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# MISCEL REPORTS

# Basic Energy Brine Well
# (API# 30-025-32394)
# near Jal, NM


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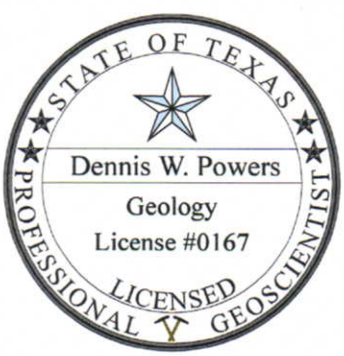


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## General Information

Basic Energy Services Brine Well Salado #002 (API# 30-025-32394) near Jal is located 1305 ft fnl, 60 ft fel of section 20, T25S, R37E, in Lea County, NM (Figure 1). This well is being examined to determine remedial actions that may be required. If these are unsuccessful or inappropriate, the well will be considered for plugging and abandonment (P&A). This report summarizes background data on the well, estimated geological conditions at the site and surroundings, and proposes a plan for restoring the well to service or P&A.

## Geology

Five formations at the Jal well are discussed further in this section, while the middle three of these formations have been identified and marked on a log cross-section (Figure 2) that crosses the Jal well location. Near-surface formations of the Dockum Group and the Ogallala are not shown here. The deeper Permian Yates Formation is not included in this discussion or cross-section, which is at the same scale as the cross-section included in the report for the Eunice brine well (Powers, 2010).

### *Permian Tansill Formation*

The Tansill lies between the Yates (not discussed) and the Salado in the area of the Jal brine well. It marks the transition from back-reef environments upward to more evaporitic deposits (Salado). The Tansill is generally composed of carbonates and anhydrite. The Tansill is at a depth of 2600 ft below ground surface at the adjacent well (#11661; Figure 1).

### *Permian Salado Formation*

The Salado is the principal salt-bearing unit in the backreef areas. [The Castile Formation underlies the Salado in the Delaware Basin and overlies formations equivalent in age to the Tansill. The Castile is restricted by definition to the Delaware Basin.] The Salado is 1342 ft thick in #27837 and 1430 ft thick in #25174. These two logs bracket the brine well location and are best suited for determining the thickness. This cross-section indicates that the upper Salado, at least locally, thickens slightly to the east. The Salado is estimated to be ~1380 ft thick at the position of the brine well, based on the log of the adjacent well #11661.

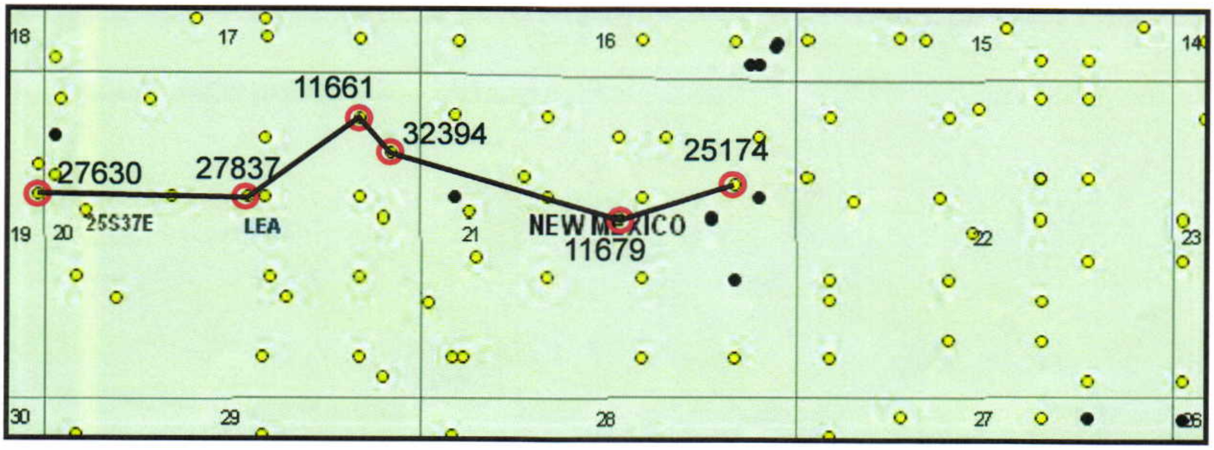


Figure 1. Location map of five wells in the vicinity of the Jal brine well (API # 32394) used in a cross-section (Figure 2). Wells show shortened API # (30-025-xxxxx).

The Salado is characterized generally by a high proportion of halite (~85%) and sulfate (~15%) beds. A mineral analysis would be a little different, accounting for the minor compositions. The formation is organized in depositional cycles that are a few feet thick and show characteristics of desiccating-upward environments (Holt and Powers, 1990). The typical cycle is caused by initial flooding of the basin that deposits sulfate (anhydrite or gypsum). As time passes, the brine becomes more concentrated and halite is deposited. Through the cycle (probably thousands of years) the basin dries up more frequently between flooding events, and it then becomes a dry salt pan with infrequent flooding or rainfall and a brine table below the surface. The cycle ends with a new major flooding period and a new cycle begins.

A characteristic of the Salado is that some of the sulfate beds are thicker because of longer flooding by less evaporated brines. Within the Delaware Basin, 45 of these (mainly those with greatest thickness and lateral continuity) have been numbered from 144 (lowest) to 100 (highest) and are called marker beds (MB). In addition, there are two named similar beds (Union and Cowden Anhydrites). Two upper thicker marker beds in the cross-section (Figure 2) are believed to be equivalent to MB 103 (upper) and MB 109 (lower). A third MB from the top of Salado is likely to be MB 116, but the correlation is less certain.

Another important correlation horizon in the Salado is the Vaca Triste Sandstone Member. In geophysical logs and geologic descriptions of boreholes for potash exploration in the Delaware Basin, this horizon is commonly well described or interpretable. It is widespread in the Permian Basin, and it represents a desiccation surface that was exposed longer than other desiccation surfaces in the formation. It is commonly more clay-rich and thicker than other desiccation surfaces, and it likely has poor tensile strength although it also can show halite cements.

Halite beds in the Salado at the Jal well are high purity halite, although geophysical logs indicate some thin sulfate interbeds (< 2 ft thick).

### *Permian Rustler Formation*

The Rustler in the Delaware Basin is divided into five formal members, from base to top: Los Medaños, Culebra Dolomite, Tamarisk, Magenta Dolomite, and Forty-niner.

The lithology of Rustler members at Jal differs somewhat from the sequence in the center of the depositional basin to the west (Powers, 2008).

The Los Medaños is generally similar in thickness and lithology – mainly clastic (siltstone, fine sandstone) beds and some halite to more halite. Near the eastern margin of the Delaware Basin, some halite beds are distinct.

The Jal well location is in a transition zone for the Culebra Dolomite. To the northeast, the Culebra tends to either not be present or be of different lithology and thinner. At the location of the brine well, the Culebra appears to be present and dolomitic (Figure 2). To the north and east, the Culebra does not exist, and the interval immediately above the Los Medaños is halitic. In the cross-section, the Culebra is noted by a light brown background with a dolomite pattern. The Culebra is between 1130 and 1112 ft below ground level at well #11661. This interval is not likely to be the location of the upper cavern from the sonar survey, given the good log signatures in nearby wells indicating higher density and acoustic velocities than for halite.

The Tamarisk has lower and upper sulfate (anhydrite) beds separated by either mudstone that is relatively thin (<20 ft thick) or halite that is thicker (up to ~200 ft) (e.g., Powers and Holt, 2000). *This member is important to understanding the current situation at the Salado #2 well.* The lower anhydrite (informally called A-2) ranges from 1112 and 1104 ft below ground level at well #11661. The middle unit (either mudstone M-3 or halite H-3) ranges from 1104 to 1083 ft below ground level and probably includes halite. The natural gamma indicates significant siliciclastics (mudstone), and the density and acoustic signatures in nearby wells are consistent with either mudstone or mudstone/halite mixture. *This mudstone or mudstone (with halite?) is most likely where the upper larger cavern was detected by the sonar survey* (see below). The upper anhydrite (A-3) of the Tamarisk is from 1050-1083 ft at #11661, which is about 20 ft thinner than to the west in the Delaware Basin.

The Magenta Dolomite is relatively thin (~16 ft) through this area and is 1050 to 1034 ft below ground level; it is more commonly 25-30 ft thick to the west. The composition is generally a mix of dolomite and gypsum or anhydrite in approximately equal proportions. In normal stratigraphic sequences, such as this, the Magenta typically exhibits minor porosity and isn't a significant hydrologic unit.

The Forty-niner is similar to the Tamarisk, with lower (A-4) and upper (A-5) anhydrites and a middle mudstone (M-4) or halite (H-4) unit. The anhydrites are somewhat thinner than to the west, and the mudstone is of normal thickness. There is no indication of halite within the Forty-niner in the logs.

The Rustler Formation at the Jal Salado #2 brine well is generally similar to the Rustler as found in a complete core taken east of Eunice (Powers, 2008). The most significant difference is that the logs indicate a dolomite is present in the Jal well at the stratigraphic position of the Culebra.

### *Permo-triassic Dewey Lake Formation*

The Dewey Lake is the base of a sequence of red bed formations ranging from Permian to Triassic in age. The Dewey Lake is a relatively uniform, fine-grained clastic deposit that is reddish-brown in color with greenish-gray reduction spots. Fibrous gypsum fills small fracture apertures in the middle of the formation, and the middle also has sulfate (anhydrite) cements. In general, the Dewey Lake appears to be low in permeability for a clastic unit. The Dewey Lake is thinned dramatically over the Central Basin Platform, including the Jal area, when compared to the eastern Delaware Basin west of this location. At well #11661, the Dewey Lake is 419 ft thick, whereas it commonly exceeds 600 ft to the west in the Delaware Basin. It also is thinner to the northeast of Jal.

### *Triassic Santa Rosa Formation*

The Santa Rosa is a fluvial redbed sequence that is 242 ft thick and has an upper contact at 352 ft below ground level at #11661. The Santa Rosa is a minor aquifer in the region, producing water that can be less than 10,000 ppm total dissolved solids.

The stratigraphy of higher units at the Jal location, including upper Dockum Group and Ogallala or Gatuña Formations, is not described here.

## Hydrology near Jal Salado #2 Brine Well

The Salado #2 brine well continues to accept water while not returning brine. While this condition is discussed further below, the evaluation must consider losses either within the injection horizon or possibly to formations above the injection formation. Some general hydrologic conditions are reviewed here.

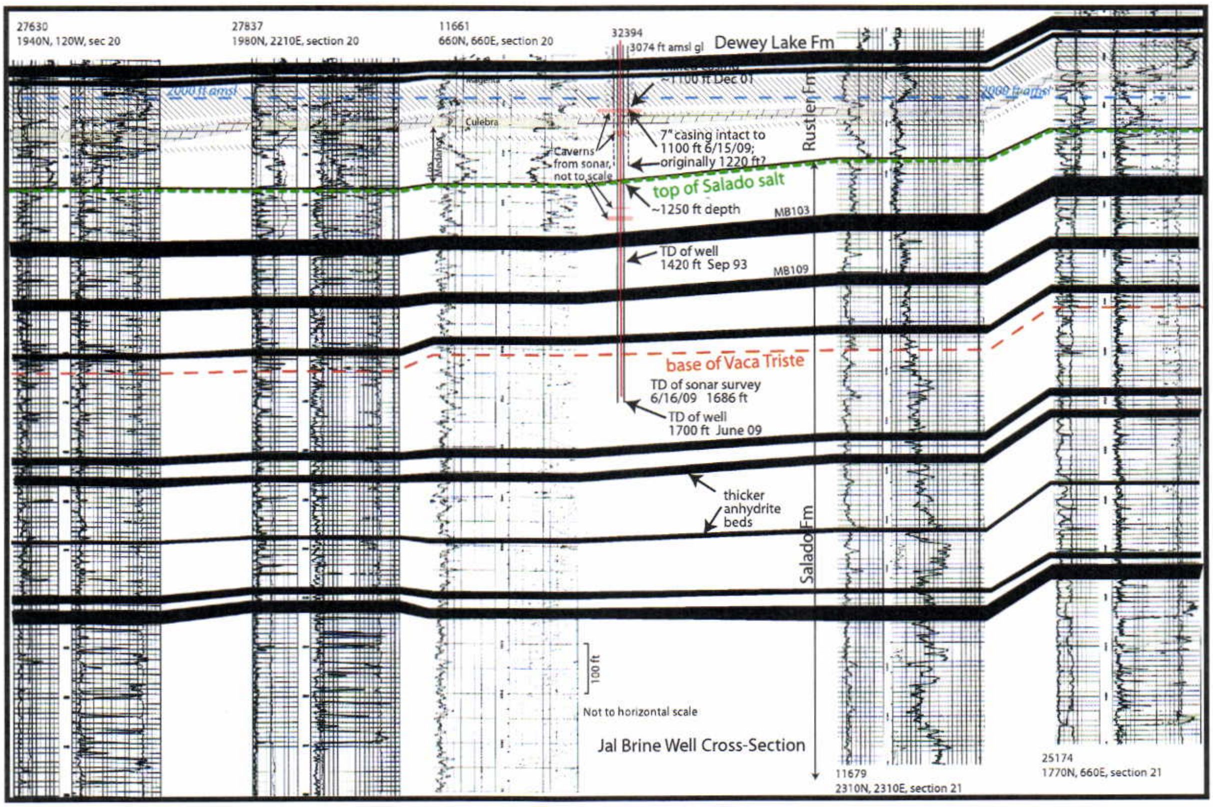


Figure 2. Geophysical log cross-section from west (left) to east (right) across the location of the Jal Salado #2 well (#32394). The logs of 27630, 27837, and 25174 are natural gamma-density log combinations through the important intervals that are very useful for interpretation of the lithologies. The diagonal line pattern indicates sulfate (anhydrite) beds. The Culebra is indicated by a light brown dolomite pattern, but it may also be halitic, especially to the east. A tabloid-size version is attached to the end of this report.

An early assessment of the hydrology of Lea County ( Nicholson and Clebsch, 1961) provides early estimates of the hydraulic heads within the Santa Rosa and Ogallala Formations, the two significant water-bearing intervals above the evaporites. On the west side of Jal, potentiometric surface contours for the "Dockum Group" (most likely to be water from the Santa Rosa) are about 2900 ft amsl. A projection of this contour eastward a short distance indicates that the potentiometric surface was likely to be slightly above 2900 ft at Salado #2. This would be less than 200 ft below ground level. The driller's report for the Salado #2 well indicated "red sand & water" at a depth of 340 ft, but no potentiometric surface was measured. Two wells completed in the Ogallala near the brine well location were reported to have water levels 60-65 ft below ground level. While these level data are relatively old, they provide a baseline. An enquiry of the website of the State Engineer of New Mexico produced no data from near the site. Three wells in the township to the south showed water levels 230-253 ft below ground level in wells having a depth of 550-600+ ft below ground level; these are likely to be Santa Rosa wells.

## History and Current Conditions of Jal Salado #2 Brine Well

The Jal Salado #2 brine well abbreviated history here is compiled from data posted on the NM OCD web site as well as from information from more recent company files.

Form C-101, dated 5/10/1993, proposed drilling the well to 1700 ft.

Form C-103, dated 9/27/1993, reports that a 14.75 inch hole was drilled to 60 ft and a 10-inch surface casing was cemented with cement circulated to the surface. This C-103 also reports a 9.875-inch hole was drilled to "top of salt" and 1220 ft of 7-inch casing was installed with cement circulated to the surface. A 6.125-inch hole was drilled to TD of 1420 ft and 1385 ft of 2.875-inch tubing was placed to 1385 ft.

Form C-103, dated 12/29/2001, reports that a cast-iron bridge plug at 1083 ft was drilled out. The hole was re-entered ("drilled") to 1247 ft with a 4.75-inch bit, and the bit was left on the tubing. The well was then put back into production on 12/28/2001.

Form C-103, dated 6/3/2009, reports that a bit and scraper were run to bottom of casing. After pulling out of the hole with the bit and scraper, a packer was run into the hole and the casing was tested. A 6-inch bit on 4.5-inch workover pipe was run to TD of 1650 ft. The bit was cut off, and a sonar survey was run inside the pipe. Production tubing (2.875-inch) was run into the well to 1650 ft and the well was put back into production.

Form C-103, dated 7/16/2009, reports activities similar to the previous C-103. A bit and scraper were run to the bottom of casing. Gray Wireline ran a density and collar survey log inside 4.5-inch tubing to 1650 ft and below to 1690 ft (file provided by Basic Energy Services). The bottom of the "intact" 7-inch casing was found at 1100 ft. The following comment was included with the Gray Wireline log:
*Based on density and sonar surveys, the intact 7" casing ends at 1100'. Records say casing shoe should be at 1200'. After pulling 18 joints of 4 1/2" tbg sonar shows parts of csg wall milled, below 1100'. Unable to get below 1150', without tubing in wellbore.* A packer was placed at 1080 ft to run a casing integrity test. A 6-inch bit was run on 4.5-inch workover pipe to 1650 ft, and the bit was cut off. The sonar survey (dated 6/16/09) was run inside the workover pipe from 1686 ft to 1100 ft. Production tubing (2.875-inch) was run to 1620 ft.

The sonar survey of 6/16/09 indicates significant enlargement at the following depth intervals:
1108-1115 ft, max diameters 54-108 ft;
1154-1158 ft, max diameters 12-16 ft;
1312-1313 ft; max diameters 19-20 ft;
1329-1336 ft; max diameters 16-28 ft;
The TD for the sonar survey was 1686 ft.

Form C-103, dated 3/8/2010, reports swabbing at four intervals between 1291.63 ft and 1449.73 ft produced brine from 8.34 lbs/gal at the higher levels to 10.1 lbs/gal from two lower sample points. The report indicates that 1418.23 ft of tubing was left in the well. Following the tests, fresh water injection was resumed.

The annual report, dated 4/22/2010, reported that 80 bbls of fresh water were being added per day following an initial injection of 1700 bbls in March to fill the cavity. The annual report also shows casing to 1220 ft, open hole to 1420 ft, and tubing to 1418.23 ft.

Form C-103, dated 10/26/2010, reported planned actions at the well and also reported that the well had not made brine after circulating water down the tubing for 1 month. A discussion with David Alvarado (Basic Energy Services) indicates that fresh water continues to be injected per directions of NM OCD to maintain pressure, although no brine is being produced at the surface.

## Discussion

The first point of discussion is that the depth of the 7-inch casing is uncertain. The most definitive statements place an initial casing depth at 1220 ft. The Gray Wireline survey indicates "intact" casing to 1100 ft and is not explicit about casing depth below that, other than to state that the log could not be run below 1150 ft without tubing in the well. The report of drilling out the CIBP at a depth of 1083 ft is generally consistent with comments on the Gray Wireline log regarding milled casing below 1100 ft. The subsequent casing test was conducted with the packer at 1080 ft, presumably to avoid the milled portion of the casing. No record available to me indicates why the CIBP had been placed in the hole. The casing test and log indicate casing integrity above ~1100 ft and uncertainty below that point.

A second point of discussion is that the cavern volume (5441 bbls) determined by the sonar survey in 2009 is far less than the apparent volume that would be required to produce the reported brine production from this well just for the period 2006 through 2008 (average 4560 bbls brine per month; Basic Energy summary). There are three obvious possible explanations of this disparity. The first possibility is that the sonar survey, while it looks appropriate, is incorrect or did not accurately reflect the cavern dimensions in the tested interval, especially if there is a casing from ~1100-1220 ft. The second is that the reported production volumes are incorrect. The third is that caverns exist below or above the interval that was tested by the survey. Some combination of any of these possibilities may have occurred.

The first possibility (inaccurate sonar survey) would provide a simple explanation in view of the uncertainty of the casing below 1100 ft. The other consequence is that the cavern diameters high in the section may be underrepresented. While a repeat sonar survey is practical, it is not the first choice to resolve questions about this discrepancy.

Early reported production volumes from 1993 to 2006 are not available to me. The later production reported by BES appears established well enough to conclude there is a discrepancy between the volume of brine and the volume of the caverns estimated with sonar. The production volumes are taken to indicate considerable excess of salt removal compared to the sonar cavern volumes. As with the Eunice brine well, the exact differences are less important, pending resolution of other factors, than the belief that those differences are currently unresolved.

The last explanation is not very satisfactory. The sonar survey of 2009 reached 1686 ft, which is very near the TD of the well reported in 2009 as well as in original drilling proposals. The history of the well is limited, however, and there are reported activities that provide no explanation for their necessity (e.g., drilling out a CIBP).

A third important point is that this well has a casing (at either 1100 or 1220 ft) that does not reach the top of the Salado Formation. Original drilling reports by West Texas Water Well Services indicates salt at a depth of 1140 ft and the geophysical logs of adjacent wells permit some possibility of halite or halite cements above this point. The upper two caverns indicated by sonar are clearly within the Rustler, and the larger, upper cavern is located in a zone (M-3/H-3) that certainly includes some mudstone based on the natural gamma log. This zone may include some halite cements, but the cavern development may be more from erosion than solution. Injected fresh water may be entering through a leaky, milled casing (or around the base of a casing ending at 1100 ft, which seems unlikely). The second highest cavern is small and developed either just above or just below a thin anhydrite (called A-1) in the upper Los Medaños in mudstone/halite units. As with the upper cavern, erosion may have played a more significant part than dissolution of halite.

The early configuration of the well after drilling is problematic with respect to cavern development. The original tubing depth of 1385 ft may be the source of the lower caverns, although the tubing is likely to have been placed within MB 103 if the depths are correct. The 2001 configuration with the tubing at 1247 ft is at the inferred depth of Rustler-Salado contact and may have played a part in developing the upper caverns.

The report from the fall of 2010 that this well continues to take fresh water without producing brine at the well head indicates loss of fluid that needs to be addressed.

It is very unlikely that the fluid loss is within the Salado Formation. Tests at the Waste Isolation Pilot Plant (WIPP) as well as in a drillhole in the Salado east of Eunice both indicate high fluid pressures within the formation. Longer testing periods of the Salado at the WIPP show that fluid pressures greatly exceed the hydrostatic column, even for brine, because the evaporite beds transmit most of the lithostatic load to the limited interstitial fluids in the formation.

The most transmissive unit within the Rustler is commonly the Culebra Dolomite, unless the Culebra underlies or is sandwiched between halite-bearing beds. At the brine well location, there is limited information regarding salt above the Culebra, and the Culebra does appear to be dolomitic, especially westward. It is a possible thief zone, especially considering the cavern development above and below it.

The Rustler mudstones have some transmissivity, but halite cements should limit this in the lower part.

The upper sulfate units and Magenta are unlikely to have significant transmissivity. These units tend to develop porosity if fractured or dissolved as part of karst processes at shallow depths.

The Dewey Lake is mainly claystone to fine sandstones with a middle zone of sulfate cements. It commonly has little permeability unless thin sands in the upper part of the formation are not cemented. These sands are between 650 and 700 ft below ground level at the well site. Nearby neutron and density logs show no indication of additional water or saturation in the interval of the sands or of any of the Dewey Lake.

The geophysical logs indicate that the Santa Rosa ranges from about 350-600 ft below ground level, and the natural gamma log indicates it is more sandy (likely more transmissive) than the underlying Dewey Lake or overlying Dockum Group.

The well location offers multiple intervals of salt at greater depths that appear more suitable than anything in the Rustler or uppermost Salado. Further work on this well will need to focus on establishing the current conditions and ability to drill deeper or reconfigure to focus solution in deeper intervals.

## Summary and Recommendations

The correlation and interpretation of the Rustler and Salado from west to east across the site of the Jal Salado #2 brine well show generally consistent thicknesses of units, slight general dip to the west, and that halite may be as shallow as ~1100 ft below ground level (in the Rustler Formation). Although Salado salt sections are much thicker and purer than any Rustler salt section, the sonar survey indicates that only a modest amount of Salado halite has been dissolved. In any event, the volume indicated by the sonar survey is inadequate to explain the brine volume produced from the well.

Geophysical logs show that several Salado marker beds, consisting mainly of the sulfate mineral anhydrite, are thick and continuous across the section. Thin (<3 ft) anhydrite beds are also present. The Vaca Triste Sandstone Member is also clearly identifiable. Halite beds between these marker beds are of high purity, based on the natural gamma log. Thus abundant salt is available at this location.

A sonar survey of the well conducted in 2009 indicates one main cavern located below the top of the survey at 1115-1108 ft. The maximum diameter of this cavern is 108 ft from the sonar survey. The ratio of diameter to depth is < 0.10, which is much less than the ratio of 0.67 considered critical for stability. The three lower caverns are much smaller. The upper cavern shows some offset to the well, being elongate updip to the east-northeast. The upper cavern also shows an apparent near-planar upper boundary and lower boundary that is interpreted to be a consequence of bounding, much less soluble and stronger sulfate beds. The two lower, small caverns show some evidence of relatively planar upper boundaries that may also indicate control by less-soluble, but thin, anhydrite beds.

There are inconsistencies among reports of the depth of the casing and a large discrepancy between the volume of the caverns mapped with sonar in 2009 compared to the recent estimated brine volume for his well. Before final recommendations can be made regarding continued operation or P&A of this well, some of these discrepancies need further investigation. The discrepancies may not be resolved with reasonable further work, and the decisions about the well will have to consider this.

The first recommended activity is to estimate the connections to any hydaulic units in the area by running a simple test. The test is to cease injection into the well and monitor and measure the fluid level until it either stabilizes (comes to equilibrium with another unit) or drops below the 1100 ft depth. The purpose of this test is to estimate whether the well may be in communication with the Dockum or Ogallala behind the casing. There is no known Rustler (Culebra) water levels from this area, and a connection with that unit will be uncertain.

The second activity is to conduct geophysical logging or other means of determining the quality of the the casing-cement-formation bonds from bottom of the casing to the surface. Such a survey is expected to help define whether there is connection behind the annulus that is allowing injected water to escape without returning brine to the surface. It also should help further define the depth of the 7-inch casing. If possible, all tubing should be removed from the hole for this survey.

The casing-cement-formation bond and quality survey will also help determine what further measures, if any, may be required to minimize behind-casing fluid movement or connection for either continued operation or P&A. One or more zones may need to be perforated and squeezed with cement if the bond log indicates fluid movement.

The caverns in the Rustler should be prevented from further development, if possible, if the well is operated in the future. Possible solutions depend on the depth and condition of the casing. If the formation-cement-casing bond can be determined to be good below the second (from the top) cavern, an inner sleeve may isolate the upper zones and allow further development at depth. The best solution would be to land an inner casing in or below MB 103 or MB 109 and seal off the annulus. The well could be developed near TD or it could be deepened by another 100 ft before resuming production. Deepening below the current TD (1700 ft?) may also allow installation of an inner casing and better sealing of the upper zones and caverns from the operational interval. Costs may be the deciding factor.

In the event that further examination of the well indicates the lower casing and upper cavern conditions cannot be sealed off for continued operation, the well should be plugged and abandoned. The casing annulus should be perforated and squeezed if the bond log shows possible zones of circulation. The well plug at its simplest is simply cementing the well on a CIBP or other plug placed as low as the casing shows integrity, possibly above the milled zone from 1100 ft down. It is probable that a plug cannot be retained if the casing has holes adjacent to, or near, the uppermost caverns.

A more complex plug can be designed (e.g., cement-bentonite-cement) based on conditions found in the well that would require P&A.

The highest possibility of continuing operation of this well requires the following conditions:

1. good determination of the current well configuration,
2. good results for the casing-cement-formation bond log and water level monitoring,
3. that it is practical to bypass the upper caverns and seal them from further fresh water intrusion,
4. acceptance that the discrepancy between current sonar-based cavern volumes and salt volume for total estimated brine production is reasonably accounted for,
5. no further evidence is found that the ratio of diameter to depth of any salt cavern is near or exceeds the ratio of 0.67 (currently $< 0.10$), and
6. a clear plan of limited operation and monitoring is presented and accepted.

A bare bones plan for item #6 could include reconfiguring the tubing to attempt further development above or below MB 103 or 109 and preferably well below the top of Salado, combined with a plan for regular (annual?) resurvey by sonar to determine if the solution is proceeding near the base of the tubing or developing elsewhere.

The activities to determine well configuration, including depth of casing and quality of the casing-cement-formation bonds are appropriate regardless of further activities in the well. For either P&A or proposals to continue operating the well, these are necessary. An inner casing cemented back to surface may be required, depending on any other suitable remedial action for the current casing, for the well to be put back into service.

One of the major concerns in abandoning brine caverns is the expansion of the brine over a period of time as it equilibrates from a (usually) lower temperature injection water to the (usually) higher temperature regime within the salt column. For larger caverns and greater differential temperatures, the period could take tens of years. For smaller caverns such as these, the period could be smaller. Creep within the salt beds and higher fluid pressures within the halite (~lithostatic) can also contribute to increasing fluid pressure with time. The weakest part of the system is commonly the cement-casing-cement system of the plug, and it will be subjected to pressures that will increase with time, as this part of the system may also degrade. It has been recommended in some situations that the well system not be P&A until after this initial pulse of brine expansion has passed. An open well, monitored over time to determine the decrease in pressure buildup, may provide a better opportunity for P&A in the near future (in this case).

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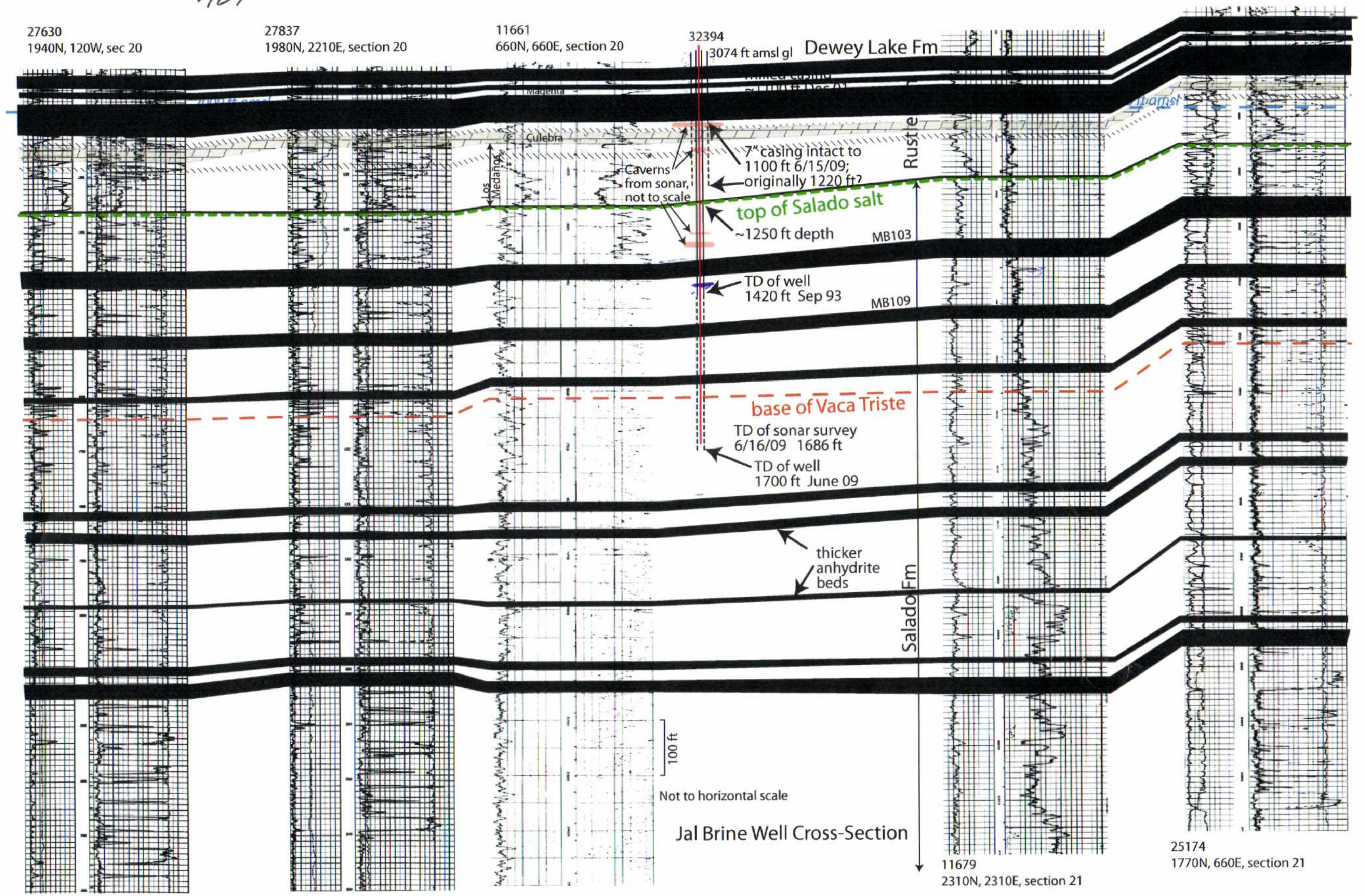

27630
1940N, 120W, sec 20
27837
1980N, 2210E, section 20
11661
660N, 660E, section 20
32394
3074 ft amsl gl
Dewey Lake Fm
Magenta
Culebra
Los Medanos
Rustle
7" casing intact to 1100 ft 6/15/09; originally 1220 ft?
Caverns from sonar, not to scale
top of Salado salt
~1250 ft depth
MB103
TD of well 1420 ft Sep 93
MB109
base of Vaca Triste
TD of sonar survey 6/16/09 1686 ft
TD of well 1700 ft June 09
thicker anhydrite beds
Salado Fm
100 ft
Not to horizontal scale
Jal Brine Well Cross-Section
11679
2310N, 2310E, section 21
25174
1770N, 660E, section 21