, preparing to take initial core. Photograph November 11, 2016.

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Geology of C-3976-1 (Dewey Lake 1) for Waste Isolation Pilot Plant (WIPP)*

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EXECUTIVE SUMMARY

C-3976-1 is located in section 20, T22S, R31E, in Eddy County, NM. The location is west of the current main facilities at the Waste Isolation Pilot Plant (WIPP). The drillhole was permitted by the Office of the State Engineer (New Mexico) as a monitoring well. The objective was to test and monitor for the possible presence of naturally occurring water at the top of a natural cement change in the upper Dewey Lake Formation.

C-3976-1 was drilled and cored from ground level to 201.5 ft (by drill pipe tally) to obtain reference samples and provide direct data regarding the shallow (to ~200 ft) geology as a prelude to completing the well for monitoring. The core was measured, photographed, and described in the field, then boxed, and put into climate-controlled, secure storage. Core recovery was highly variable near the surface and improved with depth (ave: 72.1%). Rock Quality Designation (RQD) data were recorded (ave: 65.9). Cores were re-examined in the lab, and these data are included in the descriptions.

C-3976-1 was logged in open-hole with a suite of geophysical tools including natural gamma, neutron, density, various electrical measurements, caliper, and spectral gamma at a few select depths. A deviation survey after reaching TD showed total deviation to the east of ~4 ft ft at ~190 ft.

Known near-surface geology was only partially recovered. These include dune sand, Berino soil, Mescalero caliche, Mio-pleistocene Gatuña Formation, and Triassic Santa Rosa Formation. The Permo-triassic(?) Dewey Lake Formation was encountered from 33.9 ft to total depth (TD). The interval above ~165.5 ft was variably cemented by calcite. Below ~165.5 ft, the Dewey Lake is well cemented by gypsum and displays fibrous gypsum that fills fractures or separations.

The stratigraphy and lithologies encountered in C-3976-1 compare well to the air intake shaft (AIS), the pre-shaft corehole (C-3977), and thre other shallow monitor wells on the same drillpad.

There was no observed water inflow at C-3976-1 while drilling and coring. This included both upper zones near the top of the Dewey Lake where the possibility existed for anthropogenic water as well as the interval at the natural cement change. Compressed air was used to 110 ft; air with mist and soap were used below 110 ft.

The well is open (sand pack) from 139-180 ft, with screen from 150-170 ft. Observations since completion have found the well dry or with a small amount of water, likely from condensation.

Immediately after recovery and descriptive activities were completed, some core samples from this well and from an adjacent well (C-3976-2) were preserved for geotechnical testing. The samples were tested at the soils laboratory of Daniel B. Stephens and Associates. The report is attached to this report.

*This report is based on a geological team effort by Rick Salness (RES), Brett Seal (RES), Allen Hall (RES), John Thurston (RES), Robert Holt (University of Mississippi), and Dennis Powers (Consulting Geologist).

INTRODUCTION

Purpose of Waste Isolation Pilot Plant (WIPP)

WIPP is a deep geologic repository for permanent disposal of transuranic and mixed waste that are byproducts of the US nuclear defense program. The facility is located ~25 miles (40 km) east of Carlsbad, NM (Figure 1) in Eddy County.

Purpose and Location of C-3976-1

C-3976-1 (also referred to as Dewey Lake 1) was proposed, permitted, cored, and completed to determine if natural shallow groundwater is present above the natural cement change in the upper Dewey Lake Formation.

Natural shallow groundwater above this natural cement change in the Dewey Lake was initially encountered in potash corehole P-9 (Jones, 1978). P-9 is located about 2.3 miles southeast of C-2976 -1.

WQSP-6 and WQSP-6A, approximately 0.9 mile south-southwest of C-3976-1, are the nearest encounters (relative to C-3976-1) of water above this cement change in the Dewey Lake. Both wells were drilled in 1994, and WQSP-6A specifically monitors the Dewey Lake (DOE, 1995). Damp cuttings were reported in WQSP-6 below 105 ft to 165 ft, and the driller's report estimated 40-50 gallons per minute flow. Geophysical logs for WQSP-6A show sharp deflections at ~163 ft; cuttings include gypsum below 180.6 ft.

There were earlier reports of moist cuttings at similar positions relative to this cement change. Monitor wells H-1 and H-3, both drilled in 1976, reported moisture/moist cuttings from the Dewey Lake at depths of ~172 ft and ~169 ft below ground level, respectively (Mercer and Orr, 1979). Geophysical logs indicate the cement change is ~178 ft and ~168 ft below ground level, respectively. The H-2(a,b,c) monitor wells are ~0.38 mile southwest of C-3976-1 and were drilled and completed mid-1977 (Mercer and Orr, 1979). The first well (H-2a) was drilled to 188 ft and tested in open hole for 5 hours with no appreciable liquid. H-2b produced moist cuttings at 185 ft. H-2c produced moist cuttings at 181 ft. Geophysical logs indicate probable cement changes at ~180 ft below ground level.

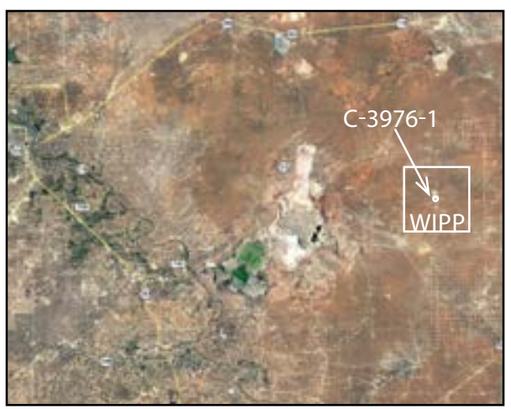
Holt and Powers (1990) noted the change in natural cements in the Dewey Lake in the air intake shaft and suggested that this change in cements might explain some of the encounters of water in the Dewey Lake south of the center of the WIPP site.

C-3976-1 was to be located near the southeast corner of the drillpad for the proposed location (Figure 2; see also inside cover) for a new shaft designated the unfiltered exhaust shaft (UES). Geophysical logs were to be obtained from C-3976-1. After coring and logging the borehole was to be completed for monitoring the interval above the natural cement change in the upper Dewey Lake.

C-3976-1 is located in the southwest 1/4 of the southeast 1/4 of section 20, T22S, R31E. The lat/long (Figure 2) is 32° 22' 22.55" (32.37293056°), -103° 47' 55.59" (-103.798775°). The surveyed elevation of an adjacent benchmark is 3402.64 ft amsl (Figures 2 and 5).

C-3976-1 was permitted by the Office of the State Engineer (NM) on August 15, 2016 (Appendix A). The location as permitted was lat 32° 22' 21.88", long -103° 47' 56.99", which is on the drillpad location.

Figure 1. Google Earth image showing location of WIPP and C-3976-1.



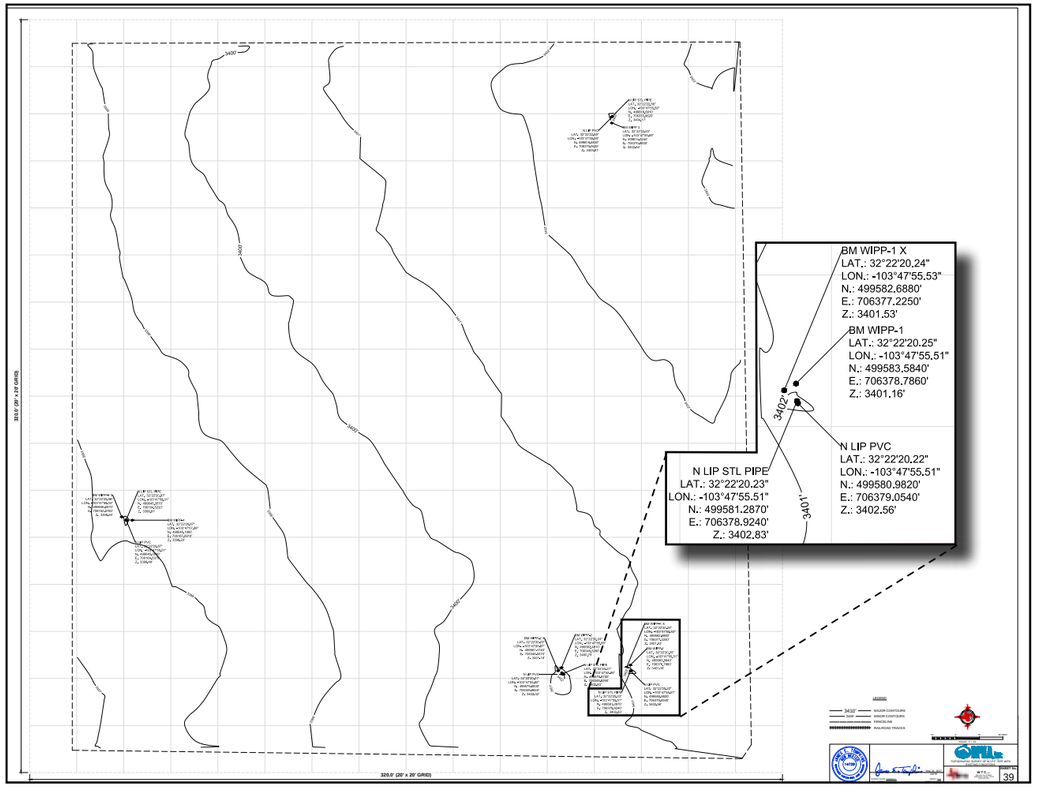


Figure 2. Survey of the location of C-3976-1. James E. Tompkins, surveyor, April 26, 2017.

Purpose of Report and Remarks

This report provides basic to general information for C-3976-1. Complementary reports are available for the three other similar shallow monitor wells on the same drillpad (Powers et al., 2019a,b,c). The deep corehole (C-3977) at the center of the proposed location of the UES on this drillpad has been separately reported (Powers et al., 2018).

Core run and recovery data are presented in Appendix B in tabular form with notes.

For most of this report, English units are used. We have mixed units in some of the detailed core descriptions, as metric units in the mm-cm range are much more convenient than either fractions of an inch or decimal ft.

Some of the descriptions are not as detailed as might be expected. The upper 20 ft is poorly represented, due mainly to limited recovery. In addition, all descriptions are based on features displayed on the outside of the core; none have been slabbed to date.

Some samples were taken and provided to Daniel B. Stephens and Associates (Albuquerque) for testing to confirm geotechnical parameters. Data from this testing are available (see attachments).

Geophysical logs in pdf and tif format are included as attachments.

The borehole was mainly cored, with a total depth of 201.5 ft below ground level (bgl) according to driller's measurements.

General Activities Summary for C-3976-1

Drilling began November 11, 2016 and ended November 30, 2016. The well was completed on December 2, 2016 (see Driller's Report at end of Appendix A and copy of NM Office of the Stae Engineer Point of Diversion Summary).

About 15.7 ft of coring from the surface was attempted; recovery was poor. The hole was reamed to a larger diameter and deepened to 20 ft; a 10.5-inch casing was set. Coring continued from 20 ft to 110 ft with compressed air. Core diameter was 4 inches (~10 cm) and hole diameter was 6.25-inches (20.5 cm). Recovery improved with depth. From 110 ft to TD, mist and soap were circulated to assist in coring.

Prior to using mist and soap, no water was observed at the beginning of the drilling for the day. On the next to last day (11/29/16), the corehole was advanced to 161.5 ft. At the beginning of 11/30/16, water and/or foam was detected ~151 ft below ground level.

C-3976-1 was logged with standard geophysical tools at TD. Following the logging, the borehole was completed for monitoring.

For the complete depth of C-3976-1, the sum of recovered core lengths for individual runs was 145.3 ft (72.1%). The sum of core segments >4 inches over the entire borehole depth is 95.8 ft or RQD of 65.9 (Appendix B). This includes the uncored interval from 15.7 ft to 20.0 ft.

Core was extruded into wooden troughs, fitted to the extent practical, marked, measured, photographed, described, and boxed. With a few exceptions, these tasks were completed prior to retrieving another core.

Core boxes were inventoried, put under chain of custody, and transferred to climate-controlled, secure storage in Carlsbad, NM. NWP retains custody of the core.

Photographs were taken in the field at ~0.5 ft (~15 cm) intervals with a frame width of ~1.2 ft (~36.5 cm) to provide good overlap. These photographs are an initial field record and have been supplemented with higher quality photographs, at ~0.25 ft intervals, under more carefully controlled conditions. Contact NWP for electronic files of these higher resolution photographs on transportable media.

Geophysical logs (Figure 3) taken prior to completing the well for monitoring include: deviation survey, resistivity, natural gamma, neutron, density, and spot spectral gamma measurements. See file attachments to this report for pdf and tif formats.

C-3976-1 was drilled and completed operating during daylight hours only.

C-3976-1 Well Completion

After geophysical logging of the well at TD, the lower part of the borehole was cemented (Figure 4). The borehole was reamed to a diameter of 8.75 inchs to a depth of 180 ft bgl. PVC pipe (2-inch id) was placed in the hole with centralizers. A 10-ft length of blank pipe with an end-cap is at the bottom with a 20-ft length of screen set from 150 to 170 ft bgl. The sand pack was brought up to 139 ft bgl using tremmie pipe and covered with 8 ft of bentonite. The annulus was cemented back to the surface using tremmie pipe. The surface pad and bollards (Figure 5) were placed after drilling was completed on the drillpad.

File Attachments

Several files are attached to this report to make them available in original formats. To access the list of attachments, click the paperclip icon in the pdf file.

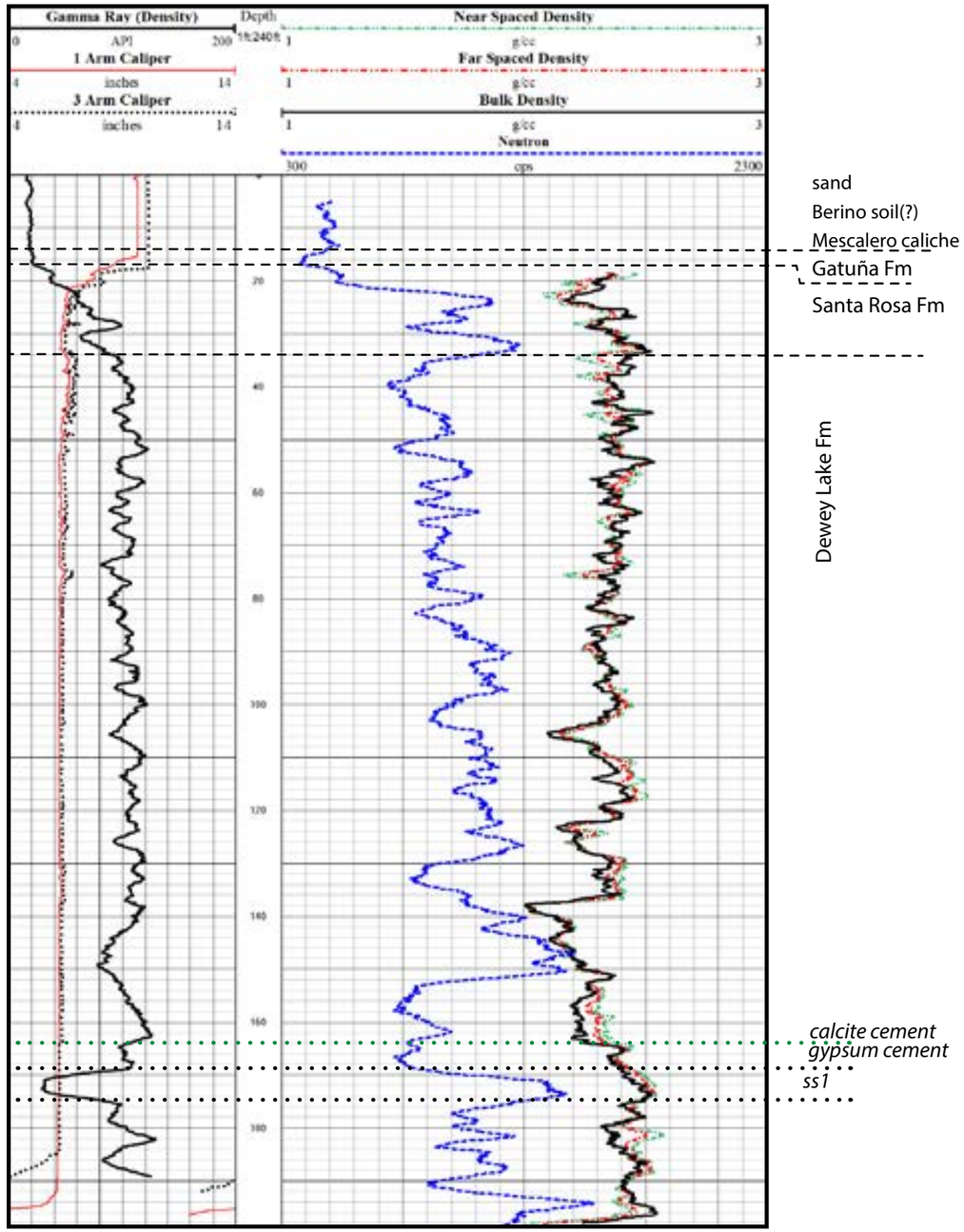
Geophysical logs by JetWest are included in two formats: pdf and tif files. Other formats (las and wcl) are included in records retained by NWP. These logs (without file extensions) are attached:

C3976-1-Deviation Survey
C3976-1-Deviation Survey- Bulls Eye
C3976-1-Deviation Survey-Closure View
C3976-1-Elec(tric)
C3976-1-GR-3Arm-Ind(uction)
C3976-1-GRDens(ity)-Neu(tron)

Geotechnical data by Daniel B. Stephens & Associations is attached as a pdf of the full report:

DBS&A_SBDC(WIPP) Laboratory Report 6-16-17.

Figure 3
Open-Hole Geophysical Logs Run By JetWest December 2, 2016. Reference point is ground level. This figure is a composite of caliper, natural gamma, neutron, and density.



GEOLOGICAL OBSERVATIONS C-3976-1

The core from C-3976-1 was initially described in the field. The cores were re-examined in the lab in more detail. Field observations were revised as needed. Detailed geological observations are included in Appendix B.

In this section, important stratigraphic units and their lithologies and features are more generally described or summarized with illustrations of some of the salient features. Core data are presented in detail in the graphic logs. The upper 200 ft of comparable geology are described in the report for C-3977 (Powers et al., 2018); separate reports have been prepared for the other three monitor wells on the drillpad (Powers et al., 2019a, b,c).

Many background references for the geology of C-3976-1 and the WIPP area are omitted to focus more clearly on the geology encountered in the upper 200 ft. Related reports on shaft mapping are Holt and Powers (1984, 1986, 1990). Early geologic information related to shallow subsurface water is included in Intera (1997) and Powers (1997).

Stratigraphy and Depths of Significant Units

The upper 15.7 ft of C-3976-1 were penetrated using a core barrel, but only Mescalero caliche and some Gatuña were recovered. Core recovery was limited above the Permo-triassic(?) Dewey Lake Formation, the first significant stratigraphic unit. In this area, the construction material for the drill pad is known to be underlain by modern sand.

Hall and Goble (2011) examined surficial sands in southeastern New Mexico, generally identifying three units, and providing optically-stimulated luminescence (OSL) age dates for these units. The "lower eolian sand" and Berino soil unit overlies Mescalero caliche. At a sample locality near present-day Intrepid West potash facility (T21S, R29E, section 2), Hall and Gobel obtained ages of 87.0 ± 4.0 ka (thousand years) and 61.1 ± 3.0 ka. The Berino soil is developed on the lower eolian sand. The "upper eolian sand" (overlying the Berino soil) and Bw paleosol yielded data (bottom to top) of 17.3 ± 0.7 ka, 13.9 ± 0.6 ka,

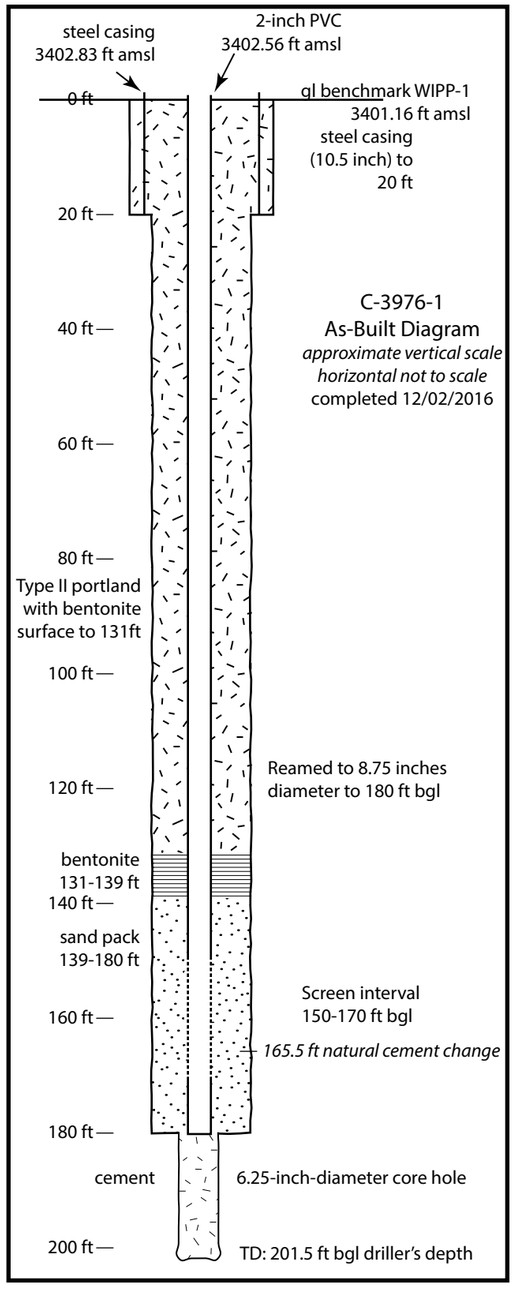


Figure 4
As-built diagram from C-3976-1.



Figure 5
Completed well pad for C-3976-1, including closeup of cap and benchmark. The second decimal corresponds to survey plat (Figure 2) but was not deeply embossed by the surveyor. Photos taken 1/7/2019.

Table 1
Geology at Drillhole C3976-1

System/ Period/Epoch		Formation or unit	Depth below surface (ft) by core markings	Depth below surface (ft) by gamma/density log
Cenozoic	Holocene(?)	surface dune sand *	not recovered	
	Pleistocene	Berino soil Mescalero caliche	not recovered ? 12.7 ft -14.7 ft	
	Pleistocene-Miocene	Gatuña	14.7 ft - 15.7 + ?	~14 ft - 17 ft?
Mesozoic	**Triassic**	Santa Rosa	? 21.5 ft - 33.9 ft	~17 ft - 34 ft
	Permian	Dewey Lake**	33.9 ft - 201.3 ft***	34.0 ft - 198+ ft

**See text discussion of dune sand and Berino age.*
***Dewey Lake is often considered Permian. Recent work suggests the upper part may be Triassic.*
****TD marked on core ~201.3 ft*
Base of neutron-density log 198.3 ft

and 7.18 ± 0.32 ka. Surficial material ("post-upper eolian sand") overlying the upper eolian sand is dated at 0.62 ± 0.04 ka. For this locality, the Bw paleosol and post-upper eolian sand are Holocene age. The lower sands are Pleistocene.

Dune sand at the WIPP site is loose and was not recovered during coring of C-3976-1. This loose sand is most likely Holocene, as found by Hall and Gobel (2011).

The *Berino soil* (Chugg et al., 1971) normally overlies the Mescalero but was not recovered (Table 1). The isochron for U-series indicates the Berino formed about 330 ka (Rosholt and McKinney, 1980). Hall and Gobel provide more precise and likely more accurate boundaries to the age of between 61.1 ± 3.0 ka and 17.3 ± 0.7 ka. Either estimate places the Berino as late Pleistocene in age.

The *Mescalero caliche* ranges from poorly lithified to hard in the area. The samples obtained from drilling C-3976-1 establish its presence but not its quality as a rock. The Mescalero caliche is a pedogenic calcrete (e.g., Bachman and Machette, 1977) and is generally 2-3 ft thick in the area around WIPP. The caliche is interrupted locally, mainly due to plant growth. The Mescalero began to form ~600 ka and may have ceased to form when the Berino sands accumulated (Rosholt and McKinney, 1980). Hall and Gobel (2011) state that the upper Mescalero caliche was eroded prior to deposition of the sand sheet.

The *Gatuña* is mainly sandstone with some siltstone in the vicinity of WIPP. Where the Gatuña underlies the Mescalero caliche, the upper part is variably lithified by infiltrated carbonate during the formation of the pedogenic calcrete. The upper Gatuña was recovered, and it is moderately indurated. It is generally light reddish brown calcareous sand and sandstone at the drillhole. Bedding was not discernible in recovered samples. Based on geophysical logs, the contact between the Gatuña and underlying Santa Rosa Formation is apparently at ~17 ft depth (Figure 3) but was not recovered. In the vicinity of WIPP, the Gatuña is thin. It thickens to the west toward Nash Draw, where it displays a wider variety of lithofacies (Powers and Holt, 1993).

The interval from ~17 ft - 34 ft is assigned to the *Santa Rosa* based on lithology and color. C-3976-1 is near the erosional edge of the Santa

Rosa/Dockum Group (Jones, 1973; plate 2). A greenish-gray sandstone (Figure 6) retrieved from core run 2 is the uppermost Santa Rosa recovered at C-3976-1.

The Permo-triassic(?) *Dewey Lake Formation* was encountered from 34 ft - 201.5 ft (driller depth at TD). P-3, a WIPP potash exploration hole ~1200 ft southwest from C-3976-1, showed similar depth to top of Dewey Lake (Jones, 1978). C-3977, AIS, and other monitor wells on the drillpad also showed generally similar depths and thicknesses.

There are no formal stratigraphic units within the Dewey Lake. The Dewey Lake above TD at C-3976-1 corresponds to the upper fining upward cycles noted in Holt and Powers (1990) and Powers (2003).

The Dewey Lake (Figure 7) is characterized by fine-grained clastics, especially very fine sandstones and siltstones. Clay-sized particles are common, but true claystones are rare and are silty to sandy. The red to reddish-brown color is relatively uniform; small spots and zones of greenish-gray ("gg") color ("reduction spots") are present throughout the formation. These spots are a helpful identifier of the Dewey Lake but are not unique.



Figure 6
Greenish-gray sandstone from Santa Rosa Formation. ~22 ft bgl in C-3976-1.

Very thin laminae to thin beds are most common (Figure 7). A few small ripples were observed in the lower 10 ft of the corehole. Bedding is parallel, horizontal to slightly wavy. A zone with low-angle cross-cutting relationships was observed at ~194 ft. Small desiccation cracks were observed but are sparse. A few zones displayed pedogenic slickensides. No bioturbation was identified in the core from C-3976-1. Intraclasts, generally siltstone, were found at a number of intervals (Figure 8A). Some overlie well defined erosion surfaces and other are found within the upperpart of generally fining upward intervals.

The natural gamma for C-3976-1 is significantly diminished in the interval from ~169 ft - 175 ft (Figure 3). The geologic log (Appendix B) shows this sandstone from 172.3 ft - 176.3 ft.

Ss1 is an informal designation for a prominent sandstone bed in the upper half of the Dewey Lake (Powers, 2003). Ss1 can be defined based on natural gamma geophysical logs as well as in core or cuttings. At H-16, adjacent to the air intake shaft, the base of this sandstone is ~190 ft bgl (Mercer and Snyder, 1990). The sandstone mapped with a base at 195 ft in the air intake shaft (Holt and Powers, 1990) is interpreted as the same bed. Numerous drillholes or monitor wells have intercepted this sandstone (e.g., Powers and Richardson, 2004). At C-3977, ss1 is ~167 ft - ~172 ft bgl (Powers et al., 2018; figure 3). Ss1 is the easiest correlation point within the upper Dewey Lake.

The highest fractures or separations deemed natural (i.e., not due to coring and recovery) were identified at a depth of ~86 ft and were unfilled. A fracture at ~137 ft showed probably MnO staining. A fracture at ~147 ft (Figure 8B) was partially filled with calcite.

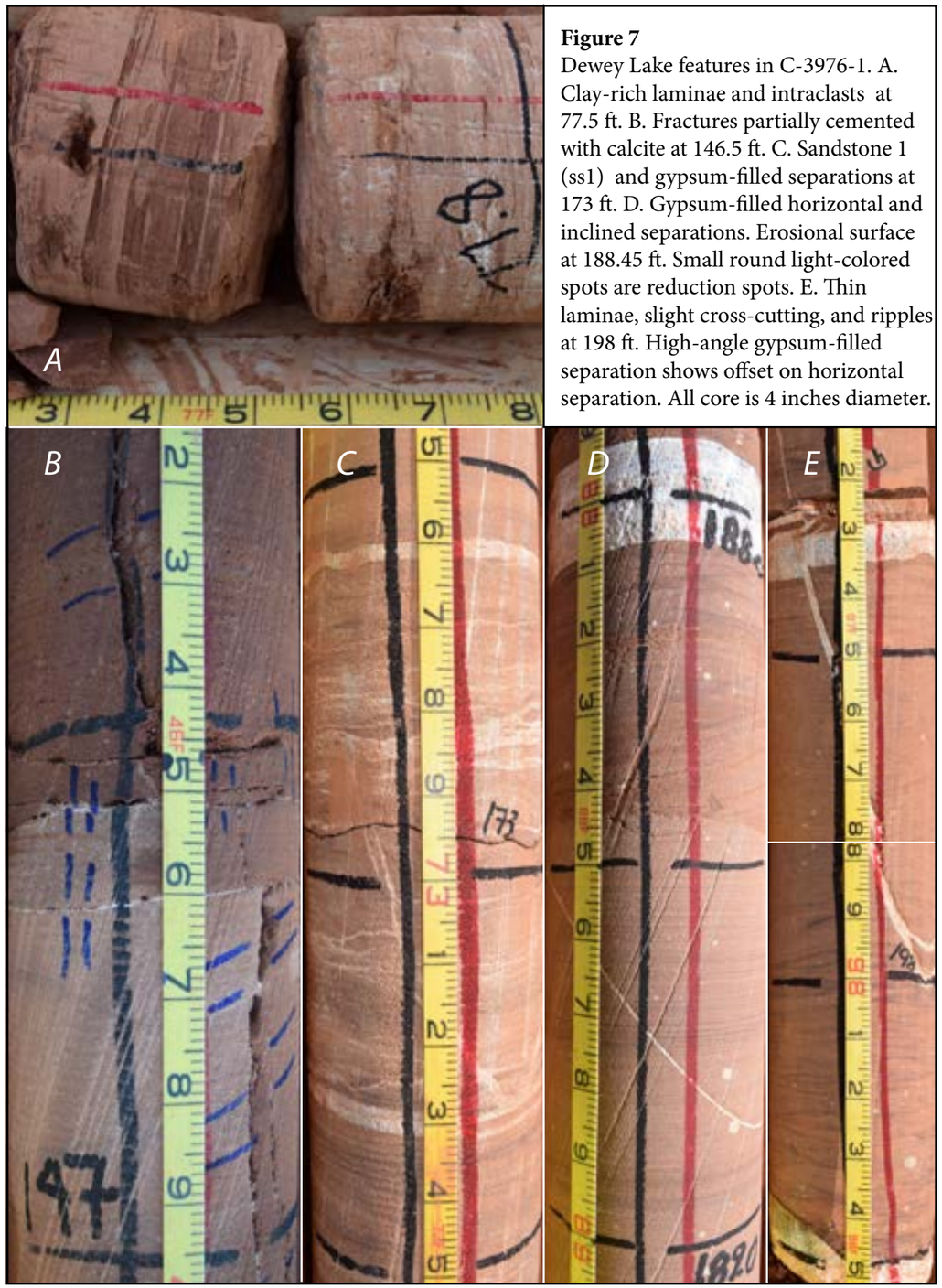
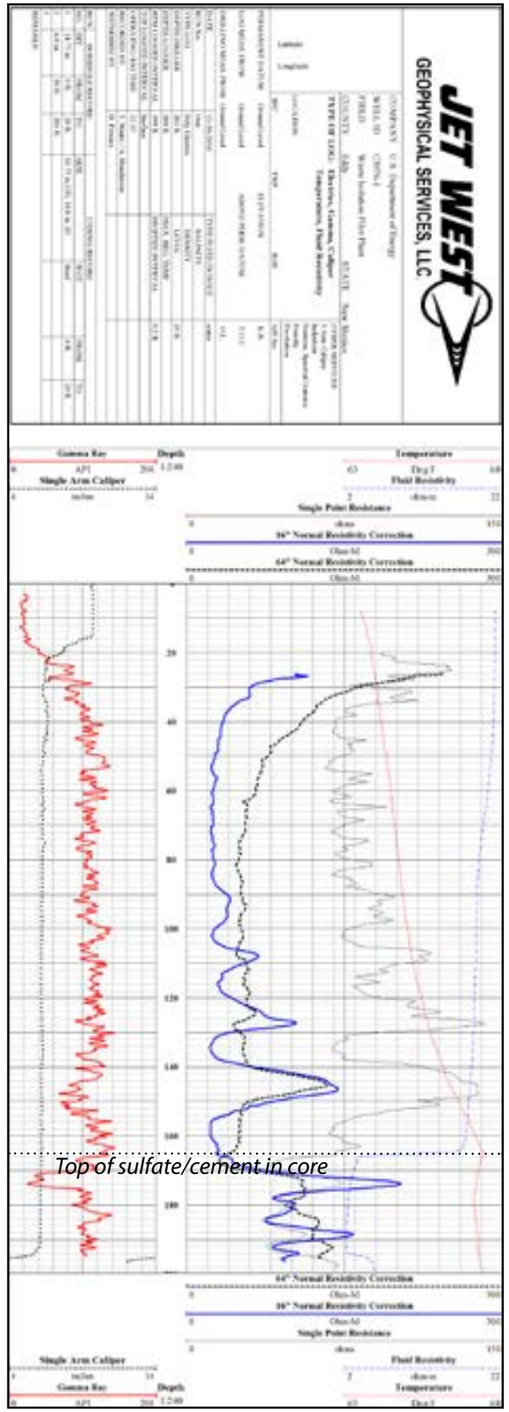


Figure 7
Dewey Lake features in C-3976-1. A. Clay-rich laminae and intraclasts at 77.5 ft. B. Fractures partially cemented with calcite at 146.5 ft. C. Sandstone 1 (ss1) and gypsum-filled separations at 173 ft. D. Gypsum-filled horizontal and inclined separations. Erosional surface at 188.45 ft. Small round light-colored spots are reduction spots. E. Thin laminae, slight cross-cutting, and ripples at 198 ft. High-angle gypsum-filled separation shows offset on horizontal separation. All core is 4 inches diameter.



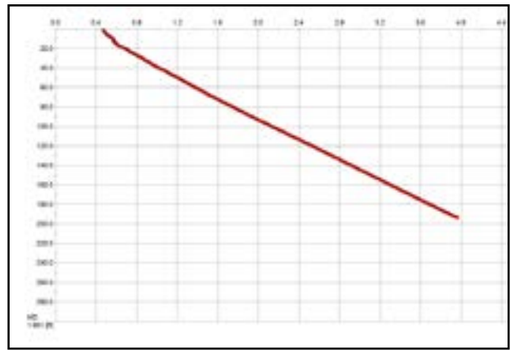
There is a change in the natural cements of the Dewey Lake at ~165.5 ft at C-3976-1. Above that point, carbonate cement is variable. Below ~165.5 ft, carbonate cements are not observed, but gypsum cement is common. Holt and Powers (1990) identified this natural cement change at a map depth of 164.5 ft in the air intake shaft. At C-3977, the cement change is at ~167.5 ft (Powers et al., 2018).

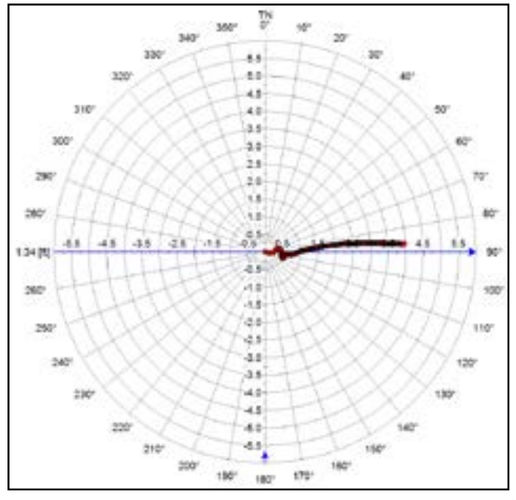
The cement change is readily observed in most resistivity logs, although such logs are rarely run in this formation in wells for oil and gas production or exploration. The resistivity log for C-3976-1 shows this relationship (Figure 8). Each of the resistivity values (point, 16-inch, and 64-inch) increase at ~170 ft (near midpoint of curves). This identifies a well cemented zone and corresponds to the top of ss1 (natural gamma log). The lower deep (64-inch) resistivity from 166 ft - 170 ft may correspond to the finding of moist cuttings, without detectable inflow, in some other wells (e.g., H-2a and H-2b; Mercer and Orr, 1979).

Changes in fluid temperature and fluid resistivity at ~165.5 ft may be related to the sequence of drilling and logging. Similar effects are observed in logs from other monitor wells (Powers, et al., 2019a, 2019b, 2019c), and C-3976-2 (Powers, et al., 2019c) is much shallower than the other wells. Drilling ended at 161.5 ft on November 29, and some fluid and/or foam (estimated ~10 ft) was detected in the drillhole on the morning of November 30. This was expected to be collected drilling water and foam. After completing the coring on November 30, the drillhole was filled with fresh water for logging.

Although the Dewey Lake is generally well indurated and gypsum cements below 165.5 ft make sandstone or sandy zones hard, the cores tend to separate along bedding planes.

Figure 8. Natural gamma, caliper, resistivity, and fluid temperature for C-3976-1. See attachments for different formats for geophysical logs for this monitor well.





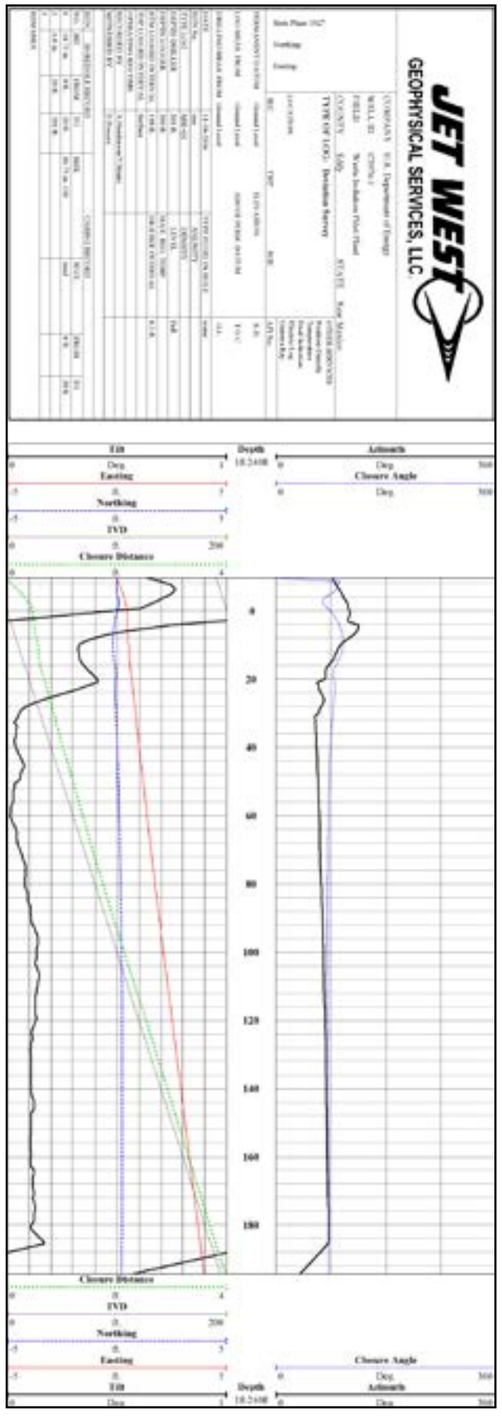


Figure 9. Deviation surveys of C-3976-1 at TD show a total deviation of ~4 feet, primarily to the east of the surface location. *Right:* Total survey with deviation expressed vertically. *Left bottom:* bulls-eye view of deviation expressed as azimuth and total deviation (ft). *Left upper:* Graph of total deviation (ft) by depth (ft).

Below the cement change, separations or fractures filled with fibrous gypsum are common (Figure 8D,E). These gypsum-filled separations generally fall into two classes: those following or subparallel to bedding planes and a subvertical set (generally between ~45°- 90° dip). The core will frequently separate at the junction of rock and gypsum.

GEOPHYSICAL LOGS OF C-3976-1

Prior to installing tubing for the monitor well, JetWest obtained a suite of logs (see attachments) that includes natural gamma, caliper, resistivity, neutron-density, and 4 spectral gamma surveys at stationary points.

The deviation survey of C-3976-1 at TD reached about 196 ft (Figure 9). Both the vertical log (with northing and easting) and the bullseye display indicate that the borehole is generally quite straight but tilted to the east from vertical. with a total deviation of ~4 ft.

GEOTECHNICAL WORK ON CORES

Of the four monitor wells (C-3976-1, -2, -3, and -4) that were cored, logged, and completed as monitor wells for possible shallow (<200 ft; < 61 m) saturated zones, samples from C-3976-1 and C-3976-2 were taken for basic geotechnical analysis. Short intervals (generally less than 3 ft) from each of these monitor wells were preserved for geotechnical work by wrapping and waxing soon after recovery. Fourteen short (1.1 ft - 3.8 ft; 0.34 m - 1.16 m) intervals from C3976-1 and C3976-2 were transported to Daniel B. Stephens and Associates lab in Albuquerque for testing. The tests have been completed, and those results have been reported (DBSA, 2017).

The suite of tests include: gravimetric moisture content (volume measurement method)

- particle size (wet sleeve, hydrometer)
- specific gravity
- Atterburg limits
- strength tests
  - unconfined compressive strength
  - unconsolidated undrained triaxial compression
  - consolidated undrained triaxial compression
  - consolidated drained triaxial compression
- slake durability

The tests have been completed and reported separately (DBSA, 2017), and the report is attached.

FIELD OBSERVATIONS RE SHALLOW GROUNDWATER

C-3976-1 was cored with air to ~110 ft and with mist and soap below 110 ft. There were no observed groundwater inflows, which includes the top of Dewey Lake where anthropogenic water has been found around the WIPP facility (e.g., Intera, 1997; Duke Engineering and Services, 1997) .

C-3976-1 was completed to examine the interval above the gypsum-cemented portion of the Dewey Lake for natural groundwater (Figures 3, 4, 8).

An inspection of the well on July 7, 2018, showed that the well was dry.

On August 8, 2018, C-3976-1 had a depth to water of 182.37 ft relative to the top of PVC tubing. The as-built shows 180 ft of PVC (bgl) in the well and 1.50 ft differential between the top of PVC and a nearby benchmark at approximately ground level.

On September 27, 2018, C-3976-1 had a depth to water of 182.39 ft from the top of PVC tubing.

The small amount of water detected to date is likely condensation; the well continues to be monitored.

SUMMARY POINTS

C-3976-1 was cored (4-inch diameter) and logged with geophysical logs to provide a record of the geology for a well to monitor for possible water at the top of a natural cement change in the Dewey Lake. Earlier drilling nearby to the south (e.g., H-2a) revealed moist cuttings at a similar stratigraphic position. WQSP-6, approximately 0.9 mile south-southwest of C-3976-1, encountered

water above this cement change, as did other wells farther south.

Core recovery from C-3976-1 was intermittent near the surface and improved with depth. Shallow stratigraphic contacts (above 40 ft depth) were estimated largely on the basis of geophysical logs. The change in natural cements at ~165.5 ft in core corresponds to geophysical log changes in resistivity as well.

The recovered samples above the Dewey Lake only partially represent the geologic units and their character. The upper Dewey Lake displays mainly fine-grained siliciclastic beds with laminae, slight cross-bedding or ripples, and some distinctive erosional surfaces. An informal bed (ss1; sandstone 1) is clearly observed in geophysical logs and corresponds to a sandstone interval in core. Below ~165.5 ft, the Dewey Lake also includes separations or fractures filled with fibrous gypsum and is well indurated due to gypsum cement.

The placement of screen in the completed well straddles the change in cements in order to test the interval for water. An initial test of the well in July 2018 indicated the well was dry. In September, 2018, a very small amount of water was detected in the bottom of the tubing.

Samples from C-3976-1 and C-3976-2 (report in preparation) for geotechnical studies were preserved shortly after recovery, initial photography, and field description. These samples were taken to Daniel B. Stephens & Associates testing laboratory. The results of the testing are included as an attachment.

The final deviation survey for C-3976-1 indicates a total deviation ~4 ft near TD, with the deviation being mainly east of the surface location.

ACKNOWLEDGMENTS

Ashleigh Pope and Rodney Whisenhunt (both NWP) provided management support during drilling. Tom Goedjen and Ariana Gonzalez (both NWP) supervised followup reporting.

Stewart Brothers supervisors and drillers worked closely with us to obtain the cores and logging that was the objective of the program.

Michael Schuhen and Owen Lofton (Sandia National Laboratories) supplied critical support for core transport and handling. Sandia provided needed support in the form of storage at the secure, climate-controlled environment at Iron Mountain facilities in Carlsbad. NWP has taken custody of the core, and it continues to be stored at Iron Mountain.

Andy Ward (DOE-Carlsbad) provided useful comments and discussions during planning as well as observation and discussion during the execution of the drilling.

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Clockwise from top left: John Thurston marking depths and orientation on Dewey Lake core; marked core from final core run in C-3976-1; soil color chart used to differentiate colors of rock cored in C-3976-1; example of screen used to complete C-3976-1 and other monitor wells on drillpad.



APPENDIX A PERMIT FOR C-3976-1 (POD1)

OFFICE OF STATE ENGINEER

NEW MEXICO

AND

DRILLING RECORD

(STEWART BROTHERS DRILLING COMPANY)

Tom Blaine, P.E.
State Engineer

Roswell Office
1900 WEST SECOND STREET
ROSWELL, NM 88201

STATE OF NEW MEXICO
OFFICE OF THE STATE ENGINEER

Trn Nbr: 591694
File Nbr: C 03976

Aug. 19, 2016

GEORGE BASABILVAZO
ANDERSON WARD
US DEPARTMENT OF ENERGY
PO BOX 3090
CARLSBAD, NM 88221-3090

Greetings:

Enclosed is your copy of the above numbered permit that has been approved subject to the conditions set forth on the approval page. In accordance with the conditions of approval, the well can only be tested for 10 cumulative days, and the well is to be plugged on or before 08/31/2017, unless a permit to use the water is acquired from this office.

A Well Record & Log (OSE Form wr-20) shall be filed in this office within twenty (20) days after completion of drilling, but no later than 08/31/2017.

Appropriate forms can be downloaded from the OSE website www.ose.state.nm.us or will be mailed upon request.

Sincerely,

Juan Hernandez
(575)622-6521

Enclosure

explore

UNIQUE #	DOE LOG NO.	DATE RECVD	ADDRESSEES
1602087	31487	AUG 24 2016	G Basabilvazo A Ward

File No. C-3976

NEW MEXICO OFFICE OF THE STATE ENGINEER

APPLICATION FOR PERMIT TO DRILL A WELL WITH NO CONSUMPTIVE USE OF WATER

(check applicable box):

For fees, see State Engineer website: http://www.ose.state.nm.us/ 237412

Purpose:
☐ Pollution Control And / Or Recovery ☐ Geo-Thermal
☐ Exploratory ☐ Construction Site De-Watering ☐ Other (Describe):
■ Monitoring ☐ Mineral De-Watering

A separate permit will be required to apply water to beneficial use.

☐ Temporary Request - Requested Start Date: Requested End Date:

Plugging Plan of Operations Submitted? ☐ Yes ■ No

STATE ENGINEER OFFICE ROSWELL, NEW MEXICO 2016 AUG 15 PM 1:55

1. APPLICANT(S)

Name: U.S.Department of Energy	Name: U.S.Department of Energy
Contact or Agent: George Basabilvazo check here if Agent ☐	Contact or Agent: Anderson Ward check here if Agent ☐
Mailing Address: P.O. Box 3090	Mailing Address: P.O. Box 3090
City: Carlsbad	City: Carlsbad
State: New Mexico Zip Code: 88221-3090	State: New Mexico Zip Code: 88221-3090
Phone: Phone (Work): 575-234-7488 ☐ Home ☐ Cell	Phone: Phone (Work): 575-234-7488 ☐ Home ☐ Cell
E-mail (optional): george.basabilvazo@cbfo.doe.gov	E-mail (optional): Anderson.ward@cbfo.doe.gov

FOR OSE INTERNAL USE — Application for Permit, Form wr-07, Rev 6/14/12

File No.: C-3976	Trn. No.: 591694	Receipt No.:
Trans Description (optional):	POD 1-4	
Sub-Basin: CUB		PCW/LOG Due Date: 8-31-17

Page 1 of 3

2. **WELL(S)** Describe the well(s) applicable to this application.

Location Required: Coordinate location must be reported in NM State Plane (NAD 83), UTM (NAD 83), or Latitude/Longitude (Lat/Long - WGS84).
District II (Roswell) and District VII (Cimarron) customers, provide a PLSS location in addition to above.

■ NM State Plane (NAD83) (Feet) ☐ NM West Zone ■ NM East Zone ☐ NM Central Zone
☐ UTM (NAD83) (Meters) ☐ Zone 12N ☐ Zone 13N
☐ Lat/Long (WGS84) (to the nearest 1/10th of second)

Well Number (If known):	X or Easting or Longitude:	Y or Northing or Latitude:	Provide if known: -Public Land Survey System (PLSS) (*Quarters or Halves , Section, Township, Range*) OR - Hydrographic Survey Map & Tract; OR - Lot, Block & Subdivision; OR - Land Grant Name
#1	103 degrees 47' 56.99"	32 degrees 22' 21.88"	
#2	103 degrees 47' 56.99"	32 degrees 22' 21.88"	
#3	103 degrees 47' 56.99"	32 degrees 22' 21.88"	
#4	103 degrees 47' 56.99"	32 degrees 22' 21.88"	

NOTE: If more well locations need to be described, complete form WR-08 (Attachment 1 – POD Descriptions)
Additional well descriptions are attached: ■ Yes ☐ No **If yes, how many** ____

Other description relating well to common landmarks, streets, or other:
Well coordinates are the center of the well pad for which these wells will be located. Wells will be located east of the WIPP site adjacent to the WIPP North Access Road.

Well is on land owned by: U.S. Department of Energy

Well Information: NOTE: If more than one (1) well needs to be described, provide attachment. **Attached?** ■ Yes ☐ No
If yes, how many 4

Approximate depth of well (feet): 200-300 feet	Outside diameter of well casing (inches): 2-Inches
Driller Name: Not Determined yet	Driller License Number: TBD

3. ADDITIONAL STATEMENTS OR EXPLANATIONS

See attached scope of work and diagram.

FOR OSE INTERNAL USE — Application for Permit, Form wr-07
File No.: C-3976 Trn No.: 591694
Page 2 of 3

4. SPECIFIC REQUIREMENTS: The applicant must include the following, as applicable to each well type. Please check the appropriate boxes, to indicate the information has been included and/or attached to this application:

Exploratory:	Pollution Control and/or Recovery:	Construction De-Watering:	Mine De-Watering:
☐ Include a description of any proposed pump test, if applicable.	☐ Include a plan for pollution control/recovery, that includes the following: ☐ A description of the need for the pollution control or recovery operation. ☐ The estimated maximum period of time for completion of the operation. ☐ The annual diversion amount. ☐ The annual consumptive use amount. ☐ The maximum amount of water to be diverted and injected for the duration of the operation. ☐ The method and place of discharge. ☐ The method of measurement of water produced and discharged. ☐ The source of water to be injected. ☐ The method of measurement of water injected. ☐ The characteristics of the aquifer. ☐ The method of determining the resulting annual consumptive use of water and depletion from any related stream system. ☐ Proof of any permit required from the New Mexico Environment Department. ☐ An access agreement if the applicant is not the owner of the land on which the pollution plume control or recovery well is to be located.	☐ Include a description of the proposed dewatering operation, ☐ The estimated duration of the operation, ☐ The maximum amount of water to be diverted, ☐ A description of the need for the dewatering operation, and, ☐ A description of how the diverted water will be disposed of.	☐ Include a plan for pollution control/recovery, that includes the following: ☐ A description of the need for mine dewatering. ☐ The estimated maximum period of time for completion of the operation. ☐ The source(s) of the water to be diverted. ☐ The geohydrologic characteristics of the aquifer(s). ☐ The maximum amount of water to be diverted per annum. ☐ The maximum amount of water to be diverted for the duration of the operation. ☐ The quality of the water. ☐ The method of measurement of water diverted. ☐ The recharge of water to the aquifer. ☐ Description of the estimated area of hydrologic effect of the project. ☐ The method and place of discharge. ☐ An estimation of the effects on surface water rights and underground water rights from the mine dewatering project. ☐ A description of the methods employed to estimate effects on surface water rights and underground water rights. ☐ Information on existing wells, rivers, springs, and wetlands within the area of hydrologic effect.
Monitoring: ■ Include the reason for the monitoring well, and, ■ The duration of the planned monitoring.		**Geo-Thermal:** ☐ Include a description of the geothermal heat exchange project, ☐ The amount of water to be diverted and re-injected for the project, ☐ The time frame for constructing the geothermal heat exchange project, and, ☐ The duration of the project. ☐ Preliminary surveys, design data, and additional information shall be included to provide all essential facts relating to the request.	

ACKNOWLEDGEMENT

I, We (name of applicant(s)), George T. Basabilvazo
Print Name(s)

affirm that the foregoing statements are true to the best of (my, our) knowledge and belief.

George T. Basabilvazo
Applicant Signature

Applicant Signature

ACTION OF THE STATE ENGINEER

This application is:
☑ approved ☐ partially approved ☐ denied

provided it is not exercised to the detriment of any others having existing rights, and is not contrary to the conservation of water in New Mexico nor detrimental to the public welfare and further subject to the attached conditions of approval.

Witness my hand and seal this 19th day of August 20 16, for the State Engineer,

Tom Blaine, P.E. State Engineer

By: Signature Print

Title: Juan Hernandez, Engr Specialist Supervisor
Print

STATE ENGINEER OFFICE 2016 AUG 23 P 1:36

FOR OSE INTERNAL USE — Application for Permit, Form wr-07
File No.: C-3976 Trn No.: 591694
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1.0 Introduction and Background

The Waste Isolation Pilot Plant is a research and development facility designed to demonstrate the safe disposal of transuranic wastes in embedded salt 2,150 feet below the ground surface. Figure 1 shows the WIPP Land Withdrawal Area (LWA) and surrounding outer areas.

Near the center of the WIPP site, shallow subsurface water (SSW), derived at least in part from anthropogenic sources, exists in a saturated zone that is generally less than 100 ft below ground level. Farther south (WQSP-6A), natural perched water in the Dewey Lake can be found above the change in natural cement from sulfate to carbonate. This statement of work (SOW) covers coring/drilling up to four monitor wells that will be completed according to regulations of the New Mexico Office of the State Engineer (NMOSE). The monitor well drilling is required to penetrate through the saturated interval to determine the base of the SSW. One well will be drilled to test for the presence of perched Dewey Lake water. NWP will monitor these wells for a period of time expected to be a few weeks to months.

STATE ENGINEER OFFICE
2015 JUL 15

The main purpose of three wells is to determine the static water level (potentiometric surface) for the SSW, if it exists at the proposed shaft location. The coring and logging will provide more direct evidence of the base of the saturated zone to infer thickness of the saturated zone for developing shaft construction plans. Geotechnical observations on core samples will also provide useful information for construction plans.

One well will initially be drilled deep enough to test for the presence of perched Dewey Lake water, although it appears unlikely to be present. If the perched water is found as a separate saturated zone, the well will be completed for observation of the Dewey Lake water. The annulus will be cemented to isolate the SSW from Dewey Lake water. If no separate Dewey Lake saturated zone is found, the lower part of the hole will be cemented back to near the base of the SSW, and the well will be completed as one of up to three SSW wells.

Where decision points and/or hold points may be required for this SOW, these points will need to be approved by the WIPP Site Technical Representative (STR) who will be, or confer as needed with, a geologist or hydrologist. In cases involving discharges and chemicals, Site Environmental Compliance (SEC) will provide approval prior to continuing work. Approvals may be obtained verbally via phone. Verbal approvals will be documented in the driller's log and/or field notes.

Figure 2 represents a generalized geologic cross section of the WIPP. For this activity, only shallow sediments and rocks will be relevant.

- The near-surface formations or sediments, from surface down, are expected to include: pad material, dune sand that has been flattened, reddish brown Berino soil (friable to moderately indurated sand), Mescalero caliche (up to several feet of variably indurated white carbonate), and Gatuña Formation (friable to moderately indurated sands, sandstone, and siltstone to mudstone).

- Santa Rosa Formation (expected to be very thin or absent) is variegated, intensely hued sandstone, siltstone, and mudstone or claystone of variable induration.

- The Dewey Lake ("redbed") Formation is relatively homogeneous reddish brown, moderate to well indurated very fine sandstone, siltstone, and claystone.

In general, the SSW is expected to have saturated a part of the Gatuña, any Santa Rosa that may be present, and an undetermined zone of the upper Dewey Lake. NWP best estimate at this time is that the saturated zone is likely to be less than 100 ft, but the driller should be prepared to go to at least 300 ft. The initial drillhole is likely to be deeper to test for a natural Dewey Lake perched zone above cement changes in the upper Dewey Lake.

Monitor wells shall be installed in accordance with the *NM Environment Department – Ground Water Pollution Prevention Section Monitoring Well Construction and Abandonment Guidelines*.

2.0 Scope of Work

The general scope of work to be performed will be to:

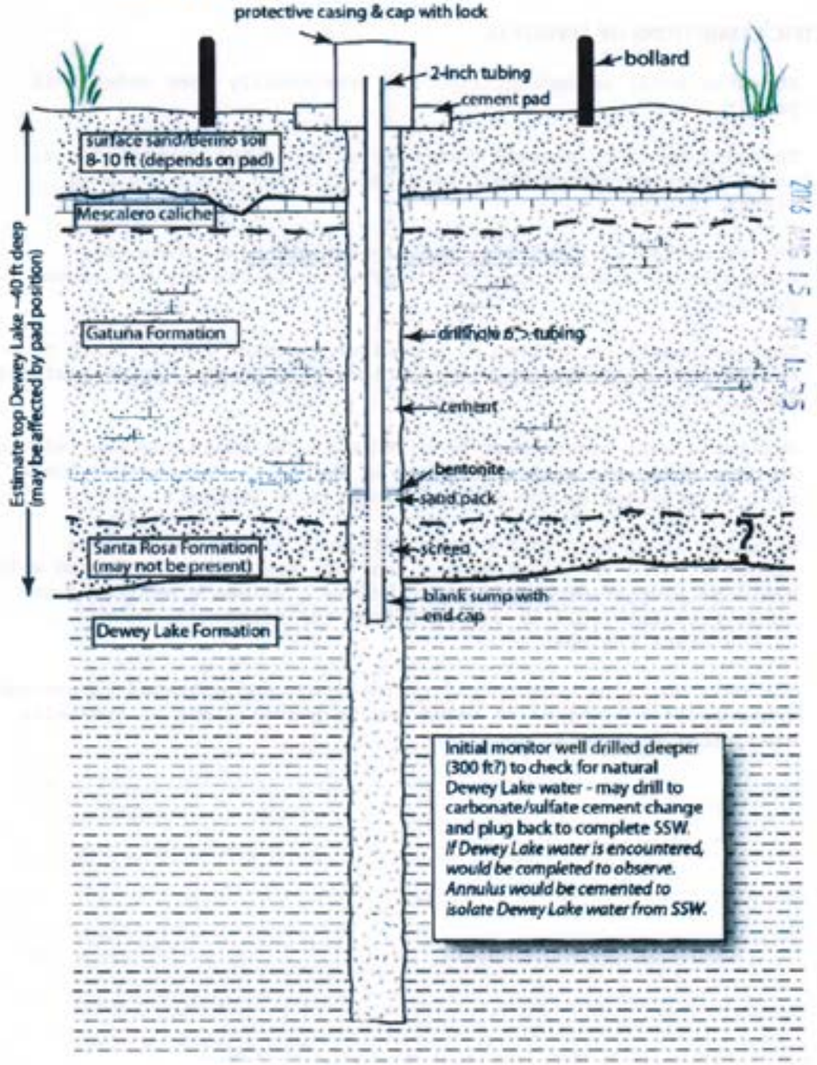
- Core/drill 1 to 4 monitor wells that penetrate through the base of the SSW (to be determined in the field during drilling) at locations selected by NWP at the edge of a large drilling pad. If no SSW is encountered at the first location, NWP reserves the right to end further coring/drilling.
- Complete all wells for monitoring by installing 2 inch PVC tubing (casing and screen) with end cap and ~10 ft of screen at depths directed by the Site Hydrologist or representative. A removable surface cap will be placed to enable access for monitoring. Note Table 1 specifications.
- Limited development at direction of STR.
- Contract for geophysical logging with recognized suppliers.
- Support temporary monitoring of water levels at direction of STR

P&A monitor wells according to NMOSE regulations based on a decision by NWP. The method and means will be determined in consultation with the NMOSE during the permitting process. Plugging typically involves leaving the casing intact and tremmie cement from the bottom to the surface. Cement will be sulfate and chloride compatible, and portland neat Type V will be used. The cement will ensure that cross contamination of ground water zones will not occur.

Figure 1 is a diagram of the expected construction of the wells.

Figure 1

Generalized Diagram of SSW Monitor Wells near New WIPP Shaft



Not to scale below top of Dewey Lake.
All depths are estimates.

NEW MEXICO STATE ENGINEER OFFICE
PERMIT TO EXPLORE

SPECIFIC CONDITIONS OF APPROVAL

4 No water shall be appropriated and beneficially used under this permit.

6 The well shall be plugged upon completion of the permitted use, and a plugging report shall be filed with the State Engineer within 10 days.

7 The Permittee shall utilize the highest and best technology available to ensure conservation of water to the maximum extent practical.

B The well shall be drilled by a driller licensed in the State of New Mexico in accordance with Section 72-12-12 New Mexico Statutes Annotated.

C Driller's well record must be filed with the State Engineer within 20 days after the well is drilled or driven. Well record forms will be provided by the State Engineer upon request.

C2 No water shall be diverted from this well except for testing purposes which shall not exceed ten (10) cumulative days, and well shall be plugged or capped on or before , unless a permit to use water from this well is acquired from the Office of the State Engineer.

P The well shall be constructed, maintained, and operated to prevent inter-aquifer exchange of water and to prevent loss of hydraulic head between geologic zones.

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NEW MEXICO STATE ENGINEER OFFICE
PERMIT TO EXPLORE

SPECIFIC CONDITIONS OF APPROVAL (Continued)

Q The State Engineer retains jurisdiction over this permit.

R Pursuant to section 72-8-1 NMSA, the permittee shall allow the State Engineer and his representatives entry upon private property for the performance of their respective duties, including access to the ditch or acequia to measure flow and also to the well for meter reading and water level measurement.

LOG The Point of Diversion C 03976 POD1 must be completed and the Well Log filed on or before 08/31/2017.

LOG The Point of Diversion C 03976 POD2 must be completed and the Well Log filed on or before 08/31/2017.

LOG The Point of Diversion C 03976 POD3 must be completed and the Well Log filed on or before 08/31/2017.

LOG The Point of Diversion C 03976 POD4 must be completed and the Well Log filed on or before 08/31/2017.

IT IS THE PERMITTEES RESPONSIBILITY TO OBTAIN ALL AUTHORIZATIONS AND PERMISSIONS TO DRILL ON PROPERTY OF OTHER OWNERSHIP BEFORE COMMENCING ACTIVITIES UNDER THIS PERMIT.

SHOULD THE PERMITTEE CHANGE THE PURPOSE OF USE TO OTHER THAN MONITORING PURPOSES, AN APPLICATION SHALL BE ACQUIRED FROM THE OFFICE OF THE STATE ENGINEER.

THE MAXIMUM DEPTH OF THE PROPOSED WELL(S), UNDER THIS PERMIT, SHALL NOT EXCEED A DEPTH OF 300FT.

CEMENT TYPE USED IN WELL CONSTRUCTION SHALL BE COMPATIBLE WITH ENCOUNTERED FORMATION CHEMISTRIES TO INCLUDE SULFATES AND HIGH SALT CONTENT.

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NEW MEXICO STATE ENGINEER OFFICE
PERMIT TO EXPLORE

ACTION OF STATE ENGINEER

Notice of Intention Rcvd: Date Rcvd. Corrected:
Formal Application Rcvd: 08/15/2016 Pub. of Notice Ordered:
Date Returned - Correction: Affidavit of Pub. Filed:

This application is approved provided it is not exercised to the detriment of any others having existing rights, and is not contrary to the conservation of water in New Mexico nor detrimental to the public welfare of the state; and further subject to the specific conditions listed previously.

Witness my hand and seal this 19th day of Aug A.D., 2016

Tom Blaine, P.E., State Engineer

By:
Juan Hernandez

Trn Desc: C 03976 POD1-4 File Number: C 03976
Trn Number: 591694
page: 3

Locator Tool Report

General Information:

Application ID: 29 Date: 08-18-2016 Time: 11:14:45

WR File Number: C-#1
Purpose: OTHER

Applicant First Name: USDOE-G BASABILVAZO
Applicant Last Name: USDOE-A WARD

GW Basin: CARLSBAD
County: EDDY

Critical Management Area Name(s): NONE
Special Condition Area Name(s): NONE
Land Grant Name: NON GRANT

PLSS Description (New Mexico Principal Meridian):

NW 1/4 of NW 1/4 of SW 1/4 of SE 1/4 of Section 20, Township 22S, Range 31E.

Coordinate System Details:

Geographic Coordinates:

Latitude:	32 Degrees	22 Minutes	21.9 Seconds	N
Longitude:	103 Degrees	47 Minutes	57.0 Seconds	W

Universal Transverse Mercator Zone: 13N

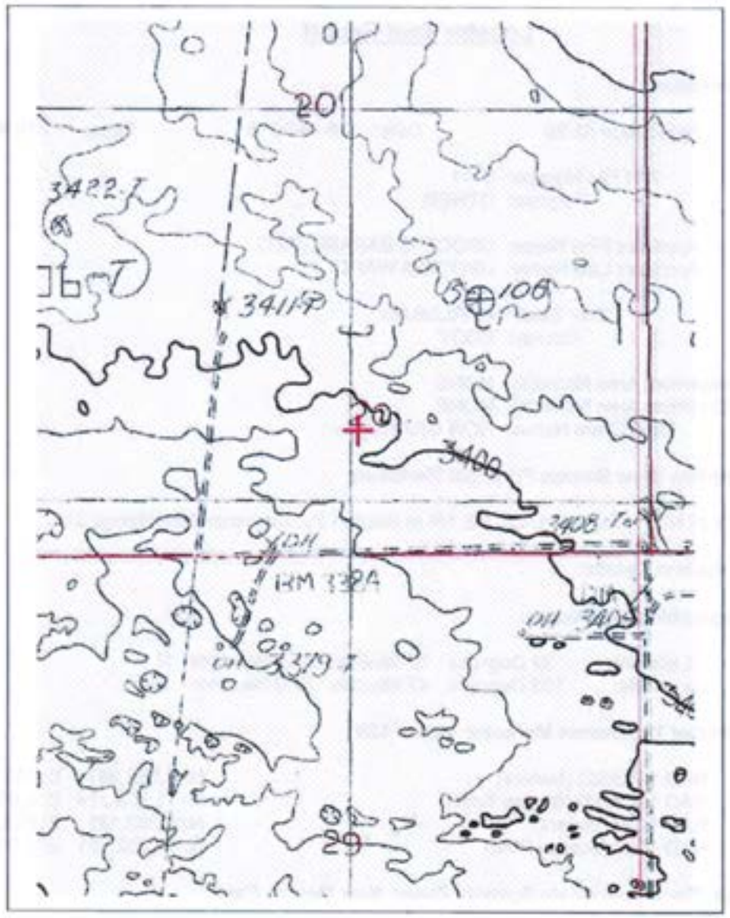
NAD 1983(92) (Meters)	N: 3,582,387	E: 612,968
NAD 1983(92) (Survey Feet)	N: 11,753,214	E: 2,011,045
NAD 1927 (Meters)	N: 3,582,185	E: 613,016
NAD 1927 (Survey Feet)	N: 11,752,551	E: 2,011,205

State Plane Coordinate System Zone: New Mexico East

NAD 1983(92) (Meters)	N: 152,323	E: 215,266
NAD 1983(92) (Survey Feet)	N: 499,748	E: 706,251
NAD 1927 (Meters)	N: 152,305	E: 202,713
NAD 1927 (Survey Feet)	N: 499,687	E: 665,069

NEW MEXICO OFFICE OF STATE ENGINEER

Locator Tool Report



WR File Number: C-#1 Scale: 1:14,368

Northing/Easting: UTM83(92) (Meter): N: 3,582,387 E: 612,968

Northing/Easting: SPCS83(92) (Feet): N: 499,748 E: 706,251

GW Basin: Carlsbad

New Mexico Office of the State Engineer
Point of Diversion Summary

(quarters are 1=NW 2=NE 3=SW 4=SE)
(quarters are smallest to largest) (NAD83 UTM in meters)

Well Tag	POD Number	Q64	Q16	Q4	Sec	Twsp	Rng	X	Y
	C 03976 POD1	1	3	4	20	22S	31E	612967	3582387

Driller License: 331 **Driller Company:** SBQ2, LLC DBA STEWART BROTHERS DRILLING CO.
Driller Name: JOEL STEWART

Drill Start Date: 11/18/2016 **Drill Finish Date:** 12/02/2016 **Plug Date:**
Log File Date: 12/21/2016 **PCW Rcv Date:** **Source:**
Pump Type: **Pipe Discharge Size:** **Estimated Yield:** 0 GPM
Casing Size: 2.00 **Depth Well:** 180 feet **Depth Water:**

Water Bearing Stratifications:	Top	Bottom	Description
	0	20	Sandstone/Gravel/Conglomerate
	20	100	Other/Unknown

Casing Perforations:	Top	Bottom
	150	170

The data is furnished by the NMOSE/ISC and is accepted by the recipient with the expressed understanding that the OSE/ISC make no warranties, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the data.

WELL RECORD & LOG
OFFICE OF THE STATE ENGINEER
www.ose.state.nm.us

1. GENERAL AND WELL LOCATION

OSE POD NUMBER (WELL NUMBER): C-3976-POD-1
OSE FILE NUMBER(S):
WELL OWNER NAME(S): U.S. DEPARTMENT OF ENERGY
PHONE (OPTIONAL): 575-234-7488
WELL OWNER MAILING ADDRESS: P.O. box 3090
CITY: Carlsbad STATE: NM ZIP: 88221

WELL LOCATION (FROM GPS): LATITUDE 32 DEG 22 MIN 23.9 SEC N; LONGITUDE 103 DEG 47 MIN 57 SEC W
* ACCURACY REQUIRED: ONE TENTH OF A SECOND
* DATUM REQUIRED: WGS 84

DESCRIPTION RELATING WELL LOCATION TO STREET ADDRESS AND COMMON LANDMARKS – PLSS (SECTION, TOWNSHIP, RANGE) WHERE AVAILABLE:
Due west of WIPP plant site on Locis Whitlock road

2. DRILLING & CASING INFORMATION

LICENSE NUMBER: wd-221 NAME OF LICENSED DRILLER: Joel Stewart NAME OF WELL DRILLING COMPANY: Stewart brothers drilling co
DRILLING STARTED: 11-18-2016 DRILLING ENDED: 12-02-2016 DEPTH OF COMPLETED WELL (FT): 180 BORE HOLE DEPTH (FT): 200 DEPTH WATER FIRST ENCOUNTERED (FT): n/a
COMPLETED WELL IS: ARTESIAN ✓ DRY HOLE SHALLOW (UNCONFINED) STATIC WATER LEVEL IN COMPLETED WELL (FT): n/a
DRILLING FLUID: ✓ AIR MUD ✓ ADDITIVES – SPECIFY: foamer
DRILLING METHOD: ✓ ROTARY HAMMER CABLE TOOL OTHER – SPECIFY:

DEPTH (feet bgl) FROM	TO	BORE HOLE DIAM (inches)	CASING MATERIAL AND/OR GRADE (include each casing string, and note sections of screen)	CASING CONNECTION TYPE	CASING INSIDE DIAM. (inches)	CASING WALL THICKNESS (inches)	SLOT SIZE (inches)
0	150	8 3/4	2 inch pvc	threaded	2 inch	sched 40	
150	170	8 3/4	2 inch screen	threaded	2 inch	sched 40	.010
170	180	8 3/4	2 inch pvc	threaded	2 inch	sched 40	

3. ANNULAR MATERIAL

DEPTH (feet bgl) FROM	TO	BORE HOLE DIAM. (inches)	LIST ANNULAR SEAL MATERIAL AND GRAVEL PACK SIZE-RANGE BY INTERVAL	AMOUNT (cubic feet)	METHOD OF PLACEMENT
180	139	8 3/4	20 x 40 silica sand	17	tremie
139	131	8 3/4	bentonite pellets	5	tremie
131	0	8 3/4	grout well cement grout	90	tremie

FOR OSE INTERNAL USE WR-20 WELL RECORD & LOG (Version 10/29/15)
FILE NUMBER POD NUMBER TRN NUMBER
LOCATION PAGE 1 OF 2

4. HYDROGEOLOGIC LOG OF WELL

DEPTH (feet bgl) FROM	DEPTH (feet bgl) TO	THICKNESS (feet)	COLOR AND TYPE OF MATERIAL ENCOUNTERED - INCLUDE WATER-BEARING CAVITIES OR FRACTURE ZONES (attach supplemental sheets to fully describe all units)	WATER BEARING? (YES / NO)	ESTIMATED YIELD FOR WATER-BEARING ZONES (gpm)
0	20	20	red sandy clay	Y ✓ N	
20	180	160	red clay with celeste lens	Y ✓ N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	

METHOD USED TO ESTIMATE YIELD OF WATER-BEARING STRATA:
☐ PUMP ☐ AIR LIFT ☑ BAILER ☐ OTHER - SPECIFY:

TOTAL ESTIMATED WELL YIELD (gpm): 0.00

5. TEST; RIG SUPERVISION

WELL TEST: TEST RESULTS - ATTACH A COPY OF DATA COLLECTED DURING WELL TESTING, INCLUDING DISCHARGE METHOD, START TIME, END TIME, AND A TABLE SHOWING DISCHARGE AND DRAWDOWN OVER THE TESTING PERIOD.

MISCELLANEOUS INFORMATION:

PRINT NAME(S) OF DRILL RIG SUPERVISOR(S) THAT PROVIDED ONSITE SUPERVISION OF WELL CONSTRUCTION OTHER THAN LICENSEE:
william bruneau

6. SIGNATURE

THE UNDERSIGNED HEREBY CERTIFIES THAT, TO THE BEST OF HIS OR HER KNOWLEDGE AND BELIEF, THE FOREGOING IS A TRUE AND CORRECT RECORD OF THE ABOVE DESCRIBED HOLE AND THAT HE OR SHE WILL FILE THIS WELL RECORD WITH THE STATE ENGINEER AND THE PERMIT HOLDER WITHIN 20 DAYS AFTER COMPLETION OF WELL DRILLING:

w.l. brunson — 12/20/2015

SIGNATURE OF DRILLER / PRINT SIGNEE NAME — DATE

FOR OSE INTERNAL USE — WR-20 WELL RECORD & LOG (Version 10/29/2015)

FILE NUMBER	POD NUMBER	TRN NUMBER
LOCATION		PAGE 1 OF 2

APPENDIX B CORE RECOVERY AND RQD
FOR C-3976-1

C3976-1

Core Run #	Depth top (ft)	Depth Base (ft)	Sum of Recovered length (ft)	Sum of Length (ft) of segments > 4 inches	Recovery (%)	RQD	
1	0.0	20.0	0.0	0.0	0.0%		Drilled, not cored
2	20.0	23.0	1.0	0.0	33.3%	0.0	
3	23.0	42.0	11.0	1.7	57.9%	15.5	
4	42.0	52.0	5.1	0.1	51.0%	1.8	
5	52.0	53.0	1.0	0.0	100.0%	0.0	
6	53.0	72.0	5.0	0.0	26.3%	0.0	
7	72.0	82.0	8.0	0.7	80.0%	8.8	
8	82.0	102.0	17.5	10.4	87.5%	59.4	
9	102.0	103.5	1.6	1.3	106.7%	81.3	from photos
10	103.5	122.0	17.3	16.0	93.5%	92.5	
11	122.0	141.5	18.4	13.7	94.4%	74.5	
12	141.5	161.5	20.5	17.3	102.5%	84.4	
13	161.5	181.5	19.1	16.6	95.5%	86.9	
14	181.5	201.5	19.8	18.0	99.0%	90.9	
TOTALS			145.3	95.8	72.1%	65.9	

APPENDIX C
CORE DESCRIPTIONS

Features and Structures
(used as needed)

- $f_{g/0°}$ fracture with fill (gypsum) and dip
- i_{Cslt} i_{Cg} intraclasts of gypsum or siltstone
- *sl* pedogenic slickensides
- 1.0+' desiccation crack (some with height indication)
- bioturbation
- soft sediment deformation
- small cross-bedding
- ripple bedding
- wavy bedding
- laminar bedding (~horizontal)

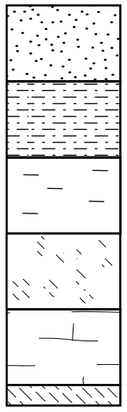
Abbreviations
(used as needed)

arg	argillaceous
c	coarse
calc	calcareous
clayst	claystone
cm	centimeter
f	fine
gen	generally
gg	greenish gray
hz	hard (drilling) zone
ind	induration/indurated
lam	laminae
ls	limestone
m	medium
mm	millimeter
mod	moderate
rb	reddish brown
sep(s)	separation(s)
ss	sandstone
sltst	siltstone
subang	subangular
tr	trace
v	very

Contacts and Bedding

- sharp contact or erosional surface within unit
- gradational contact or erosional surface within unit

Lithologies



CORE LOG — Sheet 1 of 6

Hole ID: C-3976-1 — Location: sw 1/4, section 20, T22S, R31E, Eddy County, NM

Drill Date: 11/18/2016 begin — Drill Method: rotary with air; core with air — Drill Make/Model: Schram T-130

Drill Crew: Mike King and crew (Stewart Brothers Drilling Company) — Hole Diameter: cored interval: 6.25 inch — Barrel Specs: 4 in. core; 6.25 in. hole

Hole Depth: 201 ft — Drill Fluid: air; air-mist; foam

Hole Orient: vertical — Core Preserv: waxed core box

Logged by: DW Powers and others — Date: 11/18/16-11/30/16 — Scale: 1 inch = 5 feet

	Northing	Easting	Elevation
Survey Coordinate: (m)			gl BM: 3401.16 ft amsl

Comments: lat 32˚ 22' 20.23" (32.37229˚); log -103˚ 47' 55.51" (-103.79875˚) (N lip steel pipe)

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Profile / Lithology	Features	ave. grain size (clay, silt, sand, granule)	Description	Remarks
1	0						Construction material and dune sand	
							no cuttings retained	Reamed 14.75" diameter to 20 ft'; set 10.5 inch steel casing to 20 ft.
	5							
		3.0 / 15.7	1.0 / 3.0					
	10							
							12.7: Ls, v sandy (Mescalero caliche), arg; pinkish white (7.5YR8/3; wet); base transitional over 0.1-0.2'	
	15						14.2: Sand vf - m, subang - round (~spherical); no sedimentary structures observed; soft, moldable; some fine roots	
		15.7					reamed 15.7-20 ft for casing. No samples.	
N/A; reamed 15.7-20 ft; cased				No recovery 15.7' - 20'				
	20	20		No recovery				
2		1.0 / 3.0	0 / 1.0				21.5-22.5: Ss, light gray (10YR7/2; wet); vf-f, sparse m; subang - subround, mod sorting, subspherical; tr biotite, hornblende(?), orange grains; bedding not apparent, retrieved as discs and loose sand; poor to mod induration; basal contact undetermined	
		23		No recovery				
	25							
3		11.0 / 19.0	1.7 / 11.0					
	30							

Hole ID: C-3976-1 (DL-1) CORE LOG (cont. sheet) Sheet 2 of 6

Logged by: geological team Date: 11/22-23/2016; 11/28/16

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Description	Remarks
3	30–35–40	11.0/19.0	1.7/19.0	No recovery 23.0-31.0 ft 31.0-31.5: Ss, silty, weak red (10R4/4; wet); vf, laminar, mod induration. 31.5-37.8: Ss, silty light greenish gray (Gley 2 8/1); interbedded with pale red (10R6/3; damp) thin, wavy lam; intraclast @36.5 ft. 37.8-41.0: Sltst, sandy, rb (2.5YR4/3); wavy laminae at mm scale; pedogenic slickensides; Ss, silty, gray (Gley 1 6/ to 6/1) at base.	
	42.0			41.0-42.0 Sltst, sandy, rb, similar to above; small gray reduction spots	end 11/22 @42.0'; begin 11/23/16
4	45–50	5.1/10.0	0.9/5.1	No recovery 42.0-46.9 ft 46.9-49.1: Sltst, sandy, light bluish gray at base (Gley 2 10B8/1) to reddish brown (5YR4/3) upward; near parallel laminae; base obscured; 49.1-52.0: Ss, silty; yellowish red (5YR5/6, dry) and interlaminated white (N8/); vf-f; reddish lam are more arg; slightly wavy, grades upward to reddish brown (5YR4/4) sltst with mm-scale lam.	
	52.0			52.0-53.0: Mudstone, reddish brown; uncertain source.	
5	53.0	0.5/1.0	0/0.5		
6	55–60–65	5.0/20.0	0/5.0	No recovery 53.0-67.0 ft remaining core scrambled during extraction; no depths marked; 5 ft of jumbled core assigned to 67.0-72.0 ft lithology and grain size not assigned bit chatter from 62 ft downward 67.0-72.0: core assigned to this interval but jumbled - order not determined; Clayst, silty; siltst; ss, rb (2.5YR5/4 dry), greenish gray (Gley 1 10GY7/1) nodule; includes probable chert nodule; fine lam, gen well indurated; calc.	
	70				

Hole ID: C-3976-1 (DL-1) CORE LOG (cont. sheet) Sheet 3 of 6

Logged by: geological team Date: 11/28-29/2016

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Description	Remarks
6	70				drilling with air
7	72–75–80	8.0/10.0	0.7/8.0	No recovery 72.0-74.0 ft 74.5 ft 74.5-75.0 Probable infall to drillhole (from core photos). 75.0-76.7: Ss, similar to below 79.0 ft; r-b (2.5YR4/4, r-b at base to Gley 2 5/1, gg, to 2.5YR3/3, dark olive brown). 76.7 ft 76.7-79.0: Ss overlain by sltst, similar to interval 79.0-83.5; erosional base. 79.0 ft 79.,0-83.5: Ss, red (2.5YR5/6); vf-f, grains rounded; fine lam; well indurated, slightly calc; overlain by sltst, rb to dark rb near top (2.5YR4/4 to 2.5YR3/4 upward); lam are mm-cm scale; intraclasts near top; more arg in upper 1 ft; poorly indurated, non-calc; base possibly erosional.	
	82				
8	85–90–95	17.5/20.0	10.4/17.5	83.5 ft 83.5-84.7: Ss, silty to siltst, arg, sandy, red (2.5YR4/4) with greenish gray base; laminar, possible small intraclasts; base sharp at core break. 84.7 ft 84.7-94.3: Ss, silty, to siltst, sandy and arg upward, red to rb upward (2.5YR4/6 to 2.5YR4/4); ss is vf; generally mm-scale lam, some wavy bedding with slight erosion/cross-cutting; numerous siltst intraclasts, somewhat eroded on core surface during drilling; fracture at ~45° in siltst; some calc zones; mod induration; transitional base over about 0.5 inch. 94.3 ft 94.3-97.3: Ss, silty (increases upward), red (2.5YR4/6); vf sand; mm-scale lam, slightly wavy; pedogenic slicken-sides 94.5; slightly calc to non-calc; mod induration; basal contact indistinct, probably transitional over ~0.5 inch 97.3 ft 97.3-105.5 (lost core assigned 99.5-101.9): Ss, silty at base to sandy sltst to arg sltst upward (rb to red upward (2.5YR4/4 to 2.5YR4/6) with some zones of light greenish gray (Gley 1 5GY8/1) in upper sltst; mm-scale sub-hori-zontal lam in ss; mm-scale, near-horizontal to slightly wavy lam in upper sltst with variable clay in laminae; possible desiccation cracks or shrinkage @~99.0; variably calc to non-calc; moderately to well indurated. No recovery 99.5-101.9 ft	
	100				
9	102 103.5	1.5/1.5	1.0/1.5		102 ft end 11/28/16; begin 11/29/16; no water, some sticky mud found prior to drilling.
10	105–110	17.3/18.5	16.0/17.3	105.5 ft 105.5-110.7: Ss to siltst, similar to series below 110.7 ft; ss is thicker with zones of apparent porosity (108-109); washout of probable intraclasts ~0.5 mm diameter; bedding not apparent (even with sanding of surface); opaques may be >5%.	

Hole ID: C-3976-1 (DL-1) CORE LOG (cont. sheet) Sheet 4 of 6

Logged by: geological team Date: 11/28/2016

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Description	Remarks
	110				drilling with soap & mist
				110.7 ft — Series of: (upper part): Ss, silty to silty claystone; reddish brown to dusky red (2.5YR series); lam to possibly unbedded; some desiccation cracks. (base): Ss, silty, white (N9/) (also ~10YR8/2, very pale brown); vf-f, some m-c, subang-subround; some intraclasts; trace opaques; bedding laminar to fague, rare possible ripple bedding; slightly calcareous; mod to well indurated.	
				111.9 ft	
				113.3 ft	
				114.0 ft	
	115				
		17.3 18.5	16.0 17.3	116.6 ft	
10				117.4 ft	
	120			120.0 ft — possible ball and pillow at 120.0 ft.	
		122.0			
				124.3 ft — Claystone, silty, sandy, r-b (2.5YR5/4) at top of ss sequence. Ss, light r-b (2.5YR6/4) with "white" base (~10YR8/2, very pale brown) and near top at 124.7; vf-f, possibly fining upwards; 1-2% dark grains; subround-subangular; laminae and wavy or curving bounding surfaces with poorly defined internal bedding; very little carbonate; moderate induration.	
	125				
	130				
				131.3 ft	
11				Ss, silty, red to r-b upward (2.5YR4/6-4/4); generally fining upward, vf-m; thin lam of sandy argillaceous r-b siltst, and cm-scale white beds of silty, argillaceous ss that are f-m; probable incraclasts at ~134 ft; fractures at ~45° in lower halt, MnO staining on some; moderate induration; initial field-designated lost core interval (140.5-141.0) appears to have been recovered in subsequent core - lithologic trend is continuous.	
	135	18.4 19.5	13.7 18.4		
	140				
		141.5			
12				Ss, slightly silty, r-b (2.5YR3/4-4/4); generally f, some m grains; laminar to thin bedded; carbonate cement, well indurated; calcite fill in vertical fractures with significant apparent aperture.	
	145	20.5 20.0	17.3 20.5		
	150	150			

Hole ID: C-3976-1 (DL-1) CORE LOG (cont. sheet) Sheet 5 of 6

Logged by: geological team Date: 11/29-30/2016

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Description	Remarks
	150				drilling with mist & soap
12		20.5 20.0	17.3 20.5	154.7 ft — Ss, silty, slightly arg, rb (2.5YR4/4); f-vf sand; interbedded with silty claystone lam, some slightly deformed; some intraclasts; very thin (~1 mm) gypsum along bedding planes near top; variably indurated; sharp, erosional basal contact overlain by intraclasts.	
	155				
	160				
		161.5		161.7 ft	end 11/29/16; blow hole down; 0725 MST, 11/30/16; water 152' below ground level; begin @ 161.5'
				162.6 ft — Ss, dark red (2.5YR3/6); f-m sand, well rounded, mainly quartz; lam at mm scale, slightly wavy, slight cross-cutting; variable induration; sharp basal contact.	
	165			165 ft — Ss, silty, rb (2.5YR4/4) with light greenish-gray (Gley 1 5GY7/1) spots, some to 1" or larger; vf-m; generally subhorizontal lam with some ripples; carbonate limited above 165", not found below 165'; probable sulfate cements and common gypsum separation-fill below 165'; sparse gypsum above 165'; variable induration.	
				169.3 ft	
	170				
13		19.1 20.0	16.6 19.1	171.3 ft — SS, silty, rb, with dark rb arg sltst in upper 0.1 (171.3-171.2) and c sand in finer, laminar ss at base (176.3-175.9); gen m sand with some c and some f; rounded, some subrounded, grains appear frosted; << 1% opaques; bedding not prominent, gen ~horizontal to ~5° inclination; well indurated. [Probably the bed identified as "ss1" in other well logs in the area, e.g., Powers et al., 2018.]	
	175			175.9 ft	
				176.3 ft — Ss, rb to dark rb upward (2.5YR4/4 to 2.5YR3/4), greenish gray spots to 3 mm; vf-f, some m, subrounded; <1% opaques; thin bedding to very thin lam (poorly displayed); minor desiccation cracks below scour surface near base; some soft sediment deformation; ~ horizontal and high-angle separations with fibrous gypsum fill; cement is sulfate; very well indurated.	
	180				
		181.5			
				183.8 ft — Ss, silty, red (2.5YR4/6); vf-f sand; lam with minor rippling and some intraclasts in lower part, well displayed lamin with some ripples and slight cross-cutting in upper part; may coarsen into overlying unit; minor scour surfaces at 186.5 and 186.7; well indurated.;	
14	185	19.75 20.0	18.1 19.75		
	190	190			

Hole ID: C-3976-1 (DL-1) CORE LOG (cont. sheet) Sheet 6 of 6

Logged by: geological team Date: 11/30/2016

Run Number	Depth (feet)	Recovered (ft/ft cored)	RQD (ft/ft)	Profile / Lithology	Features	ave. grain size: clay / silt / sand / granule	Description	Remarks
11	195	11.0 / 12.0	5.0 / 11.0		g; g; sl		192.1 ft: Ss, silty, rb (2.5YR4/4); f-vf sand; mm-scale lam well displayed with some slight cross-cutting/erosion; rare ripple; subround to round; non-calc; well indurated, sulfate cement; several seps with fibrous gypsum fill. 194.5: Ss, silty, rb, to sandy sltst at top with light greenish-gray spots; sedimentary structures similar to interval above; numerous horizontal to low angle seps with fibrous gypsum, one high-angle sep with fibrous gypsum in lower part of interval; well indurated. 198.5: Ss, silty, to silty clayst, rb with light greenish-gray spots; sedimentary structures similar to interval above; includes ~horizontal gypsum-filled seps. 200.3 / 201.3: Siltst, very sandy, red (2.5YR4/6); vf sand; mm-scale lam, slightly wavy; pedogenic slickensides near top; subhorizontal, bifurcating thin seps filled with fibrous gypsum; very well indurated, cemented with sulfate.	End drilling 11/30/16; driller's depth 201.5′