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REPORT & WORKPLAN

MAY 17, 2011

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SITE INVESTIGATION REPORT

<u>And</u>

REMEDIATION PLAN

NEW MEXICO SALT WATER DISPOSAL COMPANY, INC
New Mexico State Lands
SW1/4 SW1/4 Section 15, T10S, R34E

Saltwater Distribution Line Leak
Johnson Lease

Submitted to:
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I. Introduction

Whole Earth Environmental, Inc. (WEE) has prepared a Site Investigation Report and Remediation Plan on behalf of New Mexico Salt Water Disposal Company (). This report provides an overview of a salt-water leak site located in the south half of SW1/4 SW 1/4 of section 15, T10S, R34E in northern Lea County. The results of the incident, emergency response actions, and site investigations conducted by WEE are included herein.

Additionally, this report proposes a practical and cost effective method of restoring the impacted area to its normal rangeland capability with minimal surface disturbance, while ensuring that any underlying groundwater is protected. This site is located in a known habitat area of the Lesser Prairie Chicken (LPC), which currently is a highly imperiled prairie grouse species of the southern Great Plains. New Mexico holds a significant percentage of the remaining population, which is threatened by habitat loss, degradation and fragmentation.

Unfortunately, this species is on the candidate list for federal listing. Attached is Figure 9, which shows a BLM Timing Restriction Map. The site is located in the outer fringes of the habitat area.

All parties involved hopefully will agree that the state of NM is more in line with providing the proper protection of the LPC than the Federal Government. It is this implication that NMSWD and WEE wants to seek the expert advice of the State agencies in order to provide the maximum protection of the species while at the same time allowing the industry to function in order to provide good jobs and a tax base for the state of New Mexico.

The three main concerns regarding this site are:

A. Restoring the surface with as little surface disturbance as possible, in order to conserve natural resources and minimize collateral damage to protect wildlife habitat.

B. Define the depth and extent of the vadose zone and groundwater contamination, if present, and determine if the vadose zone is sufficient in its physiochemical composition to allow a surface agronomic type treatment of the oily soils and an ionic exchange method for the salt-contaminated areas.

C. Perform a cost effective remediation plan to accomplish the above concerns while ensuring that the goals of the NMSLO, OCD and G&F are carried out in a timely and conscientious manner.

Figure 1 shows the location of the leak site on a New Mexico State Trusts Land Map. The center of the site is located at approximately latitude 33°26'25.78" North and longitude 103°27'31.03" West.

NMSWD and WEE performed "Emergency Response Actions" in order to provide protection to cattle and wildlife. Free liquids were picked up to prevent any further downward migration of the fluids and damp to wet oily soils were stabilized by mixing with on site soils to mainly reduce the exposure of the contamination to cattle and wildlife.

This is a quick down and dirty method of rendering the soils to an unsaturated condition to prevent further downward and lateral migration. It enhances the natural microbes to start a natural bio-remediation process.

II. Background Information

New Mexico Salt Water is a commercial company, which collects and disposes of upstream oil and gas produce wastewater. The company employs a series of pipelines, tank batteries, and disposal wells to accomplish the task.

In October of 2010, the company discovered that a section of their disposal pipeline had failed in two places. The release was reported to the local OCD District office and a subsequent spill report C-141 was filed. Please find a copy of the C-141 in the list of figures as Figure # 10.

The spill consisted of oily produced water and the release was reported at 1200 barrels. The true amount of the spill is actually unknown, as the leak may have occurred over several hours or days.

The 1200 barrels was a figured used since that was the amount of water that was actually recovered. NMSWD recognizes that a more appropriate reporting number of barrels would have indicated that an unknown or best flow rate estimate would have been more accurate. An aerial photo of the spill site is included. (see figure #3.)

II.A. Land Use

The surface property, and minerals at the leak site are owned by the State of New Mexico and administered by the New Mexico State Land Office (NMSLO). Mr. Justin Johnson, a local rancher, leases the surface for rangeland in a beef cattle operation. The area has for years been an active oil and gas production area with numerous wells throughout. Presently, there are no buildings, windmills or other improvements in the immediate vicinity of the leak site. NMSWD has a right-of-way with the NMSLO for its pipeline operations.

II.B Site Physical Setting

The leak site is located in northern Lea County, New Mexico about 8.4 miles southwest of intersection between CR 170 and State Hwy 206 and 4.8 miles due south of CR 170 at the gate entrance to the property. The leak site is located in an upland area at an elevation ranging from about 4193 to 4199 feet above mean sea level (msl) and the land surface slopes gently to the east.

Shallow soils at the site have a fine sand surface layer in excess of 20 inches over subsurface layers of sandy clay loam to fine sand. These soils are classified as well drained to excessively drained.

II.C Soil Resource

It was determined from the Lea County Soil Survey aerial shown in Figure 2 that the land resource at the site is predominately a Tivoli-Brownfield fine sands complex. A complex is used to describe a map unit of two or more component soils that are comingled on the landscape in areas too small to be delineated at the scale of 1:24000. Tivoli and similar soils make up 50 percent of the map unit. Brownfield and similar soils make up about 40 percent of the map unit with about 10 percent as small inclusions of Springer and Gomez soils.

Tivoli fine sands (Typic Ustipsamments) have no significant horizonation within the profile apart from a change in color between the A and C horizons. These soils occur in dune areas. Brownfield fine sands (Arenic Aridic Paleustalfs) have a thick fine sand surface layer over sandy clay loam subsoil. Brownfield soils occur in areas between dunes and are well drained with moderate permeability. Springer loamy fine sand (Typic Paleustalfs) and Gomez loamy fine sand (Aridic Calciustepts) occur on similar landscapes as Brownfield soils. Springer soils do not have as thick an A horizon and less clay in the B horizon. Gomez soils have secondary carbonates throughout the profile and have a defined B horizon finer in texture than the A horizon but have not developed an argillic horizon. Series descriptions and other pertinent soils information is presented in Appendix A.

II.D Groundwater Hydrogeology of the Area: (Layman's Approach)

The site is located in Northern Lea County, New Mexico and is on the far extreme west side of the Llano Estacado, which is the southern extension of the High Plains in southeastern New Mexico.

The area of the leak site is located in a lineation of one of the well-defined entrances to the high plains known as the "Sand Gate". It has a significant signature as it represents an area where the west side of the caprock per se, does not exist and has some of the same surface features and formations as the Pecos Valley west of the site.

Most importantly is the fact that the Ogallala formation is either very thin or virtually missing in this area. The rocks and soils of this area generally cannot be distinguished between Ogallala materials from more older or recent deposited materials. Windblown sands generally cover the area and in some areas are underlain by thin beds of Caliche.

Caliche (caprock) has always been associated with the Ogallala formation throughout southeastern New Mexico. However, for one to make a generic conclusion that if caliche is found, it would imply that the Ogallala may be present, probably is not totally accurate. Case in point is the fact that in the Pecos Valley just west of the site, which is generally void of the Ogallala formation, has vast sand dunes with underlying caliche.

At the entrance of the Sand Gate, Triassic Red Beds are exposed at the surface as is the Ogallala formation, as is the limestone of the Lower Cretaceous unit, part of the Tucumcari shale.

There is a large area that has an irregular boundary (highlighted in Appendix D maps) where the Tucumcari shale actually outcrops in several places and is generally overlain by alluvium deposits. It is in this area where the release site is more or less located.

Please refer to the Ground-Water Conditions in Northern Lea County, New Mexico, reports by Sidney R. Ash 1963 contained in its entirety in Appendix section of this report. (Appendix D)

Also Included in Appendix D is a copy of a 1988 report " Hydrogeology of Lower Cretaceous strata under the southern High Plains of New Mexico" by Fallin of the Texas Water Development Board.

The irregular boundary is noted to be the approximate boundary of bedrock highs that interrupt the water table in the deposits of the Cenozoic age, i.e. the Ogallala formation aquifer. Included in Appendix F, is a highlighted section of this area Ts-10S R 34E depicting the location of the site and records from the state engineers office showing that no water well records are registered in this area.

Also included, are some well records that are just a few miles away from the site in an adjacent Township Ts-11S. This information is included to basically show how quick a transition occurs in this area. There are several water wells in this area, which is the Ogallala Aquifer.

It's important to point out here that lack of well records is not a definite indication there is no protectable ground water in this area, but it certainly shows this is an area where very little water is found and beneficially used.

The water in this bounded area, where present, is generally derived from the lower Cretaceous beds of the sandstone near the base of the Tucumcari shale. The Fallin report shows a good composite stratigraphic section of this formation. The release site more likely sets in or over the Duck Creek or Kiamichi formations, as confirmed by the yellow clay that is found at shallow depths.

The average thickness of the yellow clay is approximately 25-35 feet across the site according to the boring logs found in appendix B. The depth of this unit appears to be approximately 40-60 feet BGS. This unit probably is a very good barrier for any downward migration of infiltrated water, natural or man-made.

The lower unit of the Tucumcari shale is generally where groundwater is normally found in small usable quantities, i.e. for windmills and stock tanks. The depth is generally greater than 100 feet with a saturated thickness of usually less than 15 feet in the release area. The groundwater flow rates are generally unknown in the study area, but most likely extremely low. Even in areas of large flows such as in the Texas-New Mexico state line area, due east of the site, flow rates are generally less than one foot/day.

The only occurrence of Tucumcari shale waters discharging into the Ogallala is found near the New Mexico-Texas state line and in parts of Texas.

Exceptions are to the northwest in the Causey/Lingo area where irrigation wells pumped high volumes during the very late homestead years and up to the dust bowl days. Some of these wells are now dry and no longer used for irrigation farming.

The water quality of these waters is generally of lesser quality than the adjacent Ogallala waters. NMSWD has collected water samples from three water wells located as shown on Figure 11 and the analytical is included in Appendix E.

The chlorides for these wells are 400 mg/l for the Lucky well located approximately 2 miles southwest of the site, 530 mg/l for the Sand well Located approximately 1.75 miles to the northwest, and 60 mg/l for the Johnson Ranch well located about 2 miles south-south east of the site.

It is obvious that the Lucky and Sand wells are most likely in the Tucumcari (Cretaceous) water zone while the other well is probably in shallow sand alluvium or in a drainage course connected to adjacent or up-gradient Ogallala water.

The geochemistry of the two Cretaceous wells has high relative calcium content versus the other well on the order of 3:1. This most likely indicates the two wells are indeed being produced from a limestone formation versus from sand and gravel bed.

The recharge of the Cretaceous water in this area has been suggested to be from the Ogallala formation west and southwest of the site (see Falin fig 6 &7). Referring to Ash 1963, this area is also where the Tucumcari shale outcrops at several playa lakes in the area. It's likely this is where the salt is being picked up where the Ogallala overflows into the Cretaceous formation. The outcrops have been observed to consist of dark gray siltstone and thin interbedded stringers of limestone. (Ash 1963)

Both reports point out that the general dip for both the Ogallala and the Tucumcari shale is generally to the east and southeast. However, in the Sand Gate lineation, it thickens and dips to the northeast with local deviations. This is consistent with the inferred groundwater contours shown on the Ash report Sheet 2 of 2.

It is more than obvious there is no Ogallala Aquifer groundwater present at the release site. There is a high probability of Cretaceous water in a deeper horizon. This water is considered an Aquiclude, as noted in the referenced reports, since it's over and underlain by clays of the upper Cretaceous and Dockum group respectfully. Parts of the formation have demonstrated to be under confined conditions with water levels rising to the surface. This occurrence is probably not likely at the leak site, due to the fact it is so close to the recharge point.

An equally important question, is there protectable ground water lying on the upper Cretaceous clay layer? Included in Appendix D is a copy of the "Geologic and Hydrogeologic Evaluation of Borings and Monitor Well At And Around New Mexico Salt Water Disposal Co., Inc. Station 11-AP053 located in Section 21, Township 10 South, Range 34 East." Dr. Kay Havenor- Professional Geologist authored this report.

This site is less than one mile west of the NMSWD Johnson release site, see topo map in the figure section. (Fig. 12). Dr. Havenor's report indicates the lower Cretaceous water zone has not been impacted from Station 11 produced water spills. The report also concludes that the sand found on top the upper Cretaceous clay unit ***"is not"*** a water zone that produces beneficial use water.

What the report does show, is that man-made water is present on top of the clay and has the same physical and chemical characteristics as oilfield produced water. The same conclusion may be determined for the NMSWD Johnson site.

The Havernor report also correlated the fact that groundwater flow in the area is from the southwest to the northeast. This was concluded by the fact that the #2 Lucky well, discussed above, had nitrates, which migrated toward the Station 11 area. The discussion on the depths of this well also correlates that the Tucumcari shale dip in the Sand Gate area, is to the northeast.

This really substantiates why the water level in the Lucky well is producing at a shallower level than at the Station 11 or the Johnson leak site. According to Justin Johnson, the local rancher, the water level in this well is 50-60 feet BGS. This water well is approximately 1.5 miles to the southwest of Station 11. Station 11 water level, in the lower unit, is reported to be about 117 ft BGL.

The distance from Station 11 and North Lake is about three miles. Since there is documented evidence of the lower Tucumcari shale outcropping in this area, an estimated water level depth can be calculated in the Lucky Well.

Since the Lucky well is almost directly inline between Station 11 and North Lake, a formation gradient (117 ft/ 3 miles) equates to about 39 feet/mile. The Lucky well is approximately 1.5 miles from Station 11, multiplying this distance by the gradient of 39 ft/mile equals to about 58 feet. Subtract this from 117-58 = 59 feet to the depth of water. This correlates with what the rancher has indicated.

The significance of this is the fact that the agency (OCD) may have estimated or assigned a ground water depth to a C-141 remediation project in order to determine a clean-up ranking.

Sometimes, the best estimation may be from a local landowner, water well driller or from some database, or the local field inspectors general experience.

What the agency generally does not do is perform a hydro-geologic study as completed herein.

While the agency has a very good history of evaluating such sites, sometimes, as in this case, it may provide a false positive. In this particular case, both in Station 11 and the Johnson leak site area, it appears the agency may have inappropriately determined that high quality Ogallala water is present in this area at shallow depths.

Such a conclusion is not unheard of since some maps or databases do not provide the proper geologic data, water chemistry, or other essential information required to make an accurate assessment. If the agency used water depths found in the adjacent Ogallala Aquifer formation or from the Johnson House Well, this would have lead to a false conclusion that shallow high quality ground water is present at the Johnson site.

On the other hand, companies assume that such determinations can be made on limited data supplied, which hampers the agency's ability to perform a proper assessment. Usually when such data is not properly supplied, the project is stalled, and sometimes never completed.

However, there are cases where the agency never accepts data for what ever reason, and the project is stalled. The bottom line on these situations is that the environment and wildlife generally suffers.

Using these reports, along with other studies of the area, including anecdotal evidence, experience working in the area, and input from other state agencies, NMSWD seeks to obtain a technical determination and an approved path forward from the OCD concerning in-situ remediation.

III. Site Investigation and Work Scope

III.A Preliminary Site Investigation

WEE conducted a preliminary investigation of the leak site consisting of an electromagnetic induction (EM) survey to delineate the horizontal extent of produced water impacted soil and a light drilling rig to collect soils for analysis to delineate impacted soil vertically. The EM survey was made using an EM-38 device. EM devices work on the principal that soils are naturally low in electrical conductivity. Since produced water is high in salt when spilled to soil it dramatically increases the soils EM response with the response proportional to the amount of salt in the soil.

Stained areas captured in the aerial photograph presented in Figure 3 correspond well to the findings of the EM-38 survey shown in Figure 4. The interpretation is that the stained areas reflect the distribution or pattern of the release to the land surface. Soil samples summarized in Table 1 showed elevated chlorides in the impacted area to the maximum depth sampled before auger refusal. It was concluded that a larger drilling rig capable of advancing a hollow stem auger to 100 plus feet and collecting undisturbed soil for analysis was necessary to delineate the vertical extent of the produced water leak.

Following a review of the previous data, WEE prepared a work plan with specific objectives to augment the existing data to provide a surface soil restoration plan, to fully characterize chemicals of concern in subsurface soils, specifically their distribution with depth and potential for an adverse impact to groundwater resources.

III.B. Scope of Work and Investigation Strategy

The proposed scope of work was as follows:

- Conduct EM-38 and EM-31 surveys over a grid area extending to background soil conditions in all directions from the leak sites.

- Soil borings were completed at 5 target locations using a 2-in hand auger. Soils borings will be advanced to a total of depth of 5-ft with the samples collected in 1-ft intervals to develop salinity profiles for correlation to EM-38 readings.

- A total of 5 deep borings were completed in the vicinity of the two leak sites and at three background areas to define background soil quality and/or groundwater, if encountered. Additional borings may be necessary to determine the vertical and lateral extent of impacted media.

- Deep borings were completed using a hollow stem auger with discreet samples collected using a split spoon device every 5-ft to a depth of 20 feet and at 10-ft intervals to total depth.

- A portion of each sample was screened for petroleum hydrocarbon using an organic vapor analyzer (OVA) equipped with a photoionization detector (PID) and for salinity measuring the electrical conductivity (EC) in a 1:1 soil: water extract.

- A portion of each sample interval with a noted elevated PID reading was placed in 4-oz jars labeled as to borehole, depth, date and time then placed on ice for total petroleum hydrocarbon (TPH), benzene, toluene, ethyl benzene, xylenes (BTEX) and chlorides.

- A minimum of 2 samples per boring reflecting the highest PID reading and the deepest sample interval were transported under chain of custody to an analytical laboratory for TPH, BTEX and chloride.

III.C. EM-31 Survey

While the EM-38 survey identified anomalous high areas associated with the two separate leak sites, initial borings at these locations indicated that salt levels were increasing with depth below the range of the EM-38 device. This required a new survey with the EM-31 sensor. This survey was conducted using a continuous data logger and Tremble GPS tracking device to define the area surveyed in preparation of the 0-18 ft salinity contour map.

The EM-31 response was used to locate the deep borings and chart the distribution of salt associated with the two leak sites.

III.D Field and Laboratory Program

III.D.1 Shallow Borings

As noted previously, shallow borings were completed to a depth of 5-ft using a 2-in i.d. hand held sand auger. Samples were collected in 1-ft intervals for the purpose of measuring soil EC and calculating the profile EC. Profile EC is the test statistic used to correlate to the EM-38 response and determine soil salinity of the entire root zone. Profile EC is calculated from saturated paste values. In practice the soil EC is measured using a 1:1 soil: water extract which is then converted to a saturated paste EC (SPEC) using the saturated paste moisture (SP) equivalent determined on another portion from the same depth interval expressed in percent moisture. The computing formula is as follows:

$$SPEC = EC_{1:1} \times 100/SP$$

III.D.2 Deep Borings

Deep borings were constructed using a hollow stem auger to advance the borehole. Samples were collected using a 2-ft split spoon at the start of each boring and at 5-ft intervals to a depth of 20 feet and at 10-ft intervals thereafter to total depth.

Samples were analyzed for TPH using EPA Method 8015 M with differentiation as to gas range organics C6-C10 (GRO) and diesel range organics C10-C28 (DRO). Samples will be analyzed for BTEX components benzene, toluene, ethyl benzene and xylenes using EPA Method 8260B. Chloride was analyzed using EPA Method 9253 or other approved EPA method.

IV. Results and Discussion

IV.A EM Surveys

Contour maps of the EM-38 and EM-31 soil electrical conductivity, measured in the vertical dipole configuration, are presented in Figures 4 and 5, respectively. These plots show very similar distribution patterns in that the anomalous high areas, which correspond to the two, produced water leaks found. The east leak source was obviously the largest in terms of volume. Both plots reflect the distribution pattern of the stained soil mentioned previously.

The magnitude of the EM-38 response compared to EM-31 values in anomalous high areas suggests that the mass of salt is greater in the upper part of the profile but there has been significant movement down. It was observed that the EM-38 device identified a surface area of impact estimated at 70,000 ft^2, compared to an area of about 65,000 ft^2 using the EM-31 unit and the same EM response value of 150 mS/m.

It is instructive to note that the EM-38 device does not integrate soil electrical conductivity linearly with depth. Readings are weighted proportionately with depth similarly to the way plant roots absorb water from the soil.

IV.B Shallow Soil Borings and Soil Salinity

Three shallow borings SB1, SB3 and SB4 (Figure 6) were constructed inside the anomalous high area and SB2 at the background location to measure saturated paste electrical conductivity as a function of depth to ground truth EM-38 survey results and evaluate soil quality in terms of agronomic potential. The saturated paste electrical conductivity (SPEC) and paste moisture are summarized in Table 2. In order to compare EM readings to the water-uptake-weighted conductivity we first calculate the weighted profile EC from the measured SPEC values using the following equation:

$$\text{Profile EC} = 0.43*EC_{0\text{-}1ft} + 0.21*EC_{1\text{-}2ft} + 0.1*EC_{2\text{-}3ft} + 0.06*EC_{3\text{-}4ft} + 0.1*EC_{4\text{-}5ft}$$

Profile EC was then correlated statistically to the corresponding EM38 reading in the vertical mode to define a response curve. Regression analysis revealed the data best fit a multiplicative model (Y = a*X^b) with the 'Profile' EC = 0.000266507*EM38V^1.8337 and with a r^2 = 99.1

(Figure 7). EM-38 values in the vertical mode ranged from a high of 950 mS/m at the east leak source to a low of 50 mS/m in the background area. Corresponding profile EC calculated from the regression model then range from EC 0.35 mmhos/cm to EC 78.7 mmhos/cm.

The magnitude of salt in the anomalous high, impact areas clearly show that this site cannot recover without remediation to lessen the level of salt in the root zone. Paste moistures confirm the sequence of sand over sandy clay loam and the Brownfield soil resource.

IV.C. Deep Soil Boring Findings:

Five deep borings listed in the order constructed are identified in Appendix B as the East Leak Source Well, Northwest Background Well, Northeast Background Boring, South Background Well and West Leak Source Boring locations. Each boring except the west source was constructed using a hollow stem auger with the goal of sampling in 5 feet intervals to a depth of 20 feet, then in 10 feet intervals thereafter to total depth. Indurated caliche between the soil mantle and lower soils resulted in a few no samples collected for some intervals.

Soil boring physical descriptions are presented in Table 3 with the drillers logs attached as Appendix B. The lithology observed in each of the borings confirmed the sequence of soil over caliche followed by dry tan loose sand, sandy clay, and sandstone and the upper and lower units of the Tucumcari shale (Cretaceous units).

Field measurements and screening of salinity as chloride and total dissolved solids, and petroleum hydrocarbon by organic vapor analysis (PID) are presented in Table 4A, 4B, 4C, 4D and 4E This data reveals that salt levels were highest in the east source boring followed by the west leak source. These are the two areas where the pipeline failed.

IV.C.1 East Leak Source Well

The presence of salt throughout the profile in the east source boring may have been attributed to cross contamination from the upper media with produced water, carried down into the lower horizons during the drilling process.

Soil analyses showed an abrupt decrease in salinity parameters between the 48 and 58 feet sample intervals for the east boring (Table 4A). These were sampled on December 6, 2010 with drilling suspended at a depth of 64 feet. The augers remained in the borehole over night with drilling commencing the next day. The east source boring was completed to a total depth of 98 feet.

Drilling was stopped at this depth after a show of what appeared to be oil droplets and some streaks in saturated brownish yellow clay circulated to the surface. Confirmation soil samples were collected for laboratory analyses from the east source boring at 90 and 98 feet. Test results summarized in Table 5 and presented in Appendix C showed high chlorides in the soil most likely due to cross contamination with produced water from the upper zone carried down during the drilling process.

TPH and volatile organics were not detected except for trace levels of toluene that was also reported in the reagent blank at essentially the same level. Drilling was terminated at the east source to prevent communication with the lower Cretaceous unit. This decision was made after consulting with the NMOCD inspector Geoffrey Leking.

The bore hole was grouted back with bentonite clay to 49 feet and a monitoring well installed with 15 feet of well screen and 20 feet of filter pack to collect water from 29 to 49 feet bgs (See East Source Well, Appendix B).

Water samples were collected from the completed well and the results can be found in Appendix E. The sample had chlorides reported at 66,000 mg/l with traces of BTEX (8260B). This correlates fairly well with previous produced water samples collected from this system in the past. While not included in this report, the source water has been noted to be as high as 80,000 mg/l as reported in the July 31, 2009 Havenor report. It was determined that any further drilling in highly contaminated zones would be performed differently to prevent cross-contamination from the different horizons.

IV.C.2 Northwest Background Boring:

Results for the northwest background boring presented in Table 4B show a slightly elevated chloride level at 50 feet corresponding to water encountered in sandstone layer just above the upper Tucumcari shale yellow clay unit at 58 and 59 feet bags.

The bore hole was grouted back with bentonite clay to 70 feet and a monitoring well installed with 15 feet of well screen and 18 feet of filter pack to collect water from 52 to 70 feet bgs (See Northwest Background, Appendix B).

Water samples were collected from this well with the results shown in Appendix E. The results for chlorides were 14,400 mg/l with BTEX results showing slight hits. Table 4B clearly shows that from the surface down to a saturated zone, is not impacted.

It appears that the same field mistake was made by drilling through the contaminated zone, which probably carried the contamination down to the lower zones. From 60 feet to 100 feet the chlorides were almost identical. This is an indication of cross-contamination from a single source. Since this well was drilled in a non-contaminated area the issue of cross-contamination appeared to be not relevant at the time of drilling.

It appears that mounding of produced water in both the east and west leak source areas have caused produced water to flow somewhat in a horizontal radial direction along the yellow clay barrier.

IV.C.3 Northeast Background Boring

Was constructed about 220 ft northeast of the east leak source (Figure 6). Test results presented in Table 4C showed one sample collected in a sandstone layer just above the upper Tucumcari shale yellow clay unit. This sample showed elevated chlorides with nothing else remarkable about the results. Laboratory confirmation samples summarized in Table 5 revealed a high of 434-ppm chloride.

Chloride levels for samples collected at the top and bottom of the hole was 74 ppm, and other results showed similar results, apparently background. One area at 40 feet showed field chlorides of 1843 ppm and with the laboratory confirmation value of 434 mg/kg is found in Table 5.

Petroleum hydrocarbon measured as, TPH and BTEX, were not detected at the bottom of the borehole corresponding well to the very low PID reading of 0.5 ppm (Table 4C).

This well was a "***dry hole***" with no observed free liquid encountered and was grouted back to the surface with bentonite clay. (See Northeast Background, Appendix B)

IV.C.4 South Background Well

Was located about 140 feet southeast of the west leak source and about 280 feet southwest of the east leak source (Figure 6). Test results for this boring presented in Table 4D showed the highest chloride level in a 4-inch layer sampled between 49 and 49.33 feet bgs. Water was observed initially in this bore hole at about 42 feet bgs.

Chlorides observed in samples collected below 60 feet were attributed to cross contamination of the above media where higher concentration of salt water was found. The same cross-contamination issue as noted above was not anticipated for this well, since it was originally labeled down-gradient well by the driller.

Field chloride measured 709 ppm for a sample collected at 79.5 feet and compares favorably to the confirmation laboratory value of 781 ppm (Table 5 and Appendix C). The bore hole was grouted back with bentonite clay to 43 feet and a monitoring well installed with 15 feet of well screen and 18 feet of filter pack to collect water from 43 to 25 feet bgs

This well provided insufficient water to obtain a liquid sample. After the well was completed it appears from the log that it may have been completed in the wrong zone. The log indicated a wet zone at 50 feet. The well was completed above this noted wet area. (See South Background Well in Appendix B)

IV.C.5 West Leak Source Boring

Due to drilling issues and cross-contamination that was experienced on previous wells drilled, the west leak source (See West Source Well, Appendix B). was drilled to 66 feet using an air drill rig to construct a hole to set steel casing and cement to isolate the expected infiltrated man-made water i.e produced water from the lower soils and rocks.

The idea was to obtain quality information both above and below the wet zones without cross contaminating the lower soils. The hole was advanced through the cement to a total depth of 110 feet below ground surface. Test results presented in Table 4E showed a significant decrease in chloride with depth when the water was isolated from lower dry, stiff clays and the underlying Cretaceous shale.

Field chloride ranged from 4823 ppm for the 8-10 foot sample, and 6128 ppm for the 38-40 foot sample, and decreased substantially below 60 feet from 909 ppm to 103 ppm for the 100 foot sample and 137 ppm for the 110 foot sample. Chloride results for laboratory confirmation samples reported in Table 5 and presented in Appendix C measured 6650 ppm, 79 ppm and 206 ppm, respectively.

This well was used as an exploratory well to determine if the deeper zones had been contaminated. The results were very favorable, as the deeper soils appeared to be at background levels. This well was grouted back to the surface with bentonite clay in order to prevent possible migration of contaminants to the deeper zones.

IV.D Discussion of Soil and Groundwater Findings

The only water encountered in this investigation appeared to be man-made water observed above the stiff clays and sandy clays at the top of the Tucumcari shale and well above the abrupt lithic contact with the lower dark gray to black Cretaceous shale.

The best demonstrated evidence that the shallow zone does not contain protectable water is the fact that the Northeast Background Boring was a "***dry hole***." This boring is actually down gradient of the site as pointed out in the hydrogeology section above.

Chemical composition and mounded quantities underlying the leak area suggests that the source of the water is the released produced water. The amount of produced water released appears to have been very large compared to the amount reported on the spill report, as previously discussed.

As mentioned, both the east and west leak sources appear to have a substantial amount of produced water mounded in these areas. It can be concluded that radial or preferential flow probably has and is currently occurring at this time. This is confirmed by the fact that the Northwest Background Well was not located in the impacted spill area, but has evidence of this release water in the zone just above the yellow clay unit. Figure 8 was constructed to illustrate this phenomenon.

The same may also be true for the South Background Well, but of a lesser extent.
The boring soil results show this well was also completed in an area where the surface had not been impacted by the release.

However, once the zone just above the yellow clay was encountered, elevated chlorides were found at a value of 2803 ppm. It is possible due to the amount of time that had elapsed between the spill events and investigation some produced water from the mounded area has impacted this area.

Another valid conclusion, clay layers act as a natural depository over geologic time, and collects metals and salts. There are several anecdotal observations noted in many reports that clays, such as the red beds, will generally have a higher salt content than the above overlying vadose zone soils. So the presence of an elevated salt content is not always an indication that contamination has reached this point or imply usable groundwater is present at this locations. Further investigation will most likely provide a better rational.

A good analogy for this area i.e. Sand Gate, is the comparisons to the Mescalero and Quercheo sands where the Ogallala Aquifer is missing. Impermeable clays underlie both units. The Sand Gate is underlain by the Tucumcari shale while the Mescalero and Querecho sand areas are underlain by red beds of the Docken Group. Both areas receive about the same amount of recharge from precipitation and have the same approximate evapotranspiration rates.

With very few exceptions, these vast areas are void of usable groundwater. The same can be said of the shallow zones below both Station 11 and the Johnson release site.

IV.E. Philosophical Issues:

NMSWD fully understands that the agency has the right and responsibility to protect groundwater and has a responsibility to protect those very few exceptions mentioned above. However, once valid evidence is presented that no usable ground water exists in a zone of interest, and solid geologic evidence is provided showing any underlying groundwater will be protected in the foreseeable future, then the agency should acknowledge such evidence and has a responsibility to allow a path forward.

NMSWD also fully understands any such determination is very site specific and that continual leaks and spills in the area may negate any further approvals.

NMSWD understands the agency may be concerned that this site and others like it, may become nothing other than a solid waste management unit. Therefore, NMSWD would like to discuss and understand if there has been a policy change concerning how waste management practices of the Surface Waste Management and Pit Rules would come into play at this site.

In both cases, NMSWD understood that the Agency testified during hearings that long-term intentional waste disposal onto or under the ground was a separate issue concerning how accidental leaks and spills will be handled in the future. NMSWD wants to ensure that the protocol being proposed will actually provide a better outcome than just burying waste.

While it is reasonable to assume that the clays associated with the upper Tucumcari shale yellow clay unit will protect the lower Cretaceous groundwater, pumping this water would provide an additional safeguard and the site would benefit by removing the source of the contamination.

V. Remediation Proposal

V.A Soil Surface Remediation

Based on the results of this investigation it was concluded that excessive salinity is the limiting constituent requiring remediation to restore the agronomic potential of the affected area estimated at 70,000 ft^2 (1.6 acre). It was estimated that about 30,000 ft^2 (0.7 acre) or about 43 percent of the total area is arbitrarily classed as marginally impacted with profile EC > 4 mmhos/cm but < 12 mmhos/cm (corresponding EC-38 < 150 mS/m and > 350 mS/m, respectively) meaning that the land can be restored to its full agronomic potential with the incorporation of 20,000 lb/acre organic matter in the form of high quality hay, a tease application of fertilizer and seeding with a mixture of tall grasses, forbs and wild flowers compatible with managed grazing and wildlife habitat.

This leaves about 40,000 ft^2 of salt impacted soil that can be managed on site by leaching with water in conjunction with the use of a desalting amendment. The land is chiseled plowed to break up any crust and loosen the soil to receive the amendment application. The amendment of choice Desalt Plus™ is applied in aqueous solution to facilitate desorption of sodium by a cation exchange reaction. The treatment is added in a total of 4.3 inches of water (equivalent to 4.7 acre/inches). An additional 8.6 inches of water (9.4 acre/inches) is added following this treatment to flush salt deep into the soil profile and out of the root zone.

Hydrocarbon stained soils will be treated after desalinization using augmented bioremediation where a mixture of oil eating bacteria and nutrients are injected into the surface 2-ft. Soils are wet to field capacity during the treatment process adding an additional 4.3 inches of water to profile.

After desalinization and bioremediation an acre-foot of fresh topsoil will be brought in to restore the normal grade and contour of the site. The application of topsoil is followed by incorporation of 32,000 lb of organic material to the 1.6 acre site to address slight salt residuals in marginally impacted soil.

V.B. Deeper Vadose Zone Remediation

Based on the amount of water quantities observed during the drilling process, and the results of the water samples, it certainly appears that the physical and chemical characteristics of the water encountered is produced water generated by the releases.

Sixteen (16) inches of water proposed for application in desalinization and bioremediation treatments will add relative fresh water to the impacted areas. The recommendation is to remove the water collected under the impacted zones.

Another recovery well or wells, will be installed in close proximity to the leak source(s) to maximize the removal of salt with the water extracted. As previously discussed, this method actually removes source loading that would not otherwise have been accomplished.

V.C. Remediation Procedures

The restoration procedure proposed for the salt impacted and hydrocarbon stained soil is defined by the work elements listed below:

1. Resurvey impact area to define EM-38 150 and 350 mS/m contours
2. Construct recovery well in perched water zone at west leak source
3. Level and chisel plow area > EM-38 350 mS/m
4. Apply Desalt Plus™ in 2790 bbls water
5. Flush Desalt Plus™ treatment with 5581 bbls fresh water.
6. Treat hydrocarbon stained soil with microbe/nutrient media in 2790 bbls water.
7. Pump recovery wells to remove produced water and dry-up man-made water zone.
8. Apply 1 acre-foot soil to impact area and level to establish natural grade and contour.
9. Apply 32,000 lb feed quality, ground hay to 1.6 acre of impacted area and incorporate by disc operation to a depth of 6 inches.
10. Roll treated area to compact soil in preparation of planting.
11. Plant mixture of tall grasses, forbs and wild flowers as approved by the landowner.
12. Fence area to isolate restoration site from grazing animals for 2 years.
13. Continue pumping recovering wells until dry for 2 quarters.
14. After 2 years remove fence.
15. Remove recovery and monitoring wells to complete site restoration.

V.D. Remediation Rational

V.D.1 Total Dig and Haul

Using the most conservative estimates, the following is a brief summary of associated cost. Using a 100 ft radius around each spill site, and excavating to a depth of 50 feet, which equates to approximately 30,000 yards for disposal. At $150/yard, which includes back-fill, but no other charges, the cost would be over $ 4.3 million dollars.

V.D.2 Partial Dig and Haul and Liner Installation:

Removing the top 20 feet, which is considered practical with today's equipment, without staging the hole downward. The dirt disposal would be approximately $ 1.72 million dollars. Installation of a Liner would add additional $ 80,000 dollars, for a total of $1.8 million dollars. This does not include all other site charges.

V.D.3 General Remediation Discussion

Neither option above is within the monetary capability for a small company like NMSWD. While the agency has encouraged or recommended both of these options, neither is cost effective, or practical in this situation.

If the goal of the agency is to punish and discourage NMSWD from doing business in New Mexico, either above option will most likely put NMSWD out of business and be a severe detriment to the industry until another system could be put in place.

In the past, the agency has allowed major source removal near the surface and approved liner systems to prevent further downward migration to protect groundwater. This approach, at this site simply does not make sense because the majority of the contamination, i.e. oilfield produced water, already sets at a depth of 50 feet.

V.D.4 Site Specific Approach

NMSWD proposes to install addition recovery wells and actually use fresh water to flush the contaminants downward to be recovered along with produced water. This approach actually removes the contamination rather than having it become a permanent burial site.

It must be assumed, that the landowner would perfer to have a major source of the contamination removed rather than buried. Also, the in-situ surface restoration will provide a significantly reduced footprint during remediation and bring the surface back to its original condition in a faster, safer and more environmentally friendly manner.

TABLES

TABLE 1 – TEST PARAMETERS ANALYZED IN PRELIMINARY STUDY
NEW MEXICO SALT WATER DISPOSAL CO., INC
Borings West Source, #1, #2, #3 and #4

Bore ID	Depth ft	Chemical Parameter†						
		Soil	Volatile Organics				TPH	
		Cl	Benzene	Ethyl Benzene	Toluene	Xylenes	GRO	DRO
West	0.5	3440	.0113	.0225	.0422	.0877	5460	32400
Source	5	4800	<0.025	<0.025	0.033	<0.025	<10	53.7
#1	0.5	282	NA	NA	NA	NA	NA	NA
	5	7750	NA	NA	NA	NA	NA	NA
	10	4245	NA	NA	NA	NA	NA	NA
	15	3182	NA	NA	NA	NA	NA	NA
#2	.5	113	NA	NA	NA	NA	NA	NA
	5	5115	NA	NA	NA	NA	NA	NA
	10	3510	NA	NA	NA	NA	NA	NA
	15	5250	NA	NA	NA	NA	NA	NA
#3	0.5	966	NA	NA	NA	NA	NA	NA
	5	495	NA	NA	NA	NA	NA	NA
	10	206	NA	NA	NA	NA	NA	NA
	15	118	NA	NA	NA	NA	NA	NA
#4	0.5	134	NA	NA	NA	NA	NA	NA
	5	3542	NA	NA	NA	NA	NA	NA
	10	5197	NA	NA	NA	NA	NA	NA

†NA refers to not analyzed

TABLE 3E – SOIL BORING PHYSICAL DESCRIPTIONS
NEW MEXICO SALT WATER DISPOSAL CO., INC
West Leak Source

GPS WGS84: N 33° 26' 25.455" W 103° 27' 35.576"

Boring ID	Depth, ft	Description†
West Source	8-10	7.5YR8/2 pinkish white, hard rocky caliche, damp
	18-20	7.5YR8/2 pinkish white, hard rocky caliche, damp
	28-30	7.5YR8/2 pinkish white, hard caliche, sandy, damp
	38-40	10R6/4 pale red, rocky clayey sand, damp
	50	5YR4/3 reddish brown gravely sand, damp
	60	Sampling stopped to set casing and grout with cement to isolate upper perched water
	70	10YR6/4 light yellowish brown clay, dry
	80	Gley 1/5 gray sandy clay, dry
	90	Gley 1/4 dark gray sandy clay, humic carbon, dry
	100	Gley 1/4 dark gray clay, humic carbon, dry
	110	Gley 1/4 dark gray clay, humic carbon, dry

†humic refers to naturally occurring organic matter

TABLE 4A – FIELD CHLORIDE, EC, TDS AND PID ANALYSES
NEW MEXICO SALT WATER DISPOSAL CO., INC
East Leak Source

Boring ID	Depth Interval ft	Chemical Parameter† Chloride ppm	EC mmhos/cm	TDS Ppm	PID Ppm
East Leak Source	5	6495	17.7	11328	0.0
	11-13	5654	12.8	8192	0.0
	14.5	5147	12.1	7744	0.0
	19.5	5981	11.8	7552	3.0
	28.3	6321	13.7	8760	0.8
	38.5	10699	18.5	11840	1.6
	47-48	7831	15.7	10048	1.9
	48.5	5317	14.0	8960	1.3
	57-58	631	0.79	506	0.0
	74-75	840	5.67	3629	0.6
	79-80	4010	4.87	3117	1.1
	85-86	2669	9.01	5766	0.3
	97-98	7621	16.9	10816	0.2

†TDS calculated from EC

TABLE 4B – FIELD CHLORIDE, EC, TDS AND PID ANALYSES
NEW MEXICO SALT WATER DISPOSAL CO., INC
Northwest Background

Boring ID	Depth Interval ft	Chemical Parameter† Chloride ppm	EC mmhos/cm	TDS Ppm	PID Ppm
NW Background	0.5	74	0.02	12.8	0.0
	9.75	83	0.10	64.0	0.6
	20	50	0.18	115	1.0
	29.3	54	0.15	96	7.2
	40	58	0.19	122	1.0
	50	1145	3.17	2029	2.3
	60	334	1.01	646	1.0
	70	301	0.78	499	0.6
	80	390	0.27	173	0.6
	90	256	0.80	512	0.3
	100	325	0.57	365	0.9
	110	1145	NA	NA	NA

†NA refers to not analyzed; TDS calculated from EC

TABLE 4C – FIELD CHLORIDE, EC, TDS AND PID ANALYSES
NEW MEXICO SALT WATER DISPOSAL CO., INC
Northeast Background

Boring ID	Depth Interval ft	Chemical Parameter† Chloride ppm	EC mmhos/cm	TDS Ppm	PID Ppm
NE Background	0.5	74	0.08	51.2	0.0
	10	No Sample			
	20	50	0.33	211	.1
	30	No Sample			
	40	1843	1.09	698	.2
	50	124	0.38	243	1.0
	60	130	0.19	122	.3
	70	112	0.36	230	.1
	80	108	0.27	173	.2
	90	65	0.70	448	0.6
	101	74	0.80	512	0.5

†NA refers to not analyzed; TDS calculated from EC

TABLE 4D – FIELD CHLORIDE, EC, TDS AND PID ANALYSES
NEW MEXICO SALT WATER DISPOSAL CO., INC
South Background

Boring ID	Depth Interval ft	Chemical Parameter† Chloride ppm	EC mmhos/cm	TDS ppm	PID Ppm
South Background	0.5	126	0.03	19.2	0.3
	9.7	139	0.13	83.2	0.0
	19.2	195	0.31	198	0.1
	29	No Sample			
	39.75	342	0.92	589	0.2
	49.33	2803	9.17	5869	0.0
	60-61	1006	1.83	1171	0.2
	69.5	1222	4.99	3194	0.1
	79.5	709	2.01	1286	0.0
	90	1201	0.80	512	0.1
	100	819	0.57	365	0.2

†TDS calculated from EC

TABLE 4E – FIELD CHLORIDE, EC, TDS AND PID ANALYSES
NEW MEXICO SALT WATER DISPOSAL CO., INC
West Leak Source

Boring ID	Depth Interval ft	Chemical Parameter†			
		Chloride ppm	EC mmhos/cm	TDS ppm	PID Ppm
West Leak Source	8-10	4823	9.48	6067	3.3
	18-20	3507	9.06	5798	1.1
	28-30	3060	7.21	4614	1.8
	38-40	6128	7.62	4877	3.4
	50	3575	10.2	6528	1.0
	60	No Sample			
	70	909	NA	NA	NA
	80	437	NA	NA	NA
	90	243	NA	NA	NA
	100	103	1.27	3629	0.6
	110	137	1.31	3117	1.1

†NA refers to not analyzed; TDS calculated from EC

TABLE 5 - LABORATORY CONFIRMATION ANALYSES
NEW MEXICO SALT WATER DISPOSAL CO., INC
Deep Boring Soil Samples

	Analytical Results by Source and Depth, mg/kg***								
	East Leak	East Leak	NE Bkgd	NE Bkgd	NE Bkgd	S Bkgd	West Leak	West Leak	West Leak
Parameter*	**90 ft**	**98 ft**	**40 ft**	**90 ft**	**101 ft**	**79.5 ft**	**10 ft**	**100 ft**	**110 ft**
Inorganic									
Chloride, CL	7360	7360	NA	NA	<16	NA	NA	NA	NA
Chloride, ELI	NA	10200	434	<10	12	781	6650	79	206
Organics									
TPH**									
GRO C6-C10	<10.0	<10.0	NA	NA	<10.0	NA	NA	NA	NA
DRO >C10-C28	<10.0	<10.0	NA	NA	<10.0	NA	NA	NA	NA
Volatiles									
Benzene	<0.050	<0.050	NA	NA	<0.050	NA	NA	NA	NA
Toluene	0.128	0.128	NA	NA	<0.050	NA	NA	NA	NA
Ethyl Benzene	<0.050	<0.050	NA	NA	<0.050	NA	NA	NA	NA
Total Xylenes	<0.050	<0.050	NA	NA	<0.050	NA	NA	NA	NA

Notes:

*CL refers to Cardinal Laboratories; ELI refers to Energy Laboratories Inc.

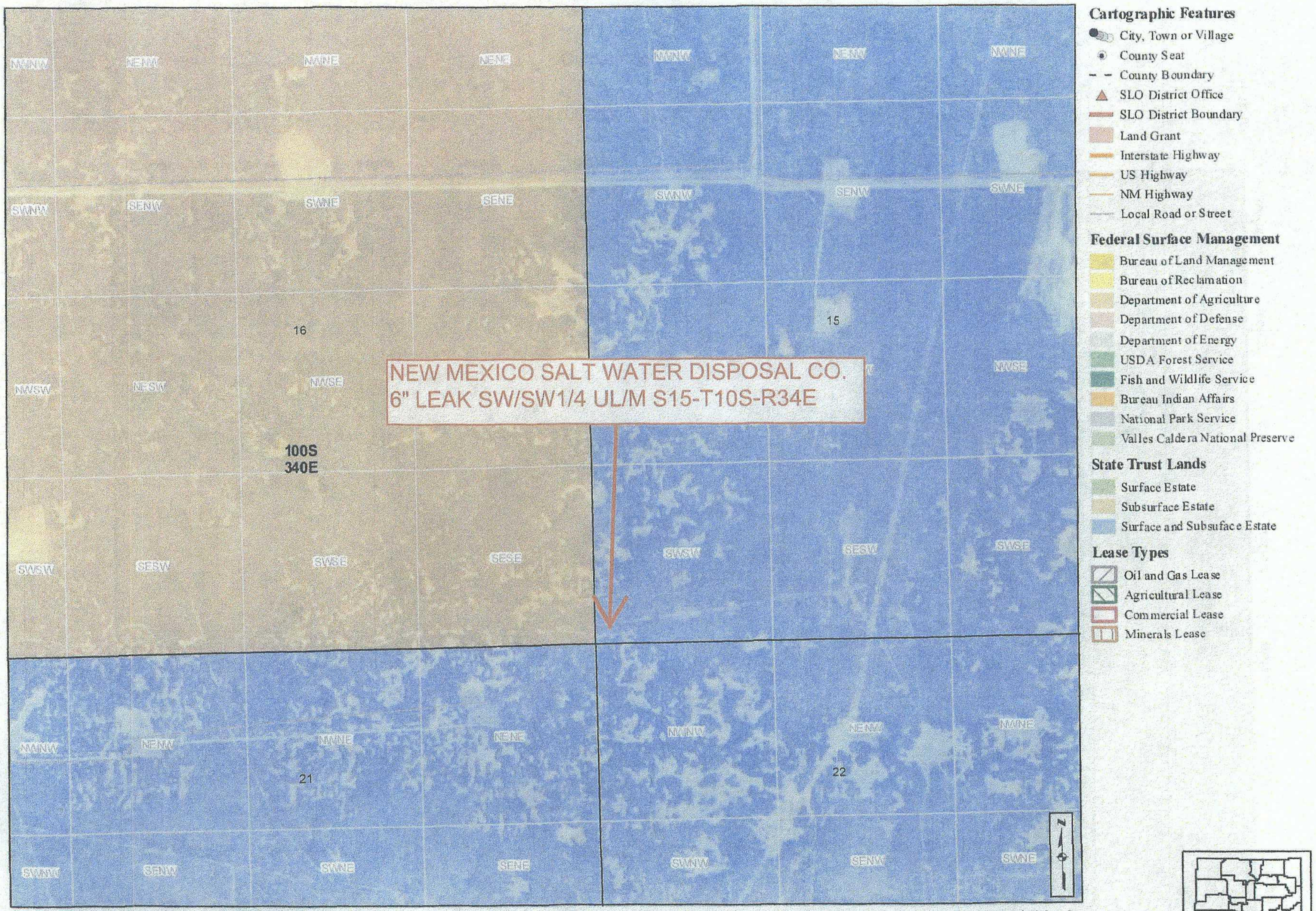
**TPH refers to total petroleum hydrocarbon; GRO refers to gas range organics; DRO refers to diesel range organics

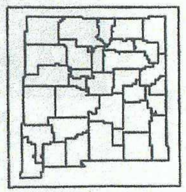
***NA refers to not analyzed

TABLE 6 – LABORATORY GROUNDWATER ANALYSES
NEW MEXICO SALT WATER DISPOSAL CO., INC
East Source and Northwest Background

Parameter	Analytical Results, mg/liter	
	East Source Well	NW Background Well
Inorganic		
Chloride	66,000	14,400
Volatile Organics		
Benzene	0.011	0.002
Toluene	0.003	0.003
Ethyl Benzene	<0.001	<0.001
Xylenes	<0.001	0.003

FIGURES





New Mexico State Land Office

Trust Land Status

0 0.035 0.07 0.14 0.21 0.28 Miles

Universal Transverse Mercator Projection, Zone 13
1983 North American Datum

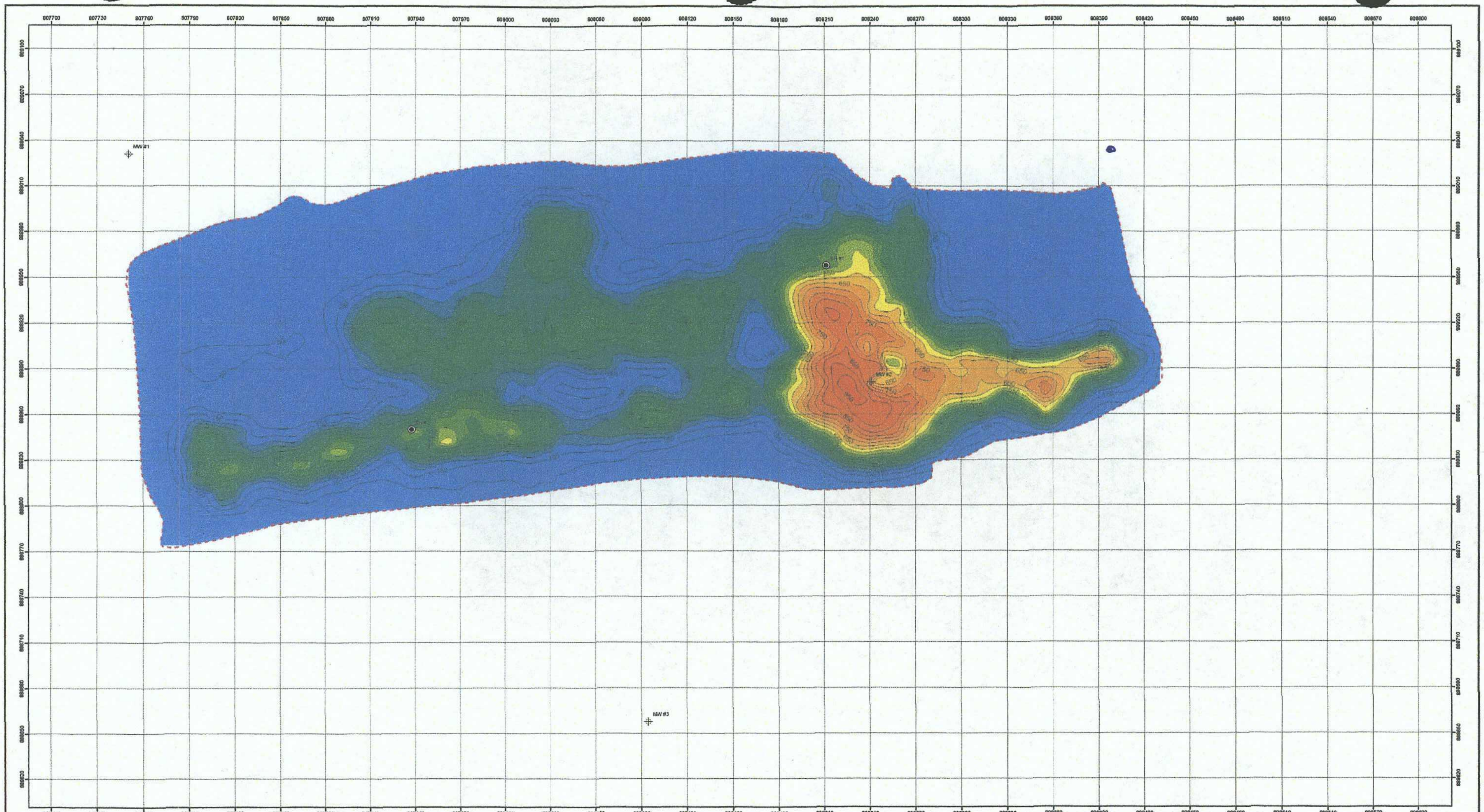
The New Mexico State Land Office assumes no responsibility or liability for, or in connection with, the accuracy, reliability or use of the information provided here, in State Land Office data layers or any other data layer.

Land Office Geographic Information Center
logic@slo.state.nm.us

www.nmstatelands.org

Figure 1. New Mexico Salt Water Disposal Co. Leak Site

Figure 4. EM-38 Salinity Contour Map



NOTES:

1. MAP PROJECTION PRESENTED IN NAD 1983, NEW MEXICO STATE PLANE EAST ZONE 3001.
2. DEPTH OF INVESTIGATION IS 0' TO 5'.

LEGEND

- BORE HOLE
- MONITOR WELL
- EM38 SURVEY BOUNDARY

WHOLE EARTH ENVIRONMENTAL

GEOPHYSICAL SUBSURFACE INVESTIGATION SURVEY

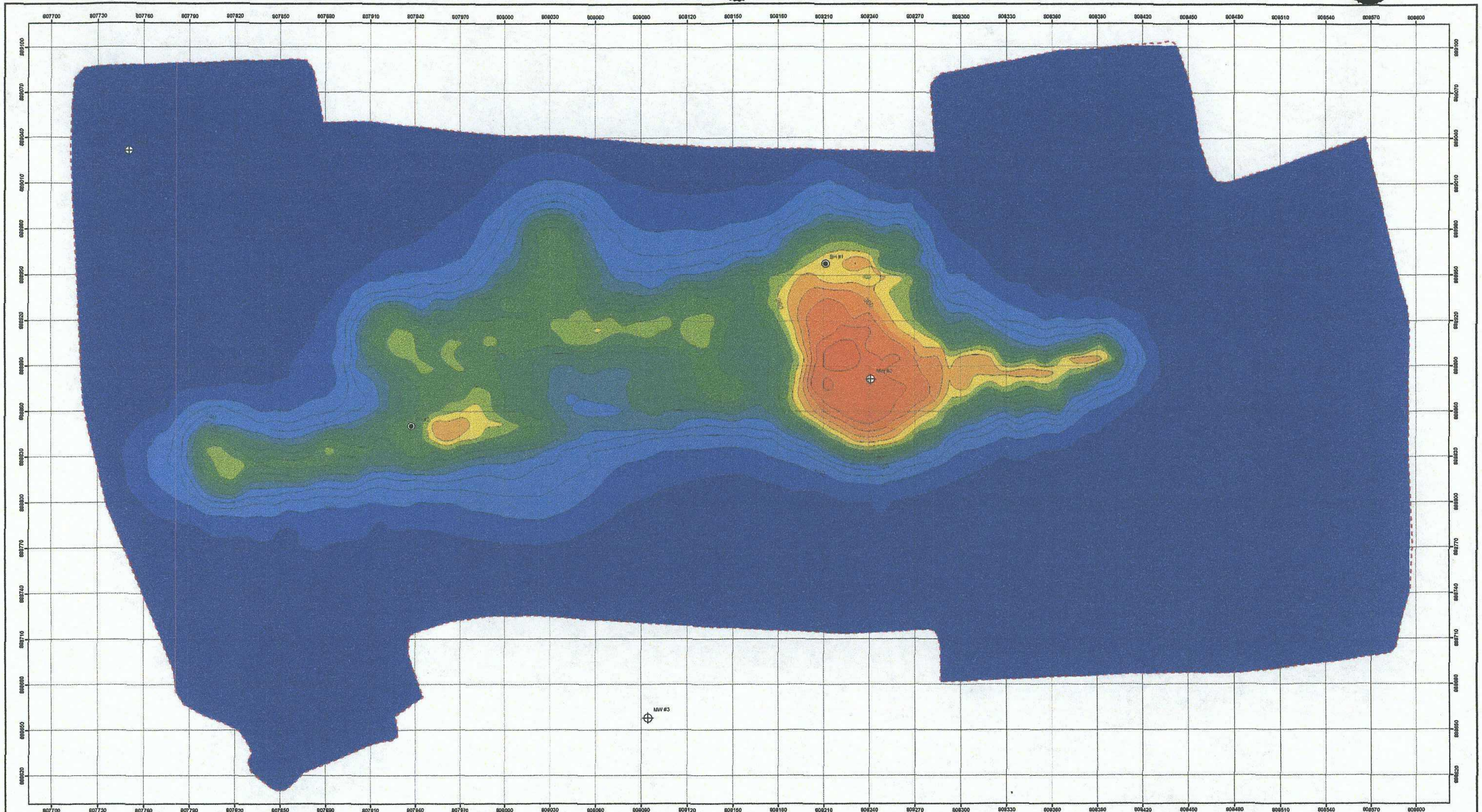
NMSWD JOHNSON SPILL
CROSSROADS, NEW MEXICO

EM-38 Salinity Contour Map

JAN. 2011

EMC
EARTH MEASUREMENT CORP.
Environmental & Engineering Geophysics
10866 KATY HOCKLEY RD.
CYPRESS, TEXAS 77433
281-829-5700
www.emcgeophysics.com

Figure 5. EM-31 Salinity Contour Map



NOTES:

1. MAP PROJECTION PRESENTED IN NAD 1983, NEW MEXICO STATE PLANE EAST ZONE 3001.
2. DEPTH OF INVESTIGATION IS 0' TO 18'.

60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380

SCALE MEASURED IN MILLISIEMENS PER METER

1 INCH = 30 FEET

0 15 30 60 90 120 FEET

LEGEND

- BORE HOLE
- MONITOR WELL
- EM31 SURVEY BOUNDARY

WHOLE EARTH ENVIRONMENTAL

GEOPHYSICAL SUBSURFACE INVESTIGATION SURVEY

NMSWD JOHNSON SPILL
CROSSROADS, NEW MEXICO

EM-31 Saninity Contour Map

JAN. 2011

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Environmental & Engineering Geophysics

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CYPRESS, TEXAS 77433
281-829-5700
www.emcgeophysics.com

Figure 6. Soil Boring Locations Map

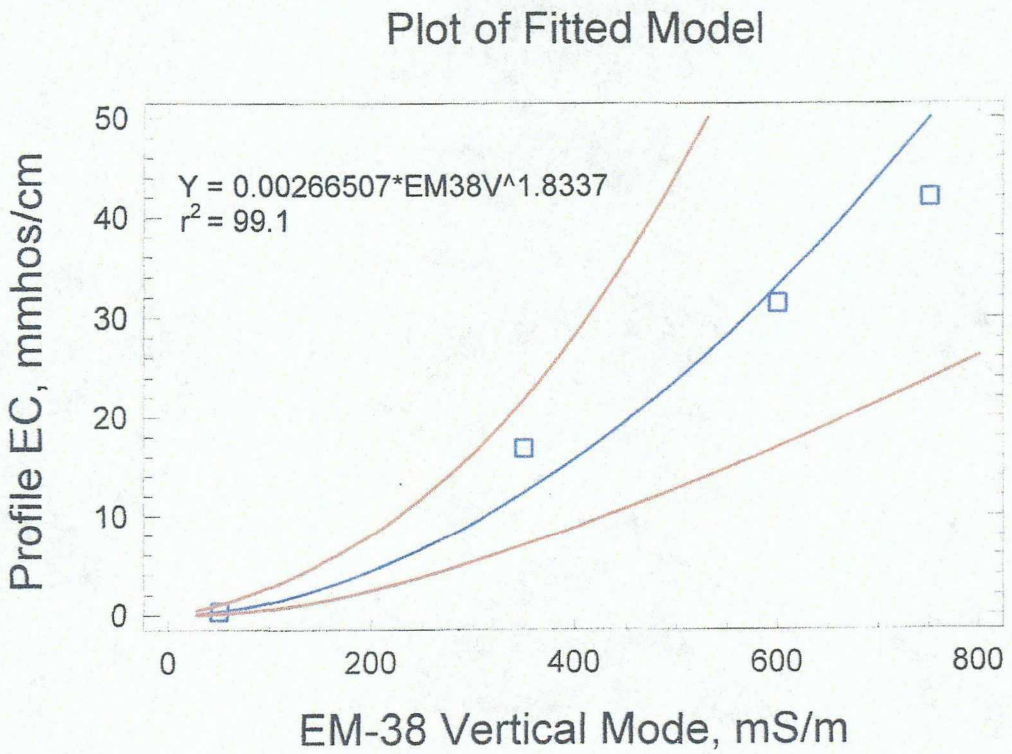


Figure 7. Regression of Profile EC versus EM-38 Reading

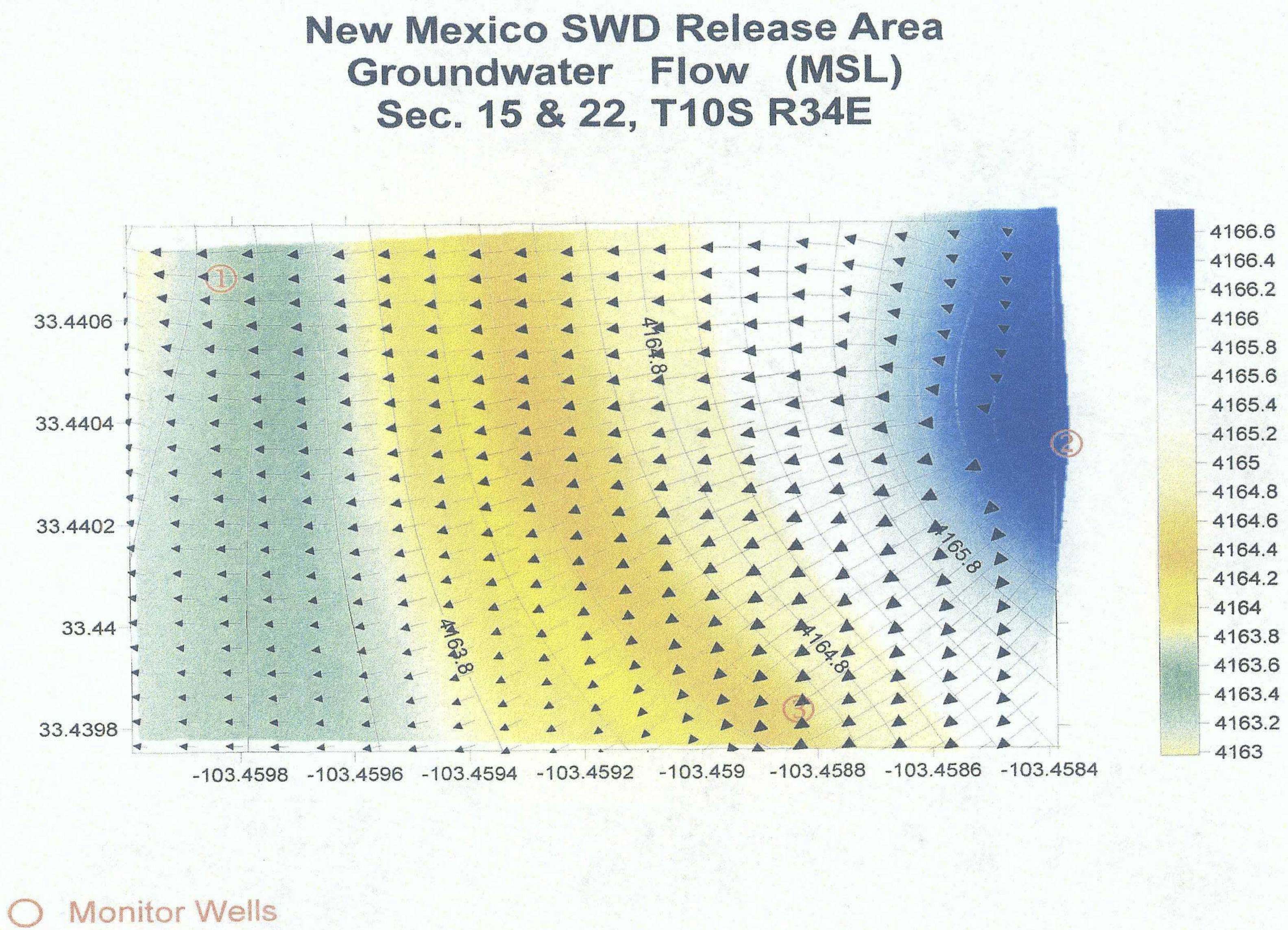


Figure 8. Potentiometric Surface Map

Subject: Open Dialog

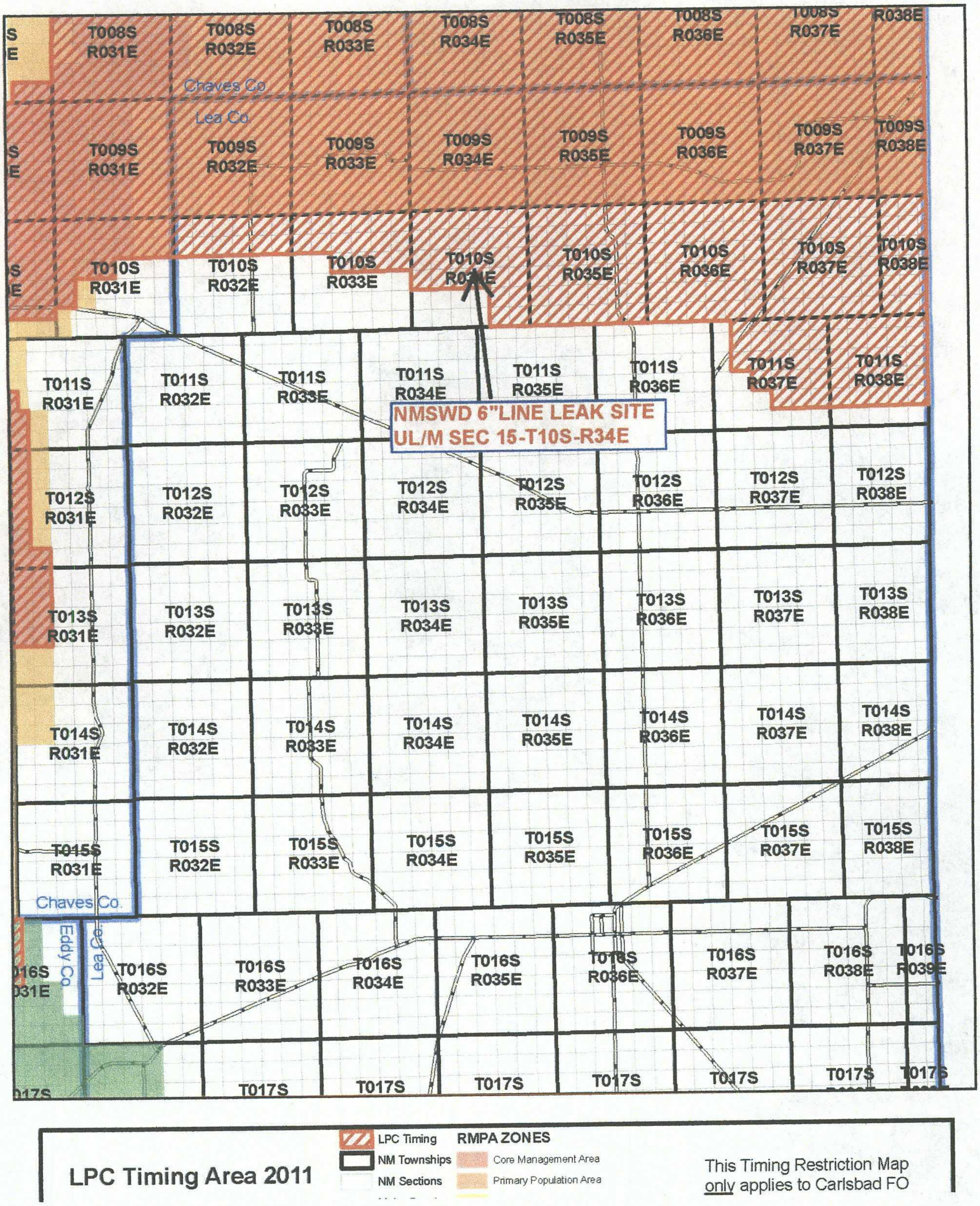


FIG. 9

District I
1625 N. French Dr., Hobbs, NM 88240
District II
1301 W. Grand Avenue, Artesia, NM 88210
District III
1000 Rio Brazos Road, Aztec, NM 87410
District IV
1220 S. St. Francis Dr., Santa Fe, NM 87505

State of New Mexico
Energy Minerals and Natural Resources

Oil Conservation Division
1220 South St. Francis Dr.
Santa Fe, NM 87505

RECEIVED
OCT 28 2010
HOBBSOCD

Form C-141
Revised October 10, 2003

Submit 2 Copies to appropriate District Office in accordance with Rule 116 on back side of form

Release Notification and Corrective Action REVISED

OPERATOR ☒ Initial Report ☐ Final Report

Name of Company New Mexico Salt Water Disp. Co.	Contact James B. Read
Address P. O. Box 1518, Roswell, NM 88202	Telephone No. 575-622-3770 ext. 310
Facility Name Pipeline	Facility Type Pipeline

Surface Owner State of New Mexico	Mineral Owner	Lease No.

LOCATION OF RELEASE API # 30-025-01814-00-00 NEARBY WELL HUMBLE STATE 001

Unit Letter	Section	Township	Range	Feet from the	North/South Line	Feet from the	East/West Line	County
M	15	10S	34E	330	South	330	West	Lea

Latitude__________ Longitude__________

NATURE OF RELEASE

Type of Release Produced Water	Volume of Release + 1200 bbls	Volume Recovered 1200 bbls
Source of Release Tank	Date and Hour of Occurrence	Date and Hour of Discovery
Was Immediate Notice Given? ☒ Yes ☐ No ☐ Not Required	If YES, To Whom? Geoff Leking	Occurred: Weekend Discovered: 10/03/2010 P.M.
By Whom? James B. Read	Date and Hour 10/04/2010	
Was a Watercourse Reached? ☐ Yes ☒ No	If YES, Volume Impacting the Watercourse.	

If a Watercourse was Impacted, Describe Fully.*

WATER @ 60'

Describe Cause of Problem and Remedial Action Taken.*

Leak in Pipeline probably due to weather in area. Rain, lightening and increment weather in area.

Drain pipeline, recovered water.

Describe Area Affected and Cleanup Action Taken.*

Water immediately recovered and drain pipeline. Determining lateral and vertical extent of impacted soil. Will submit remediation plan to OCD for approval and futher action.

I hereby certify that the information given above is true and complete to the best of my knowledge and understand that pursuant to NMOCD rules and regulations all operators are required to report and/or file certain release notifications and perform corrective actions for releases which may endanger public health or the environment. The acceptance of a C-141 report by the NMOCD marked as "Final Report" does not relieve the operator of liability should their operations have failed to adequately investigate and remediate contamination that pose a threat to ground water, surface water, human health or the environment. In addition, NMOCD acceptance of a C-141 report does not relieve the operator of responsibility for compliance with any other federal, state, or local laws and/or regulations.

Signature: James B. Read	**OIL CONSERVATION DIVISION**
Printed Name: James B. Read Buck Barajas	Approved by ~~District Supervisor~~ ENV. ENGINEER: Geoffrey Leking
Title: Agent	Approval Date: 10/28/10 — Expiration Date: 12/28/10
E-mail Address: jbro@brightok.net	Conditions of Approval: DELINEATE TO CLEAN + L. SUBMIT FINAL C-141 BY 12/28/10. — Attached ☐ 1RP-12-10-2669
Date: 10/22/2010 Phone: 575-622-3770	

* Attach Additional Sheets If Necessary

Fig. 10

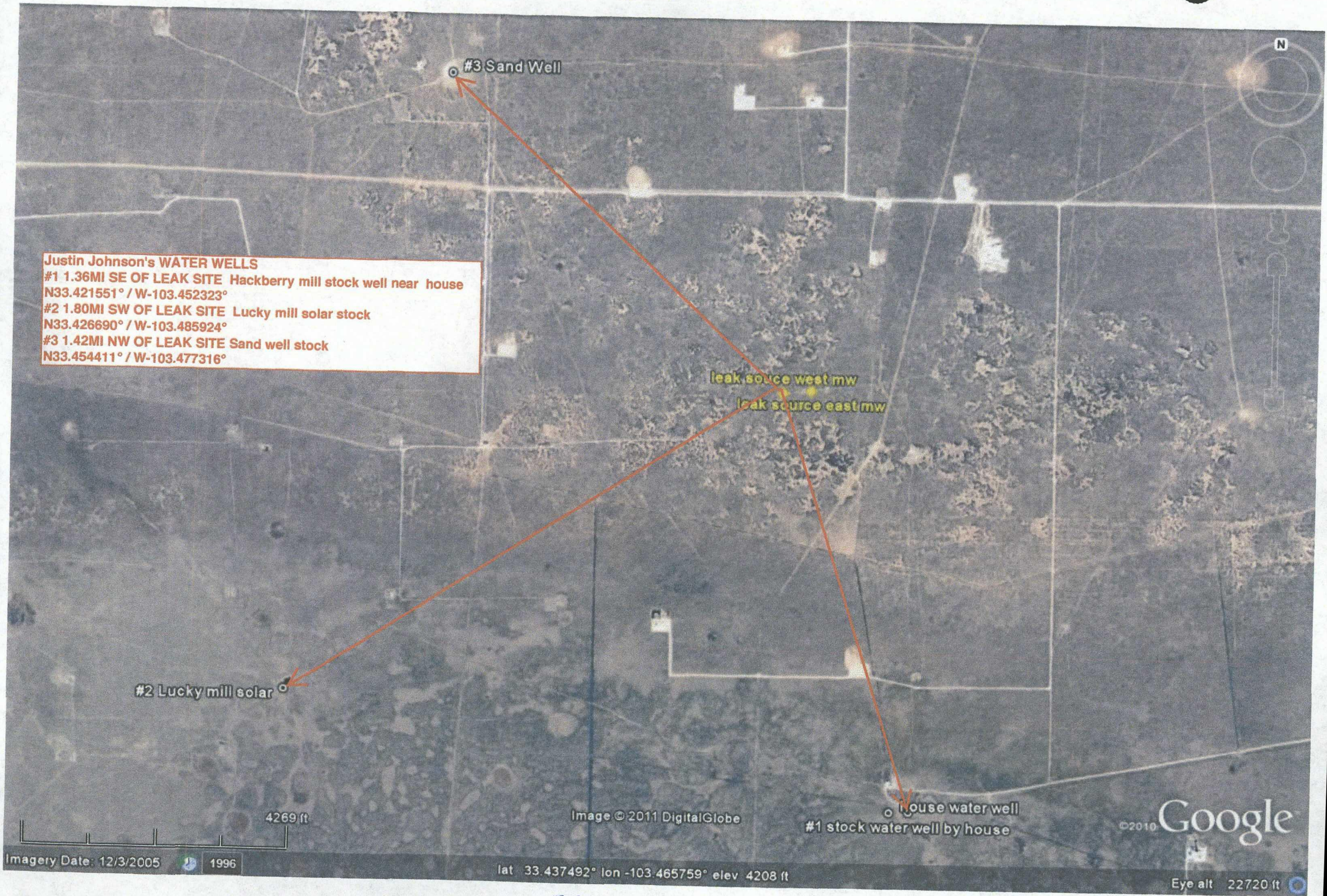
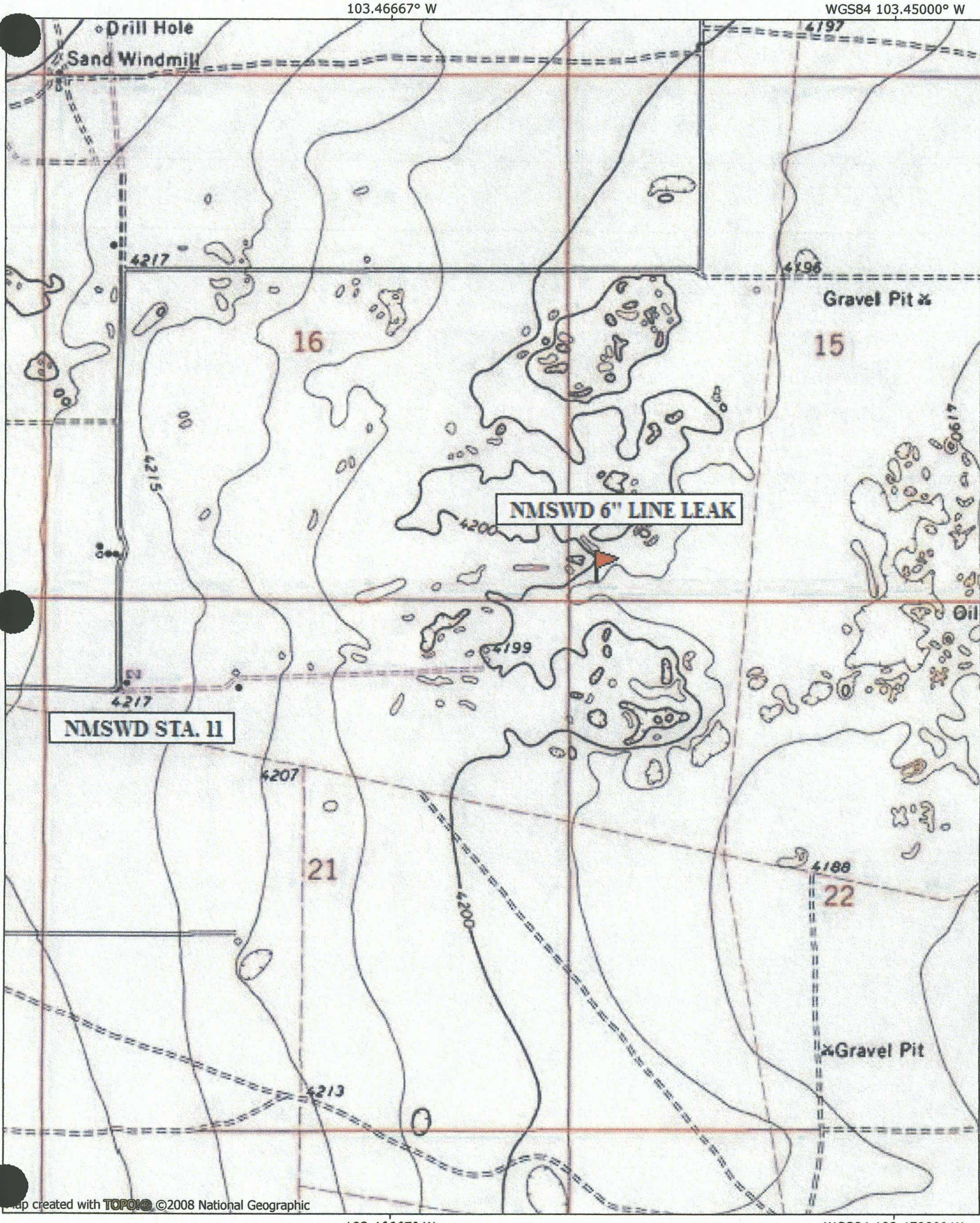

#3 Sand Well
Justin Johnson's WATER WELLS
#1 1.36MI SE OF LEAK SITE Hackberry mill stock well near house
N33.421551° / W-103.452323°
#2 1.80MI SW OF LEAK SITE Lucky mill solar stock
N33.426690° / W-103.485924°
#3 1.42MI NW OF LEAK SITE Sand well stock
N33.454411° / W-103.477316°
leak souce west mw
leak source east mw
#2 Lucky mill solar
house water well
#1 stock water well by house
4269 ft
Image © 2011 DigitalGlobe
©2010 Google
Imagery Date: 12/3/2005
1996
lat 33.437492° lon -103.465759° elev 4208 ft
Eye alt 22720 ft

FIG. 11

TOPO! map printed on 05/16/11 from "NMSWD 6IN LINE LEAK.tpo"



103.46667° W

WGS84 103.45000° W

NATIONAL GEOGRAPHIC

0.0 0.1 0.2 0.3 0.4 0.5 miles

0.0 0.5 km

TN MN 7½°

FIG. 12

05/16/11

APPENDIX A

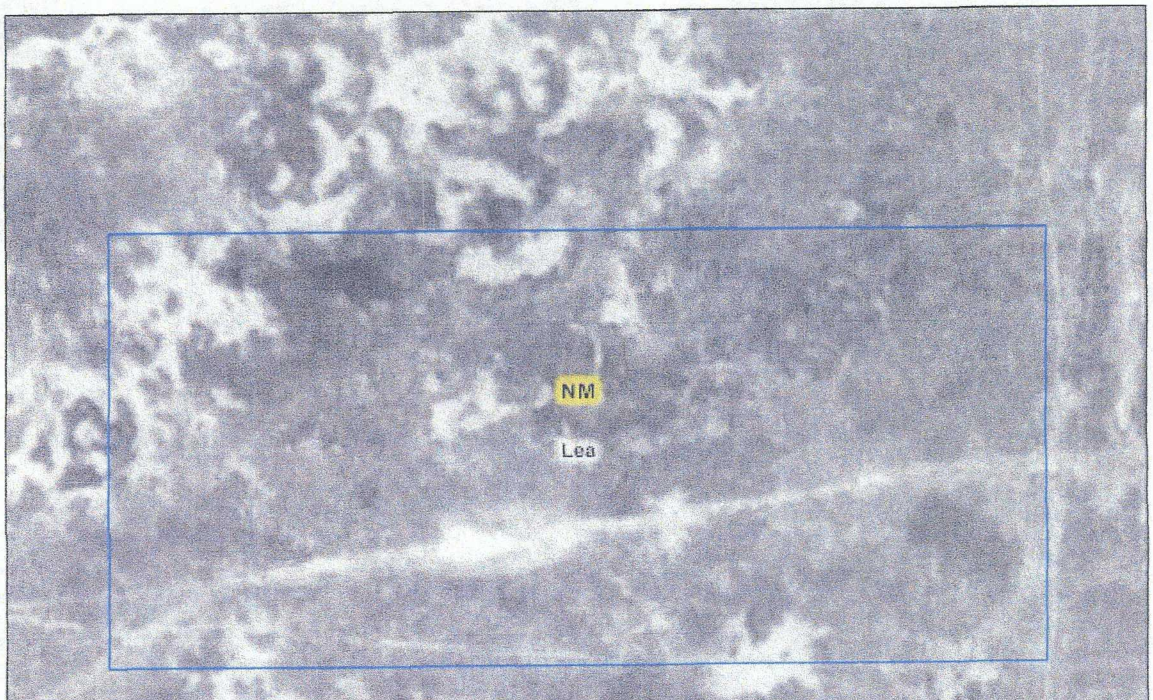
Lea County Soil Survey Information

USDA United States Department of Agriculture

NRCS Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for
Lea County, New Mexico



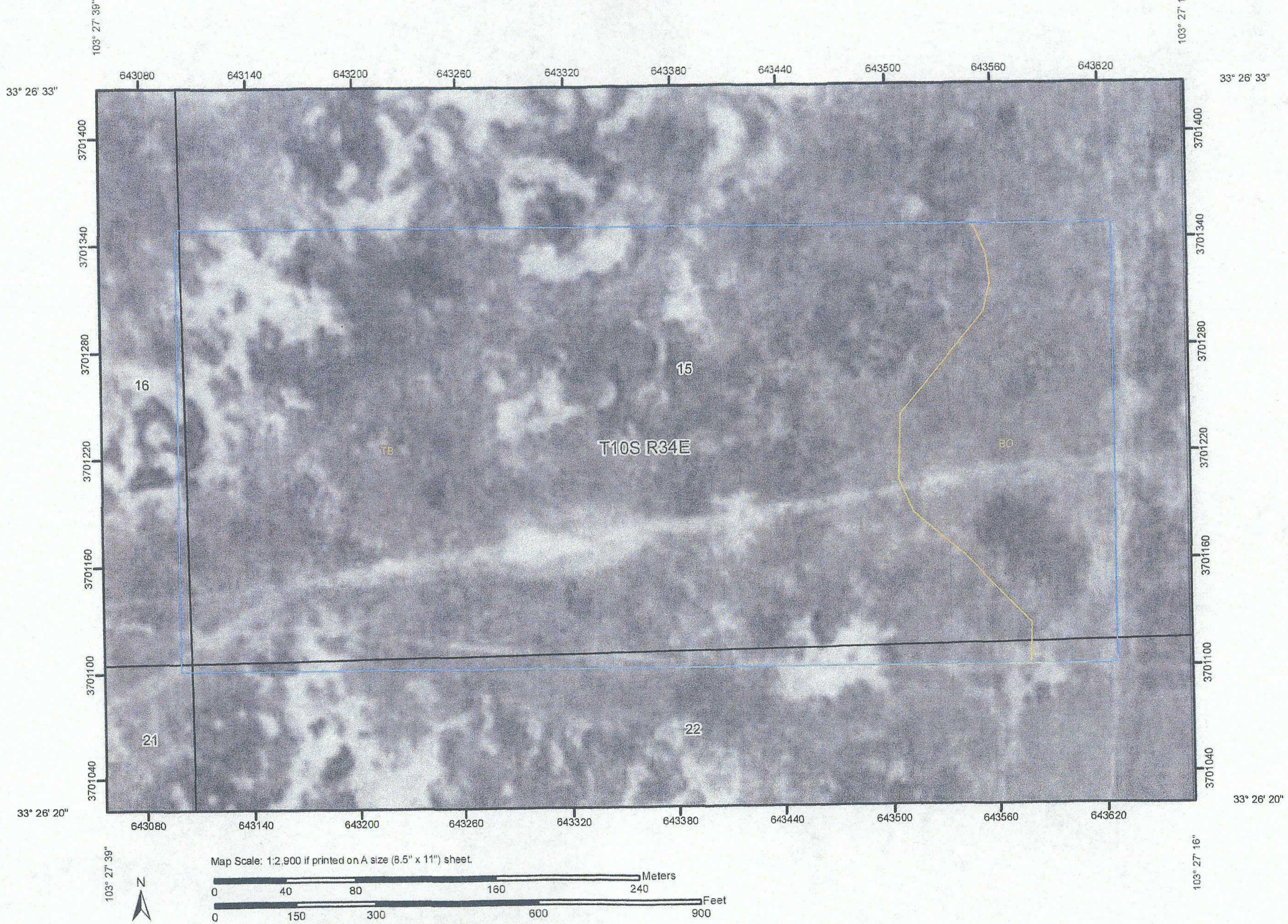
January 31, 2011

Contents

Soil Map

The *soil map* section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map


103° 27' 39"
103° 27' 15"
33° 26' 33"
33° 26' 33"
643080
643140
643200
643260
643320
643380
643440
643500
643560
643620
3701400
3701340
3701280
3701220
3701160
3701100
3701040
16
15
TB
T10S R34E
BO
21
22
33° 26' 20"
33° 26' 20"
103° 27' 39"
103° 27' 16"
Map Scale: 1:2,900 if printed on A size (8.5" x 11") sheet.
N
0
40
80
160
240
Meters
0
150
300
600
900
Feet

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features
- Cities
- PLSS Township and Range
- PLSS Section

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:2,900 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 13N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Lea County, New Mexico
Survey Area Data: Version 9, Dec 9, 2008

Date(s) aerial images were photographed: 9/19/1996

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Lea County, New Mexico (NM025)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
BO	Brownfield-Springer association	5.3	16.5%
TB	Tivoli-Brownfield fine sands, 0 to 5 percent slopes	26.9	83.5%
Totals for Area of Interest		**32.3**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series.* Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases.* Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas.* Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Lea County, New Mexico

BO—Brownfield-Springer association

Map Unit Setting

Elevation: 3,600 to 4,400 feet
Mean annual precipitation: 12 to 15 inches
Mean annual air temperature: 58 to 60 degrees F
Frost-free period: 195 to 205 days

Map Unit Composition

Brownfield and similar soils: 60 percent
Springer and similar soils: 30 percent

Description of Brownfield

Setting

Landform: Plains
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Eolian deposits derived from sedimentary rock

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 2.0
Available water capacity: Moderate (about 7.0 inches)

Interpretive groups

Land capability classification (irrigated): 6e
Land capability (nonirrigated): 6e
Ecological site: Sandy 12-17" PZ (R077DY046TX)

Typical profile

0 to 22 inches: Fine sand
22 to 60 inches: Sandy clay loam

Description of Springer

Setting

Landform: Plains
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Eolian deposits derived from sedimentary rock

Properties and qualities

Slope: 0 to 3 percent

Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 2.0
Available water capacity: Moderate (about 7.1 inches)

Interpretive groups
Land capability classification (irrigated): 4e
Land capability (nonirrigated): 4e
Ecological site: Sandy 12-17" PZ (R077DY046TX)

Typical profile
0 to 14 inches: Loamy fine sand
14 to 60 inches: Fine sandy loam
60 to 79 inches: Fine sandy loam

TB—Tivoli-Brownfield fine sands, 0 to 5 percent slopes

Map Unit Setting
Elevation: 3,500 to 4,400 feet
Mean annual precipitation: 12 to 15 inches
Mean annual air temperature: 58 to 60 degrees F
Frost-free period: 190 to 205 days

Map Unit Composition
Tivoli and similar soils: 50 percent
Brownfield and similar soils: 40 percent

Description of Tivoli

Setting
Landform: Dunes
Landform position (two-dimensional): Shoulder, backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Convex, linear
Across-slope shape: Linear
Parent material: Sandy eolian deposits derived from sedimentary rock

Properties and qualities
Slope: 1 to 5 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches

Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 2 percent
Gypsum, maximum content: 1 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 2.0
Available water capacity: Low (about 4.7 inches)

Interpretive groups
Land capability (nonirrigated): 6e
Ecological site: Sandy 12-17" PZ (R077DY046TX)

Typical profile
0 to 5 inches: Fine sand
5 to 60 inches: Fine sand

Description of Brownfield

Setting
Landform: Interdunes
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Sandy eolian deposits derived from sedimentary rock

Properties and qualities
Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 5 percent
Gypsum, maximum content: 1 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 2.0
Available water capacity: Moderate (about 7.0 inches)

Interpretive groups
Land capability classification (irrigated): 6e
Land capability (nonirrigated): 6e
Ecological site: Sandy 12-17" PZ (R077DY046TX)

Typical profile
0 to 22 inches: Fine sand
22 to 60 inches: Sandy clay loam

APPENDIX B

Atkins Log Showing Monitoring Well Construction

EAST LEAK SOURCE WELL

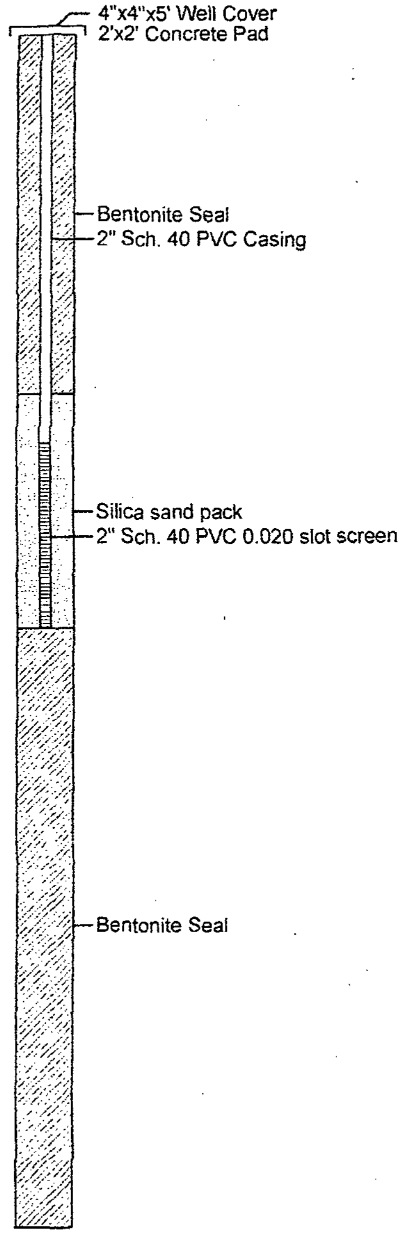
ATKINS ENGINEERING ASSOCIATES

Log of Boring East 2" Monitor Well

Whole Earth Environmental, Inc. 2103 Arbor Cove Katy TX 77494	Drill Start : 12/06/10 (07:00) Drill End : 12/08/10 (13:30) Boring Location : East side of spill Site Location : NMSWD, Crossroads Auger Type : 3¼ Hollow
Contact: Mike Griffin	Logged By : Mort Bates
Job#: CROSSRD.DRL.10	

Depth in Feet	GRAPHIC	USCS	Sample	DESCRIPTION
0		SP		Oily sand, loose, tan, damp
5				Caliche, firm, tan, reddish tan, damp
10				Caliche, hard, grayish white, dry
15				Caliche, firm, tan, dry
35		SP		Sand, loose, tan, dry
40		CL		Sandy clay, loose, reddish tan, damp
		GW		Sandy gravel, loose, tan, wet
45		SS		Sandstone, firm, tan, wet
50		CL		Clay, stiff, tan, damp
60		CL		Clay, stiff, yellowish tan, damp
75		CL		Clay, stiff, gray, damp
95				Free phase oil at 92'
100				Total Depth 97'

East 2" MW



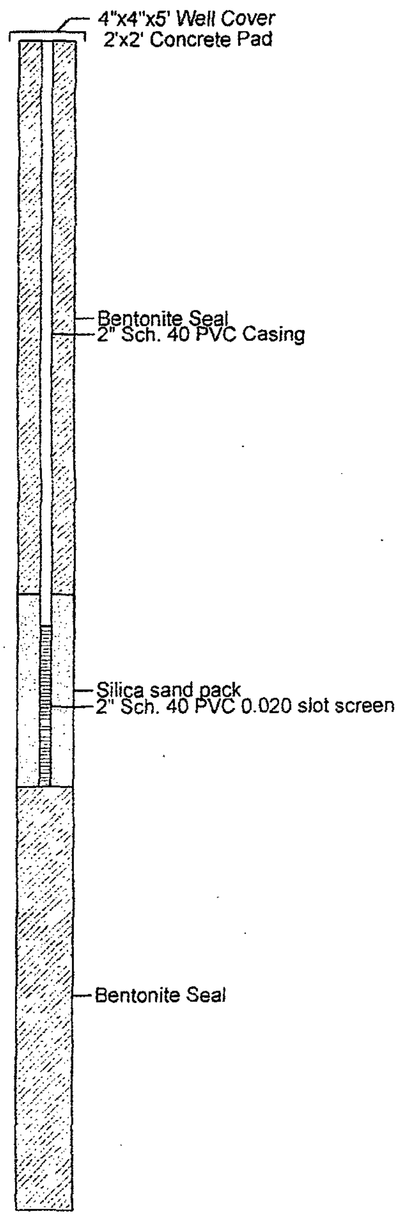
NORTHWEST BACKGROUND WELL

ATKINS ENGINEERING ASSOCIATES	Log of Boring West Background Well

Whole Earth Environmental, Inc. 2103 Arbor Cove Katy TX 77494	Drill Start	: 12/08/10 (14:00)	Logged By	: Mort Bates
	Drill End	: 12/09/10 (16:30)		
	Boring Location	: NW of spill 200'±		
Contact: Mike Griffin	Site Location	: NMSWD, Crossroads		
Job#: CROSSRD.DRL.10	Auger Type	: 3¼ Hollow		

Depth in Feet	GRAPHIC	USCS	Sample	DESCRIPTION
0–5		SP		Sand, loose, tan, dry
5–35		SP		Caliche, firm, white, dry
35–47		SS		Sandstone, firm, reddish tan, dry
47–50		SS		Sandstone, firm, yellow, dry
50–53		SS		Sandstone, hard, yellowish tan, dry
53–60		SS		Sandstone, firm, yellowish tan, wet
60–79		CL		Clay, stiff, yellowish brown, moist
79–110		SC		Clayey sand, stiff, grayish black, damp
110				Total Depth 110'

West Background Well



12-21-2010 C:\Users\Paddy\Documents\Whole Earth\Crossroads\WestBG.bor

NORTHEAST BACKGROUND BORING

ATKINS ENGINEERING ASSOCIATES

Log of Boring East Background Well

Whole Earth Environmental, Inc.
2103 Arbor Cove
Katy TX 77494

Contact: *Mike Griffin*

Job#: CROSSRD.DRL.10

Drill Start	: 12/11/10 (10:30)	Logged By	: Mort Bates
Drill End	: 12/14/10 (16:30)		
Boring Location	: NE of spill 200'±		
Site Location	: *NMSWD, Crossroads*		
Auger Type	: 3¼ Hollow		

Depth in Feet	GRAPHIC	USCS	Sample	DESCRIPTION	East Background Well
0–7		SP		Sand, loose, tan, dry	
7–36				Caliche, hard, tan and white, dry	
36–43		SS		Sandstone, firm, tan, dry	
43–49		SS		Sandstone, firm, damp	
49–77		CL		Clay, stiff, yellow, damp	Bentonite Seal
77–90		CL		Clay, stiff, gray, damp	
90–100		CL		Clay, stiff, dark gray, damp	

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105

Total Depth 100'

12-21-2010 C:\Users\Paddy\Documents\Whole Earth\Crossroads\EastBG.bor

SOUTH BACKGROUND WELL

ATKINS ENGINEERING ASSOCIATES

Log of Boring Down Gradient Well

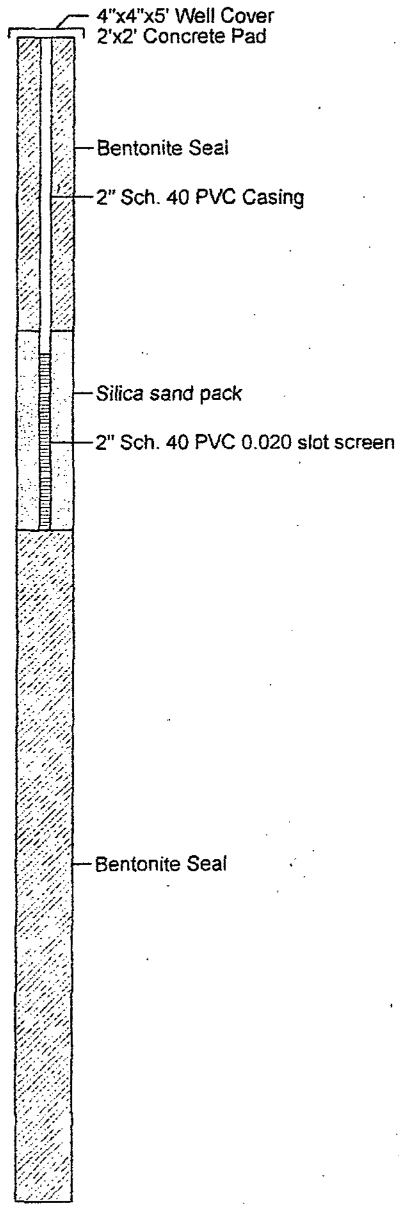
Whole Earth Environmental, Inc.
2103 Arbor Cove
Katy TX 77494
Contact: Mike Griffin
Job#: CROSSRD.DRL.10

Drill Start	: 12/15/10 (07:30)	Logged By	: Mort Bates
Drill End	: 12/16/10 (12:00)		
Boring Location	: South of spill 200'±		
Site Location	: NMSWD, Crossroads		
Auger Type	: 3¼ Hollow		

Depth in Feet	GRAPHIC	USCS	Sample	DESCRIPTION
0–4		SP		Sand, loose, tan, dry
4–6				Caliche, firm, white, dry
6–27				Caliche, hard, white, dry
27–46		SC		Clayey sand, loose, tan to yellow, dry
46–50		SC		Clayey sand, loose, tan to yellow, moist
50–83		SC		Clayey sand, firm, yellow, wet
83–100		CL		Clay, stiff, grayish black, damp

Total Depth 100'

Down Gradient Well



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WEST LEAK SOURCE BORING

ATKINS ENGINEERING ASSOCIATES

Log of Boring West Side Leak Test Hole

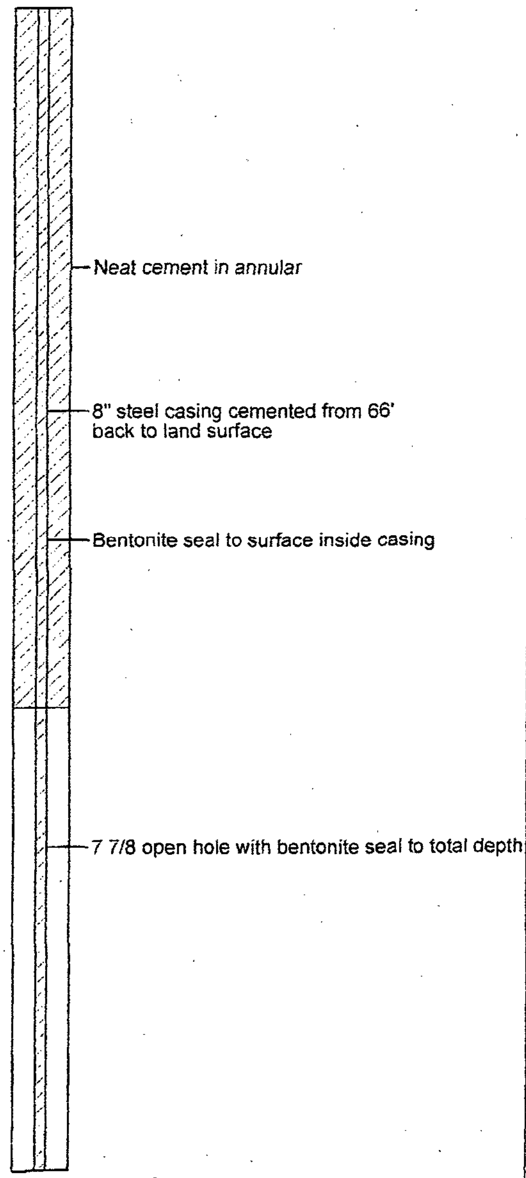
Whole Earth Environmental, Inc.
2103 Arbor Cove
Katy TX 77494
Contact: Mike Griffin
Job#: CROSSRD.DRL.10

Drill Start	: 12/12/10 (11:30)
Drill End	: 12/30/10 (15:00)
Boring Location	: West side of leak area
Site Location	: NMSWD, Crossroads
Auger Type	: Air rotary
Logged By	: Mort Bates

Depth in Feet	USCS	Sample	DESCRIPTION
0–5	SP		Poorly graded sand, loose, tan and black, damp
5–32			Caliche, firm, tan, dry
32–43	SP		Poorly graded sand, loose, tan, damp
43–49	SS		Sandstone, firm, tan, damp
49–52	SS		Sandstone, firm, yellowish tan, wet
52–55	GW		Sand and gravel, loose, yellow, wet
55–64	CL		Sandy clay, soft, yellowish tan, wet
64–70	CL		Clay, stiff, yellow, moist
70–79	CL		Clay, stiff, yellowish brown, dry
79–82	LS		Limestone with clay, firm, gray, dry
82–91	LS		Limestone, hard, gray, dry
91–110	CL		Clay, firm, gray, dry

Total Depth 110'

West Side Leak Test Hole



APPENDIX C

Cardinal Laboratories and Energy Laboratories, Inc
Soil Analysis Reports

CARDINAL Laboratories

PHONE (575) 393-2326 ° 101 E. MARLAND ° HOBBS, NM 88240

Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	12/08/2010	Sampling Date:	12/07/2010
Reported:	12/09/2010	Sampling Type:	Soil
Project Name:	NMSW DISPOSAL 6" LEAK	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	CROSSROADS		

Sample ID: SOURCE BORE E @ 90' BGS (H021472-01)

BTEX 8021B **mg/kg** **Analyzed By: CK**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Benzene*	<0.050	0.050	12/09/2010	ND	1.89	94.6	2.00	5.00	
Toluene*	**0.128**	0.050	12/09/2010	0.108	2.02	101	2.00	4.29	B
Ethylbenzene*	<0.050	0.050	12/09/2010	ND	1.89	94.3	2.00	4.72	
Total Xylenes*	<0.150	0.150	12/09/2010	ND	5.58	93.0	6.00	4.25	

Surrogate: 4-Bromofluorobenzene (PIL *104 %* *70-130*

Chloride, SM4500Cl-B **mg/kg** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Chloride	**7360**	16.0	12/08/2010	ND	432	108	400	0.00	

TPH 8015M **mg/kg** **Analyzed By: AB**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
GRO C6-C10	<10.0	10.0	12/08/2010	ND	193	96.5	200	19.4	
DRO >C10-C28	<10.0	10.0	12/08/2010	ND	190	94.8	200	9.14	

Surrogate: 1-Chlorooctane *93.4 %* *70-130*

Surrogate: 1-Chlorooctadecane *97.1 %* *70-130*

Cardinal Laboratories *=Accredited Analyte

Celey D. Keene, Lab Director/Quality Manager

CARDINAL Laboratories

PHONE (575) 393-2326 ° 101 E. MARLAND ° HOBBS, NM 88240

Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	12/08/2010	Sampling Date:	12/07/2010
Reported:	12/10/2010	Sampling Type:	Soil
Project Name:	NMSW DISPOSAL 6" LEAK	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	CROSSROADS		

Sample ID: SOURCE BORE E @ 98' BGS (H021472-01)

BTEX 8021B mg/kg Analyzed By: CK

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Benzene*	<0.050	0.050	12/09/2010	ND	1.89	94.6	2.00	5.00	
Toluene*	**0.128**	0.050	12/09/2010	0.108	2.02	101	2.00	4.29	B
Ethylbenzene*	<0.050	0.050	12/09/2010	ND	1.89	94.3	2.00	4.72	
Total Xylenes*	<0.150	0.150	12/09/2010	ND	5.58	93.0	6.00	4.25	
Surrogate: 4-Bromofluorobenzene (PIL	*104 %*	*70-130*							

Chloride, SM4500Cl-B mg/kg Analyzed By: HM

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Chloride	**7360**	16.0	12/08/2010	ND	432	108	400	0.00	

TPH 8015M mg/kg Analyzed By: AB

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
GRO C6-C10	<10.0	10.0	12/08/2010	ND	193	96.5	200	19.4	
DRO >C10-C28	<10.0	10.0	12/08/2010	ND	190	94.8	200	9.14	
Surrogate: 1-Chlorooctane	*93.4 %*	*70-130*							
Surrogate: 1-Chlorooctadecane	*97.1 %*	*70-130*							

Cardinal Laboratories *=Accredited Analyte

Celey D. Keene

Celey D. Keene, Lab Director/Quality Manager

CARDINAL Laboratories

PHONE (575) 393-2326 ° 101 E. MARLAND ° HOBBS, NM 88240

Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	12/14/2010	Sampling Date:	12/14/2010
Reported:	12/15/2010	Sampling Type:	Soil
Project Name:	NMSW DISPOSAL 6" LEAK	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	CROSSROADS		

Sample ID: NE BKGRD @ 101' BGS (H021522-01)

BTEX 8021B **mg/kg** **Analyzed By: CMS**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Benzene*	<0.050	0.050	12/15/2010	ND	1.92	96.2	2.00	6.34	
Toluene*	<0.050	0.050	12/15/2010	ND	2.03	101	2.00	6.79	
Ethylbenzene*	<0.050	0.050	12/15/2010	ND	2.07	104	2.00	6.52	
Total Xylenes*	<0.150	0.150	12/15/2010	ND	6.07	101	6.00	6.06	

Surrogate: 4-Bromofluorobenzene (PIL 101 % 70-130

Chloride, SM4500Cl-B **mg/kg** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Chloride	<16.0	16.0	12/15/2010	ND	416	104	400	0.00	

TPH 8015M **mg/kg** **Analyzed By: AB**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
GRO C6-C10	<10.0	10.0	12/15/2010	ND	205	103	200	20.2	
DRO >C10-C28	<10.0	10.0	12/15/2010	ND	174	87.1	200	3.23	

Surrogate: 1-Chlorooctane 99.0 % 70-130

Surrogate: 1-Chlorooctadecane 97.9 % 70-130

Cardinal Laboratories *=Accredited Analyte

Celey D. Keene

Celey D. Keene, Lab Director/Quality Manager

LABORATORY ANALYTICAL REPORT

Prepared by College Station, TX Branch

Client:	Whole Earth Environmental		**Report Date:**	01/18/11
Project:	NMSWD Johnson		**Collection Date:**	12/07/10 10:15
Lab ID:	T11010018-002		**DateReceived:**	01/06/11
Client Sample ID	East Source 98'		**Matrix:**	Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
1:1 EXTRACT							
Chloride	10200	ppm	D	100		E300.0	01/12/11 14:17 / ajm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by College Station, TX Branch

Client:	Soil Analytical Services Inc	**Revised Date:**	01/14/11
Project:	NMSWD	**Report Date:**	01/14/11
Lab ID:	T10120097-002	**Collection Date:**	12/11/10
Client Sample ID	NE Bkgd 40'	**DateReceived:**	12/21/10
		Matrix:	Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
1:1 EXTRACT							
Chloride	434	ppm	D	10		E300.0	12/28/10 12:58 / ajm

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by College Station, TX Branch

Client:	Soil Analytical Services Inc	**Revised Date:**	01/14/11
Project:	NMSWD	**Report Date:**	01/14/11
Lab ID:	T10120097-003	**Collection Date:**	12/14/10 12:30
Client Sample ID	NE Bkgd 90-91	**DateReceived:**	12/21/10
		Matrix:	Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
Organic Carbon, Total (TOC)	0.8	%		0.1		ASA29-3	12/27/10 10:14 / mdc
1:1 EXTRACT							
Chloride	ND	ppm	D	10		E300.0	12/28/10 13:15 / ajm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by College Station, TX Branch

Client:	Soil Analytical Services Inc	**Revised Date:**	01/14/11
Project:	NMSWD	**Report Date:**	01/14/11
Lab ID:	T10120097-004	**Collection Date:**	12/14/10 13:20
Client Sample ID	NE Bkgd 99>101	**DateReceived:**	12/21/10
		Matrix:	Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
Organic Carbon, Total (TOC)	0.8	%		0.1		ASA29-3	12/27/10 10:17 / mdc
1:1 EXTRACT							
Chloride	12	ppm	D	10		E300.0	12/28/10 13:33 / ajm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by College Station, TX Branch

Client: Soil Analytical Services Inc
Project: NMSWD
Lab ID: T10120097-005
Client Sample ID SBKGD 79-79.5

Revised Date: 01/14/11
Report Date: 01/14/11
Collection Date: 12/15/10 16:00
DateReceived: 12/21/10
Matrix: Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
Organic Carbon, Total (TOC)	0.4	%		0.1		ASA29-3	12/27/10 10:19 / mdc
1:1 EXTRACT							
Chloride	781	ppm	D	10		E300.0	12/28/10 13:50 / ajm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by College Station, TX Branch

Client: Soil Analytical Services Inc
Project: NMSWD
Lab ID: T10120097-001
Client Sample ID West 8' > 10'

Revised Date: 01/14/11
Report Date: 01/14/11
Collection Date: 12/15/10 12:40
DateReceived: 12/21/10
Matrix: Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
1:1 EXTRACT							
Chloride	6650	ppm	D	100		E300.0	12/28/10 12:23 / ajm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by College Station, TX Branch

Client:	Whole Earth Environmental	**Report Date:**	01/18/11
Project:	NMSWD Johnson	**Collection Date:**	12/30/10 12:05
Lab ID:	T11010018-003	**DateReceived:**	01/06/11
Client Sample ID	West Source 100'	**Matrix:**	Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
Organic Carbon, Total (TOC)	0.7	%		0.1		ASA29-3	01/11/11 14:03 / mdc
1:1 EXTRACT							
Chloride	79	ppm	D	10		E300.0	01/12/11 14:36 / ajm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by College Station, TX Branch

Client: Whole Earth Environmental
Project: NMSWD Johnson
Lab ID: T11010018-001
Client Sample ID West Leak 110'

Report Date: 01/18/11
Collection Date: 12/30/10 12:10
DateReceived: 01/06/11
Matrix: Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
1:1 EXTRACT							
Chloride	206	ppm	D	10		E300.0	01/12/11 13:22 / ajm

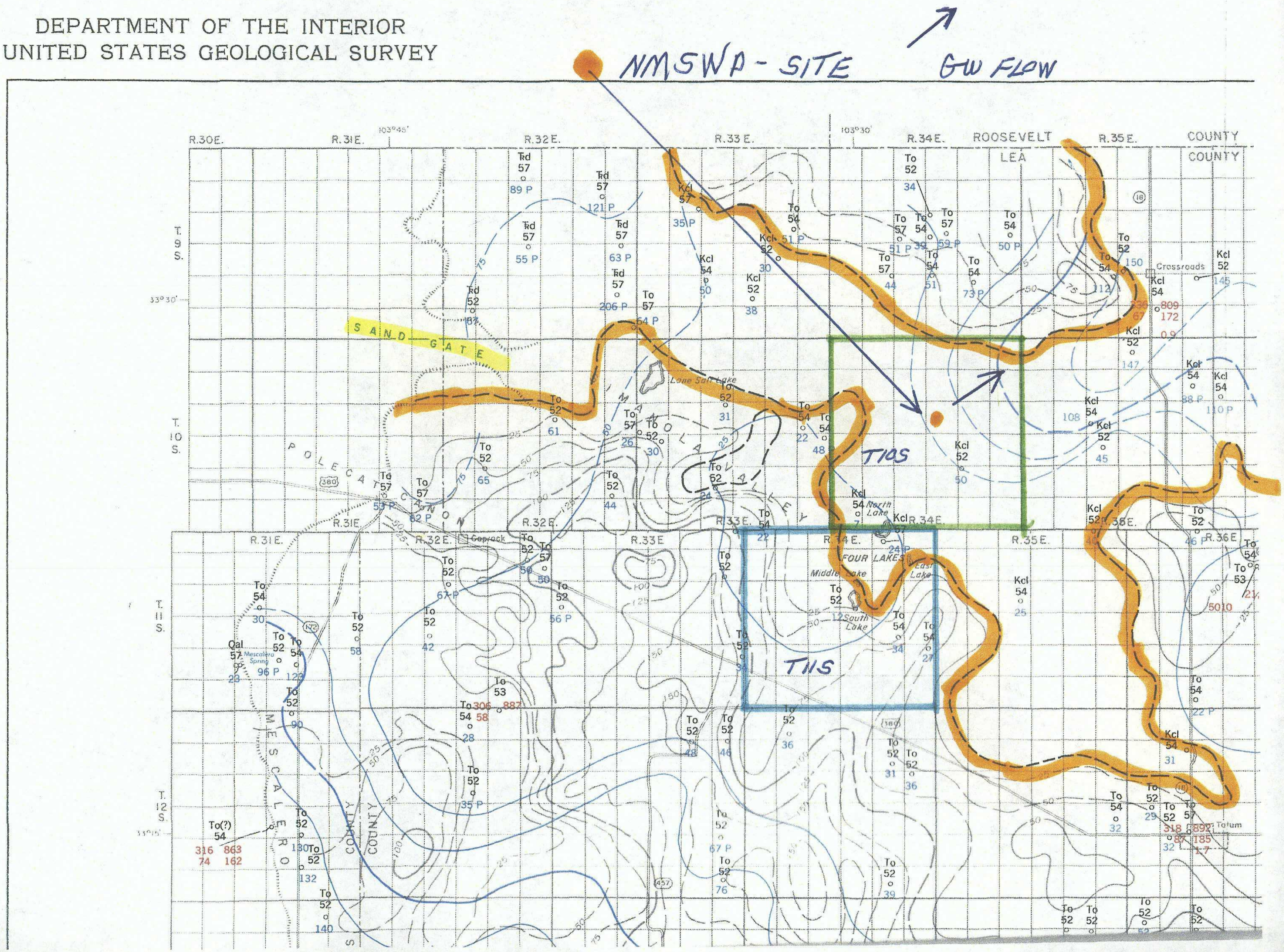
Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

Appendix D

1. Highlighted Map of Sand Gate Area.
2. Ground-Water Conditions in Northern Lea County, New Mexico, reports by Sidney R. Ash 1963.
3. 1988 report " Hydrogeology of Lower Cretaceous strata under the southern High Plains of New Mexico" by Fallin of the Texas Water Development Board.
4. "Geologic and Hydrogeologic Evaluation of Borings and Monitor Well At And Around New Mexico Salt Water Disposal Co., Inc. Station 11- AP053 located in Section 21, Township 10 South, Range 34 East." Dr. Kay Havenor

PRICE - 5-11

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



Hydrogeology of Lower Cretaceous strata under the southern High Plains of New Mexico

by *J. A. Tony Fallin*, Texas Water Development Board, P.O. Box 13231, Austin, TX 78711-3231

Introduction

Recent interpretations of seismic and other well log information indicate that Lower Cretaceous strata cover approximately 1,500 mi² under the southern High Plains of New Mexico (Fig. 1). Deposited on Late Triassic terrane, and covered largely by alluvial-fan deposits that make up the Ogallala Formation (Neogene; Seni, 1980), the strata form buried mesas with more than 200 ft of subsurface relief at some locations. The buried mesas are erosional outliers of a system that is much more extensively preserved and developed in the Edwards Plateau region of west-central Texas (Fisher and Rodda, 1969).

A typical Lower Cretaceous section under the southern High Plains of New Mexico includes a relatively thin basal sand and sandstone deposit overlain by marls, clays, and associated limestones (Fig. 2). Regional subsurface profiles show that the basal sand and sandstone deposit correlates with the Antlers Formation (Trinity Group) in Texas. The deposit is white to light blue, unconsolidated to moderately well cemented, fine to coarse grained, and quartz-rich; it has scattered lenses of gravel toward the base. Quartz grains in the sand fraction are typically well rounded and frosted in appearance, both characteristics associated with near-shore marine, beach, and dune sand depositional environments.

As an irregular sheet deposit, the thickness of the basal sand and sandstone pinches and swells while thinning regionally to the northwest (Fig. 3). Thickness of the unit ranges from less than a foot to more than 60 feet, and appears to be maximally developed where it fills erosional scour channels and other topographic lows cut into the underlying Dockum Group (Late Triassic; Fig. 4).

Light-blue clay and argillaceous, shallow-marine limestone overlie the basal sand and sandstone in southern parts of the study area (Fig. 5). The limestone is fossiliferous in places and has a spotty distribution pattern. Combined with underlying clay intervals, the limestone rarely exceeds 55 ft in total thickness. The strata correlate sequentially and lithologically with the Walnut and Comanche Peak Formations of the Fredericksburg Group in Texas.

A dark blue-gray shale interval capped with yellow-brown clay overlies all other Lower Cretaceous strata under the southern High Plains of New Mexico. Thickness of the fine-grained sediments ranges from zero to more than 160 ft, with much of the section either partially or completely removed locally by post-depositional erosion (Fig. 6). The upper yellow-brown clay covers the entire subcrop area (Fig. 7), which suggests that it may be an oxidized weathering profile that developed when the Lower Cretaceous strata were uplifted and subaerially exposed during Laramide time. Stratigraphically, middle parts of the fine-grained sequence correlate with the Kiamichi Formation (Fredericksburg Group); upper parts of the section may also include some of the Duck Creek Formation (Washita Group), a unit that has been identified at outcrop localities in neighboring Texas counties (Brand, 1953).

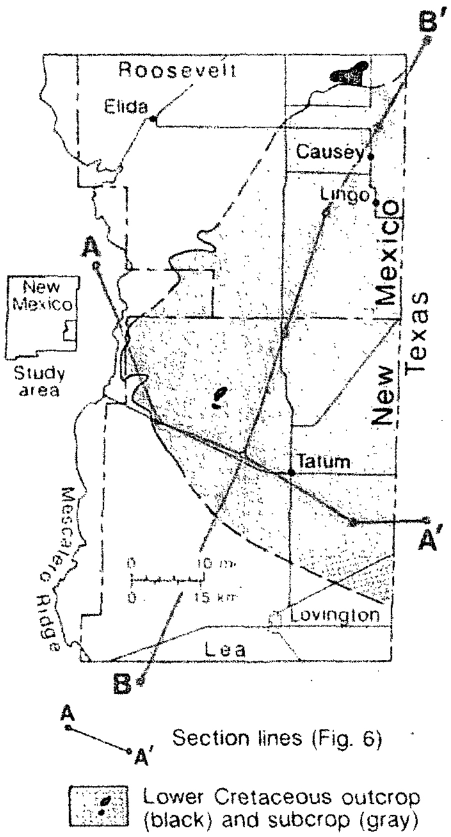


FIGURE 1—Lower Cretaceous outcrop and subcrop areas in the southern High Plains region of New Mexico. Refer to Fig. 7 for cross sections.

Hydrology

Almost all Lower Cretaceous strata under the southern High Plains of New Mexico lie below the regional water table, and are saturated with fresh (less than 1,000 ppm total dissolved solids) to slightly saline (1,000–3,000 ppm total dissolved solids) ground water. Only in limited updip areas along the northern and western edges of the province are exceptions known to occur.

The Lower Cretaceous strata are hydraulically connected with other water-bearing formations in the region, particularly the bounding and overlying Ogallala Formation, and are considered to be part of the greater High Plains aquifer system. Basal sand and sandstone beds and fractures, joints, bedding planes, and shell facies in the limestone intervals form effective ground-water reservoirs in the section, while clay, shale, and

Age	System	Group	Formation	Lithology
~100 m.y.	Lower Cretaceous	Washita Group	Duck Creek Formation	Yellow-brown to dark blue-gray shale with thin limestone and siltstone interbeds
		—?—?—	—?—?—	
		Fredericksburg Group	Kiamichi Formation	
			Comanche Peak Formation	Irregularly bedded argillaceous limestone with shell & clay interbeds
			Walnut Formation	Yellow to light-blue clay with some yellow sand
		Trinity Group	Antlers Formation	White to light-blue sand and sandstone with gravel lenses toward the base
~135 m.y.				

FIGURE 2—*Composite stratigraphic section of Lower Cretaceous strata under the southern High Plains of New Mexico.*

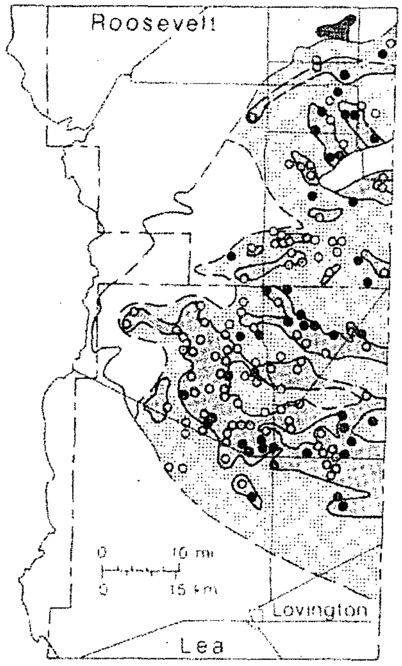
marl beds define aquicludes. Combined with underlying mudstone sequences in the Dockum Group (Late Triassic), the aquicludes confine the Lower Cretaceous reservoirs in most areas, while also influencing ground-water flow around and over the Lower Cretaceous subcrop. Ponding of ground water also occurs where Ogallala reservoirs are buttressed against fine-grained Lower Cretaceous strata in at least one updip location northwest of Tatum, New Mexico (Figs. 6 and 7).

Tilted to the southeast and confined by fine-grained deposits, Lower Cretaceous reservoirs under the southern High Plains of New Mexico commonly exhibit artesian pressures. Exceptions occur where numerous uncased seismic holes have been drilled into the system, allowing confined ground water to leak upward into the overlying Ogallala Formation while decreasing hydraulic pressures in the underlying Lower Cretaceous reservoirs (Ash, 1963).

Ground-water movement and drainage through the Lower Cretaceous section is generally to the east–southeast in conformance with the head distribution and regional structure. Local cementation, joint patterns, intraformational facies changes, and sinuosity of underlying scour channels, however, prompt local deviations in flow patterns at some locations. The cementation is primarily calcitic in nature, although some quartz also fills pore spaces in basal Lower Cretaceous sandstone beds, restricting and even preventing fluid movement in certain areas.

Surface lineament studies (Reeves, 1970) suggest that joint patterns in Lower Cretaceous limestone reservoirs may be oriented northwest–southeast and northeast–southwest in the study area. Combined with loose shell facies and bedding planes, such fractures would form effective ground-water flow zones in the limestone section.

Ground-water flow rates through Lower Cretaceous reservoirs average less than 1 ft per day (Weeks and Gutentag, 1984), with discharge being to well heads in New Mexico and Texas and to springs and seeps along



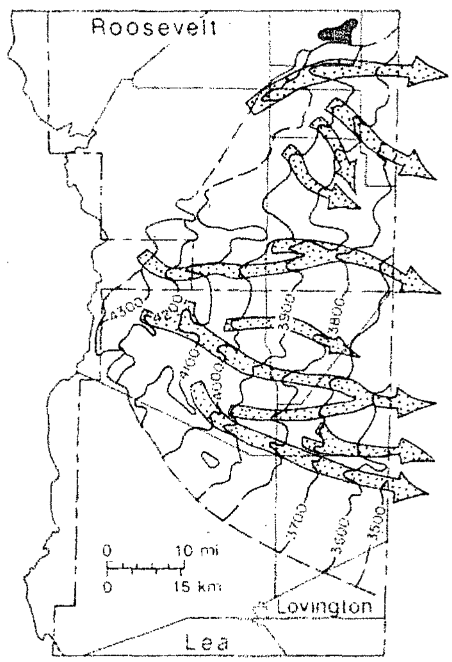
o Shothole with measured sand interval

• Shothole with reported water flow in measured sand interval

Sand present and up to 20 ft thick

Sand present and 20 or more ft thick

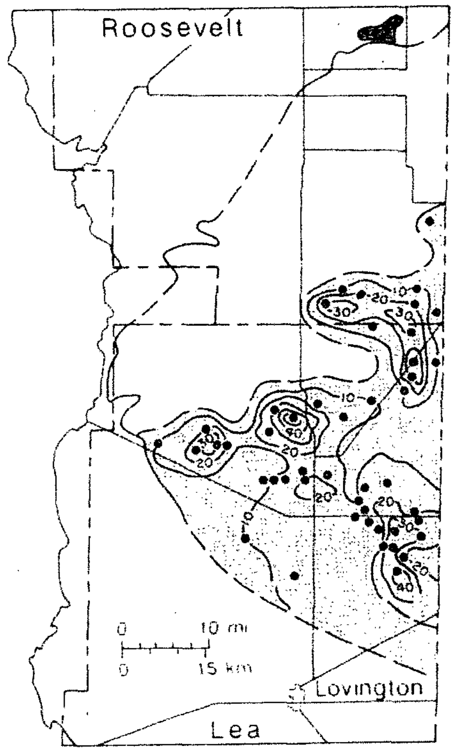
FIGURE 3—Distribution and thickness of the basal Lower Cretaceous sand and sandstone unit (Antlers Formation) under the southern High Plains of New Mexico.



3900 Structure contour

Paleo-drainage course on the Late Triassic erosion surface

FIGURE 4—Structure contour map showing the altitude of the top of Late Triassic strata under the southern High Plains of New Mexico.

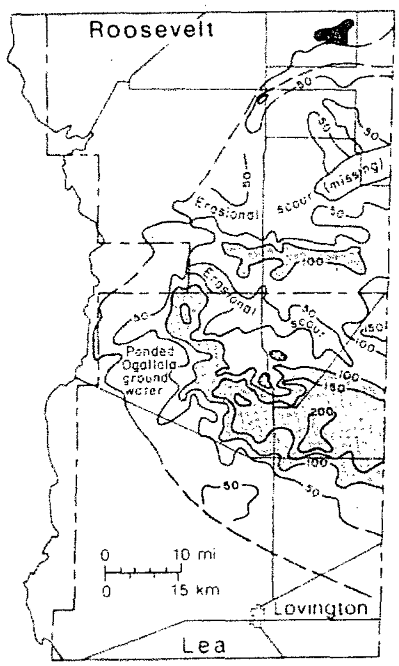


• Shothole with measured limestone interval

10 Isopachous contour

Area where limestone facies are present

FIGURE 5—Distribution and thickness of Lower Cretaceous limestone strata (Comanche Peak Formation) under the southern High Plains of New Mexico.



100 Isopachous contour

Area where Lower Cretaceous strata are 100 ft or more thick

FIGURE 6—Isopach map of Lower Cretaceous strata under the southern High Plains of New Mexico.

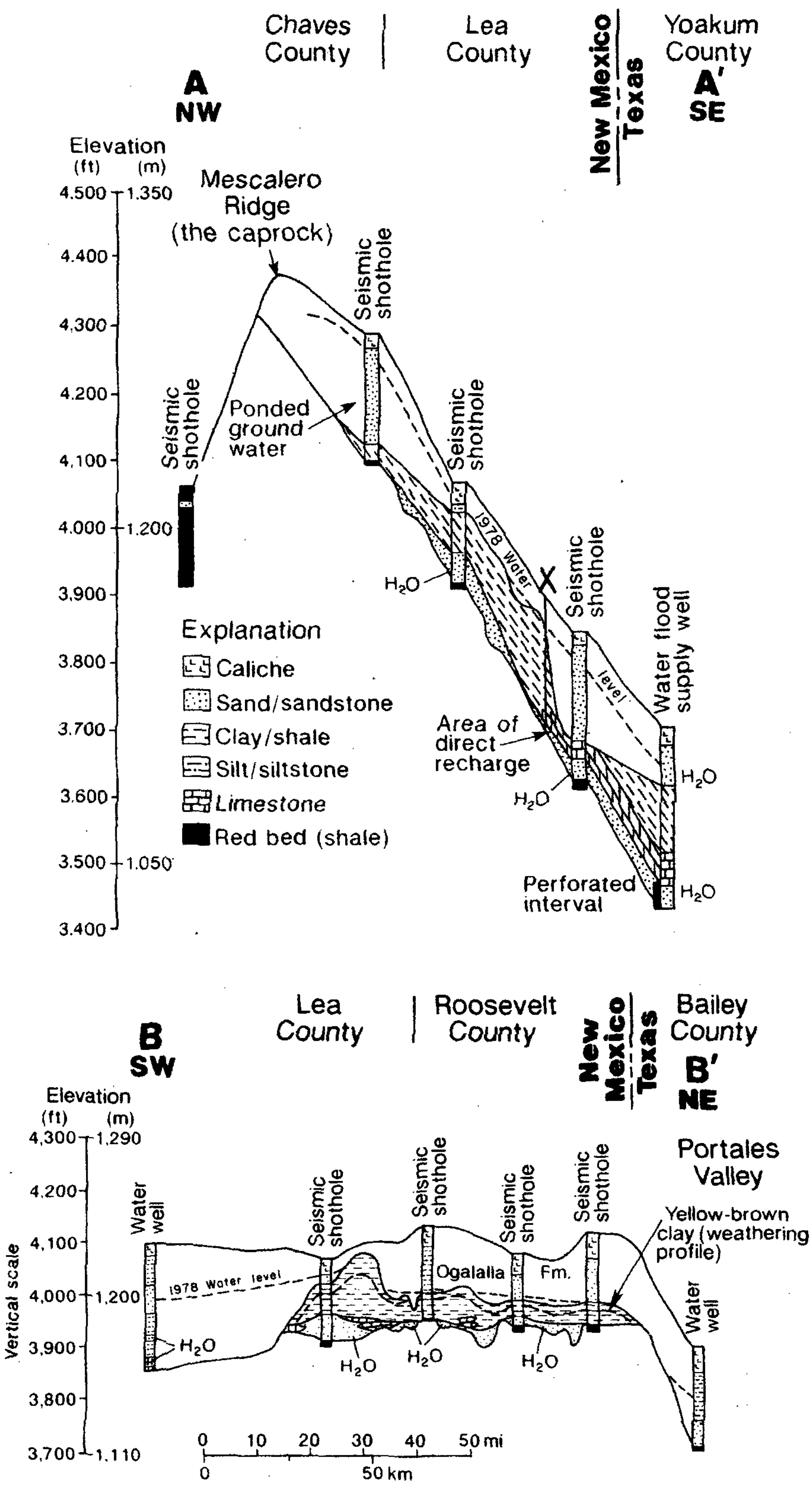


FIGURE 7—Geologic cross sections A—A' and B—B' showing profiles of Lower Cretaceous strata and regional water levels under the southern High Plains of New Mexico. (See Fig. 1 for section lines.) According to Ash (1963), a well was completed in 1940 (near the "X" on the top diagram) that penetrated rocks of Cretaceous age from 25 to 185 ft. Artesian water in the basal sand flowed 25 gal/min with a static head 14 ft above land surface until 1946 when the flow ceased. Note: Details shown on the cross sections come from additional seismic hole data that was originally plotted at a larger scale. The "H_2O" notation shows where ground-water flow was reported in seismic and water well holes.

the southern High Plains escarpment in Texas. The reservoirs have relatively low coefficient of storage, transmissivity, and conductance characteristics when compared to many ground-water flow zones in the bounding and overlying Ogallala Formation. Pumping-test data show that two wells drawing from the basal Lower Cretaceous sandstone resevoir in neighboring Cochran and Yoakum Counties, Texas, had specific capacities of 1.63 and 1.1 gallons of water per ft of drawdown when pumped at rates of 150 and 65 gallons per minute, respectively, for several hours (Rayner, 1963; Mount, et al., 1967). Notably, the Lower Cretaceous reservoirs also had low recoverable artesian storage characteristics around the investigation sites in Texas. Elsewhere, flow conditions are clearly better developed because some wells in the Causey–Lingo area of Roosevelt County, New Mexico, have produced more than 1,000 gallons of water per minute from channel fill in Lower Cretaceous reservoirs for sustained periods of time (Cooper, 1960).

Limited water-quality data show that both calcium–sulfate ($Ca–SO_4$) and sodium–bicarbonate ($Na–HCO_3$) hydrochemical facies exist in Lower Cretaceous reservoirs under the southern High Plains of New Mexico. The ground water is slightly basic, with pH values ranging from 7.5 to 8.0, and it is moderately to extremely hard, with dissolved concentrations of calcium carbonate ranging between 100 and 700 mg/l (Cooper, 1960).

Assuming an average thickness of 15 ft, 20% porosity, and an areal extent of 1,300 mi^2, it is estimated that the basal Lower Cretaceous sand and sandstone reservoir under the southern High Plains of New Mexico holds approximately 2.5 million acre-ft of ground water under full-reservoir conditions. With an average thickness of 10 ft, 1.5% porosity, and 750 mi^2 areal extent, the Lower Cretaceous limestone reservoir holds approximately 72,000 acre-ft of ground water when full.

The primary source of natural ground-water recharge to Lower Cretaceous reservoirs under the southern High Plains of New Mexico is inflow from bounding and overlying reservoirs in the Tertiary Ogallala Formation. The Ogallala Formation, in turn, receives most of its water supply via infiltration of surface precipitation and runoff that periodically fills playa lakes and other ephemeral drainages over the study area, a source of limited and often overdrawn supply in recent times.

Cross-formation recharge between Tertiary and Lower Cretaceous reservoirs occurs most readily where updip saturated sand and gravel beds in the Ogallala Formation abut against, or overlie porous and permeable intervals in the Lower Cretaceous section. Saturated sand and gravel beds in the Ogallala Formation, in turn, occur most frequently where distributary channel systems are best developed in the formation.

In the southern High Plains region, Ogallala distributary channel deposits are best developed where they fill valleys that cut across Lower Cretaceous and older subcrop terrane (Fig. 8). The valleys formed mostly before Ogallala deposition primarily by westward headward erosion across the southern High Plains (Seni, 1980).

Significantly, Lower Cretaceous reservoirs also discharge some ground water into bounding reservoir systems. In the Causey–Lingo area of Roosevelt County, New Mexico, basal Lower Cretaceous sand and gravel reservoirs are truncated in downdip areas by coarse-grained "valley fill" Ogallala deposits, permitting cross flow into the Ogallala system. Vertical leakage into the underlying Dockum Group (Late Triassic) also occurs at isolated locations, particularly where coarser-grained fluvial-deltaic facies exist in upper parts of the red bed sequence (Granata, 1981).

Wells completed in Lower Cretaceous reservoirs under the southern High Plains of New Mexico provide ground water for various surface uses. Widely spaced over much of the study area, wells drawing from the reservoirs are thus far noticeably concentrated only in the Causey–Lingo area of Roosevelt County, where they supply water for both crop irrigation and domestic use. Undeveloped parts of the reservoir systems showing potential for supplying additional surface water to the southern High Plains exist in northern Lea County, particularly where relatively thick basal Lower Cretaceous sands and sandstones occupy erosional scour channels that are cut into the underlying Dockum Group (Late Triassic).

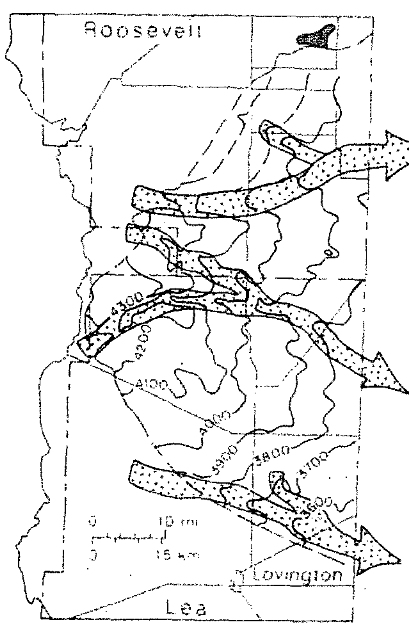


FIGURE 8—Structure contour map showing the altitude of the top of Lower Cretaceous strata under the southern High Plains of New Mexico.

ACKNOWLEDGMENTS—Sherman Galloway, private consultant, and personnel at the New Mexico State Engineer Office in Roswell, New Mexico, provided useful information and well log data used to construct maps and cross sections in this report. Funding for the investigation came partly from the Texas State Legislature and Texas Water Development Board in Austin, Texas, in conjunction with a larger regional study of Lower Cretaceous reservoirs under the southern High Plains of both Texas and New Mexico. Figure and text review are credited to Tommy Knowles, Chief, Water Data Availability and Studies Section, Texas Water Development Board; Bill Stone, New Mexico Bureau of Mines and Mineral Resources; and Robyn Wright and Barry Kues, Department of Geology, University of New Mexico.

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Continued from page 5

ACKNOWLEDGMENTS—Thanks are extended to the Phillips Petroleum Company for providing the core for this study. Technical reviews by Roger Anderson, George Bachman, Marc Bodine, Jr., Walter Dean, Robert Evans, Robert Hite, Frank Kottlowski, Charles Jones, James Markello, Charles Maxwell, Richard Snyder, and Samuel Thompson, III, and editorial comments by James Barker were very helpful. Special thanks are extended to Mary H. Miller who made substantive comments on an early version of the manuscript.

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GEOLOGICAL AND HYDROGEOLOGICAL EVALUATION OF BORINGS AND MONITOR WELLS AT AND AROUND NEW MEXICO SALT WATER DISPOSAL CO., INC., STATION 11

Section 21, Township 10 South, Range 34 East
Lea County, New Mexico
New Mexico Oil Conservation Division AP053

Prepared by:

Kay Havenor, Ph.D.

Registered Geologist # 30348, Arizona
Professional Geologist # 5806, Texas
Certified Professional Geologist # 673, AIPG

GeoScience Technologies
Deborah Havenor, Owner and Business Manager
200 West First Street - Suite 747
Roswell, New Mexico 88203
(575) 622-0283

July 31, 2009

Prepared for:

New Mexico Salt Water Disposal Co., Inc.
Roswell, New Mexico

Executive Summary

I. As the result of New Mexico Salt Water Disposal Co., Inc., (NMSWDC) produced water releases at its Station 11 tank battery, Unit D of Sec. 21, T10S-R34E, Lea Co., New Mexico State Land Office (SLO) directed soil borings be made to determine the extent of the contamination, if any, resulting from the releases. See page 1.

II. Four soil borings, SB-1, 2, 3, and 4, from 11 ft to 16 ft were made and found no water, but soil chlorides analyzed in the laboratory exceeded 250 ppm (mg/kg) and the SLO initiated requirements for additional deeper borings. See page 1.

III. Four deeper soil borings, SB-1A, 2A, 3A, and 4A were drilled to 36 ft with SB-4A stopping at 31 ft due to penetrating 0.18 ft (2.16 in) of produced water saturated silty clay. See p. 2.

IV. Recovery well RW-1 was drilled a few feet from SB-4A and encountered no water after sitting for one hour. After one week, only enough water was recovered for an analysis sample. A year later less that one liter of water was recovered. The term aquifer is defined at length and the conclusion is that this is not in an aquifer. See p. 3.

V. Monitor wells MW-1, MW-2, and MW-3 were drilled to 135 ft, 139 ft, and 135 ft. MW-2 and MW-3 had no shows of water until penetrating the water table of the Cretaceous sandstone aquifer at 117± ft. MW-1 had a small accumulation of produced water at 61 ft to 63 ft in basal Ogallala sand on top of the disconformity at the top of the Cretaceous shale aquiclude. Water in the Cretaceous sandstone is below 117 ft in the USGS aquifer unit designated as Cretaceous System (210CRCS). See p. 5.

VI. Three more monitor wells found small accumulations of produced water seen at 61 ft in MW-1. MW-4, MW-5, and MW-6 were drilled to 65 ft, 30.5 ft, and 65 ft, respectively. MW-5 encountered a show of produced water 0.9 ft (10.8 in) thick across the base of a sand and the top of a fat clay at 30 ft TD. MW-4 had 3.27 ft of produced water at 60.49 ft (basal) Ogallala sand to 63.49 ft in the Cretaceous shale at 63 ft. MW-6 similarly had 3.36 ft of water from 59.87 ft in lower Ogallala sand and Cretaceous shale to 63 ft. See page 5.

VIII. The produced waters found in RW-1 and MW-5 are very small accumulations in restricted areas, trapped on and in the top of a clay barrier. Produced water found in MW-1, MW-4, and MW-6 at approximately 60 ft is captured in and on the top of the Cretaceous shale, an aquiclude. The quantities are small as evidenced by their thickness, lack of response to bailing and recharge, and their absence in MW-2 and MW-3. The produced water occurs in zones that are otherwise void of fluid. None of the zones are in paths of recharge to the Cretaceous sandstone aquifer. Individually and collectively they form no threat to the Cretaceous sandstone aquifer. No potable or protectable water supplies are present in the area above the isolated Cretaceous aquifer.

IX. Concerns as to contamination of windmill wells are not valid. The Lucky windmill is contaminated with nitrates from livestock watering at the well. Nitrates are not found in oil/gas produced waters. Nitrates found in MW-6 had to be present in the zone prior to the accumulation of produced water at the 60 ft zone from spill(s) at Station 11. The leakage direction from the Lucky windmill to the MW-6 area is confirmed because of the absence of bromide in the Lucky water analysis, plus the nitrates occurring in MW-6.

X. The compilation of a geological profile of the shallow subsurface demonstrates that very small volumes of produced water are trapped on and in the upper surface of either the 30 ft deep fat clay in the Ogallala Formation, or the 60 ft deep disconformable Cretaceous shale. The data also shows the respective clays/shale are significant aquicludes that protect the fresh water of the deeper Cretaceous sandstone aquifer.

XI. This study concludes that the produced water releases at Station 11 have not contaminated or endangered any groundwater under or immediately adjacent to Station 11. There is no protectable water in the greater Station 11 area above the underlying Cretaceous sandstone aquifer.

XII. The Cretaceous sandstone aquifer and its water are safe and highly protected by at least one overlying, thick, contiguous Cretaceous shale aquiclude. The water in the Cretaceous sandstone aquifer is of generally good quality. No evidence can be found that places the Cretaceous aquifer water at risk, save the nitrates emanating from Lucky windmill.

XIII. More than adequate monitoring capability at Station 11 is present to insure these conclusions remain correct. The recommendation of this report is that monitoring continue for a reasonable time. No further testing is required. The meager amounts of produced water found should be left undisturbed for natural attenuation. They pose no threat of vertical or horizontal migration.

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Illustrations

Tables

Introduction

NMSWD's Station 11 is located in New Mexico Oil Conservation Division (OCD) Unit D of Sec. 21, T10S-R34E, Lea Co., New Mexico.

Since 1999, NMSWD has experienced produced water releases totaling approximately 1,700 bbls, of which about 92% was recovered. The unrecovered water amounts to approximately 136 bbls. In 2003, NMSWD was required by the SLO to make soil borings to preliminarily evaluate possible contamination as a result of the releases.

Initially, four shallow borings were scheduled with locations approximately at the corners of the E-W orientated Station 11 tank battery, Figure 1, p. 1. SB-1, SB-2, and SB-3 were 11 ft deep. SB-4 was drilled to 16 ft. No BTEX or TPH was detected. No water was detected. Soil chlorides were laboratory measured and found to be above 250 ppm (mg/l).

The SLO required addition soil borings (Figure 1, p. 1) be made because the *soil* chlorides were greater than 250 ppm (mg/kg) (the EPA ppm maximum recommendation for drinking *water*).

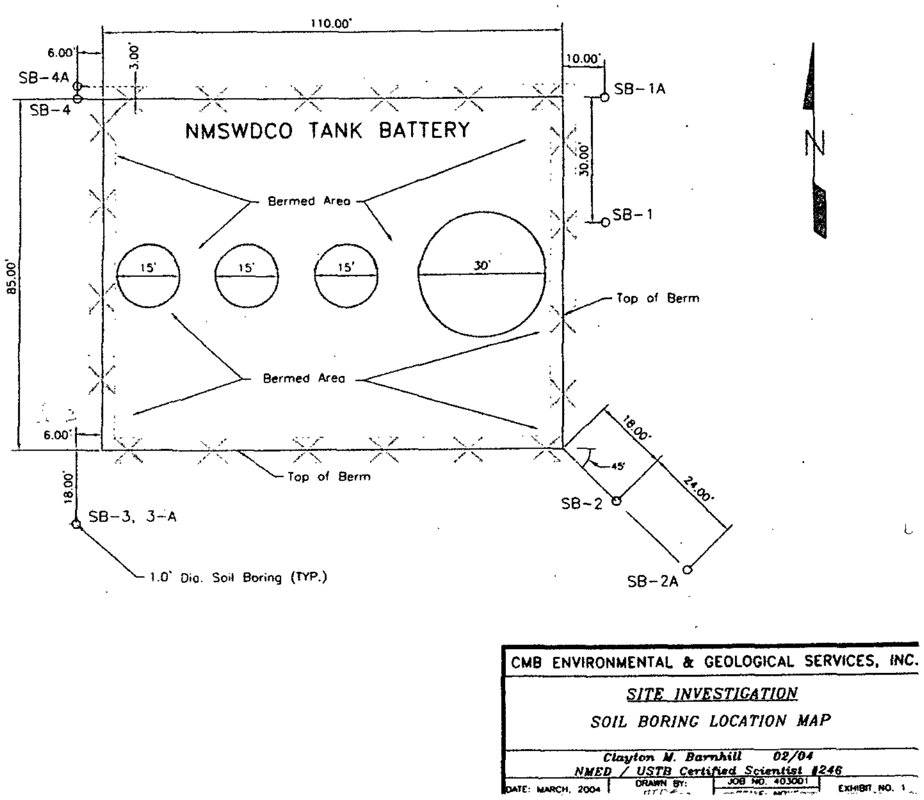


Figure 1 Locations of soil borings SB-1 to SB-4 and SB-1A to SB-4A (Barnhill, 2007)

Secondary Soil Borings

Soil borings SB-1A, SB-2A, and SB-3A were drilled to depths of 36 ft without encountering water. SB-4A drilled a clayey sand from 19 ft to 27 ft, followed by a tighter fat clay from 27 ft to TD 31 ft. Water was found within the silty fat clay at 30.82 to 31 ft that field tested 45,000 mg/l chloride, but had no hydrocarbon odor or staining. The thickness of this water zone was only 0.18 ft (2.2 inches).

Discussion of SB-4A water zone characterization

Barnhill (2004, p. 14) in reporting the drilling of SB-4A described the thin water zone saying, "A perched aquifer was found in soil boring 4A perched on top of the clay zone at 31' feet (sic) below ground surface." After examination of the drilling data, log descriptions and chemical analyses, along with numerous conversations with Mr. Barnhill, two facts emerge. First, a corrected and more appropriate description of the SB-4A water zone would have been, "A very thin water saturated zone was found within a tight silty fat clay drilled from 27 to 31 ft BGS." Those depths are from the penetration rate and descriptions of the split spoon samples of drilling the interval from 27 to 31 ft. The correctly reported show of produced water was 2.2 *inches* thick and almost 4 ft beneath the top of, and within, the clayey interval. Second, unfortunately, the graphically plotted sample log is not quite as detailed as are the on-site in-drilling handwritten descriptions. The graphic log simply is too small to accommodate the lithology change at 27 ft to 31 ft. The level of the water show interval displayed on the graphic log is correct. The field notes do correspond to Barnhill's (2004, p. 14) textual discussion. The graphic log places the water show in clayey sand whereas the on-site drilling log indicates the interval 27 to 31 ft was fat clay with brown inorganic silts. The plotted sample log notes soil chlorides from 29-31 ft at 3900 ppm. The field notes show the H_2O chlorides at 8220 ppm and VOC's at 8260 ppm. VOC's had been non-detect in all the other wells.

Unfortunately, the reader tends to focus on the graphical depictions of test holes and bypass the more tedious examination of handwritten field notes. In the case of SB-4A the difference, although small, is significant. The implications of the presence of water, albeit 2.2 inches, in the bottom of a sand is substantially different than when within a silty fat clay. Clays have very significant porosity, very low horizontal permeability, but virtually no vertical permeability. Water in a sand is visualized to have the capacity to move horizontally and vertically. The water in a clay is, for all practical purposes, immobile.

The water zone in SB-4A was not bailer tested during drilling. The show of water was correctly handled on-site by Barnhill's not penetrating deeper and potentially opening a conduit to any water that might be deeper. Bailer testing was performed after the development of a twin recovery well, RW-4, as discussed later.

Connotation of "Aquifer"

The unintended application of the word "aquifer," in it's technical sense, combined with the insufficient graphical representation of the water show having occurred in a sand instead of a clay may have allowed a misreading of the geological implications of groundwater at and around Station 11. That raised concern as to potential contamination of much deeper, quasi-potable (livestock) water suspected to underlie the immediate area. The OCD's initially conservative approach was to the presence of water with high chloride concentrations in the immediate vicinity of Station 11 and potentially above a *regionally recognized* aquifer.

The conclusion in Mr. Price's letter (AP053, 2008, p. 4) in item 12, that "the deeper, regional aquifer encountered at 100-105 feet BGS has not been contaminated by a release from Station 11" implies a shallow aquifer to be locally present. However, the OCD's concern also appears to have been to the protection of *any* water in a recognized aquifer, and the "perched aquifer" fell into that broad grouping. A brief discussion of the hydrogeological and scientific understanding of the word "aquifer" seems in order.

The lay meaning of "aquifer," from Webster (1980), is simply a "water bearing stratum of permeable rock, sand, or gravel." In the scientific realm, Todd (1980, p. 25) states, "An *aquifer* may be defined as a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs." A highly respected and accepted authority on groundwater, Driscoll (1986), describes an aquifer (p. 19) thus: "An aquifer is a water-bearing reservoir capable of yielding enough water to satisfy a particular demand." On the more contemporaneous side, Wikipedia (2009) states, "An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well." The OCD definition is: "Aquifer" means a geological formation, group of formations or a part of a formation that is capable of yielding a significant amount of water to a well or spring (NMAC 19.15.2.7.A.(13)).

Discussion of recovery well RW-1

Based on Barnhill's (2004) report of 2.2 inches of water in clay in SB-4A, a recovery well, RW-1, was drilled a few feet away from the SB-4A boring, on the northwest corner of Station 11 as shown in Figure.2, p. 4. RW-1 ws drilled on June 13, 2007 and the well was developed (completed) on June 21, 2007. Barnhill (2007, p. 11) reports that during drilling to TD 33 feet no water was encountered. The SB-4A wet zone, only a few feet away, was not present. Upon completion of drilling, the well was rested for 60 minutes to allow water entry. No water entry occurred. During development of the recovery well, one week later, a water sample was recovered, but the well "quickly bailed down and had slow recovery . . ." (Barnhill, 2007, p. 11).

The very small amount of water recovered and the nature of the poor recovery initially led Barnhill to consider the fluid was derived from construction. The well was left to recover and was completely secured. On July 10, 2007 the well was bailed dry after yielding a total of eight (8) gallons of water. After 45 minutes the well had not recovered any water.

After receiving the laboratory analysis of the RW-1 captured water, Barnhill (personal communication) reconsidered and concluded that the original sample was from produced water. Approximately one year later the well was unlocked and bailer tested for water by Mr. Barnhill accompanied by Mr. Rory McMinn. Less than a full liter of water was obtained for analysis, reportedly with considerable difficulty. The hole, for practical purposes, was virtually empty. That information is completely consistent with the lithologic description of the produced water zone in SB-4A, detailed above. It is also apparent this zone is not an aquifer.

Monitor Well Development

Monitor well development began on June 12, 2007 with the drilling of MW-1, MW-2, and MW-4. The details of drilling and construction are in Barnhill's (2007) comprehensive report.

Monitor Wells - First Phase

MW-1 is located toward the southwest corner of Station 11, as shown on Figure 2, p. 4. No water was observed at the 30 ft depth interval of SB-4A. When the driller pulled the center rod at 63 ft, after having drilled sand from 41 ft, he noticed clay. Upon going back in the hole there was 2 ft of water on top of a 40 ft thick, very-tight Cretaceous shale. The Cretaceous local aquifer, discussed below, was found beneath the shale in the lower part of a sandstone at 117.23 ft. TD was 135 ft.

MW-2 is located north of the northwest corner of Station 11. The hole was dry in drilling to below 120 ft. A log notation indicated that no water came into the hole. Drilling was temporarily suspended at 124 ft due to lightning. After resumption of drilling shale (fat clay) was penetrated from 133 to 135 ft. The well was completed at 139 ft (rathole) because of heaving sand from 129 - 133 ft. The well was set to 135 ft. Top of water was called at 117 ft, with water level at 116.91 ft, upon completion in the Cretaceous local aquifer.

MW-3 is located southeast of Station 11. After drilling the sand from 49 ft to 64 ft (through the interval with water in MW-1 and MW-4) with no show of water, drilling was shut-down for night. The next morning the hole was dry. Drilling was advanced to 119 ft where the hole was dry. Additional drilling with meager to no sample returns went to 139 ft. The water level on completion was at 119 ft in the Cretaceous local aquifer. Based upon meager samples, the TD of the well appears to have been at the top of the Triassic Dockum Formation.

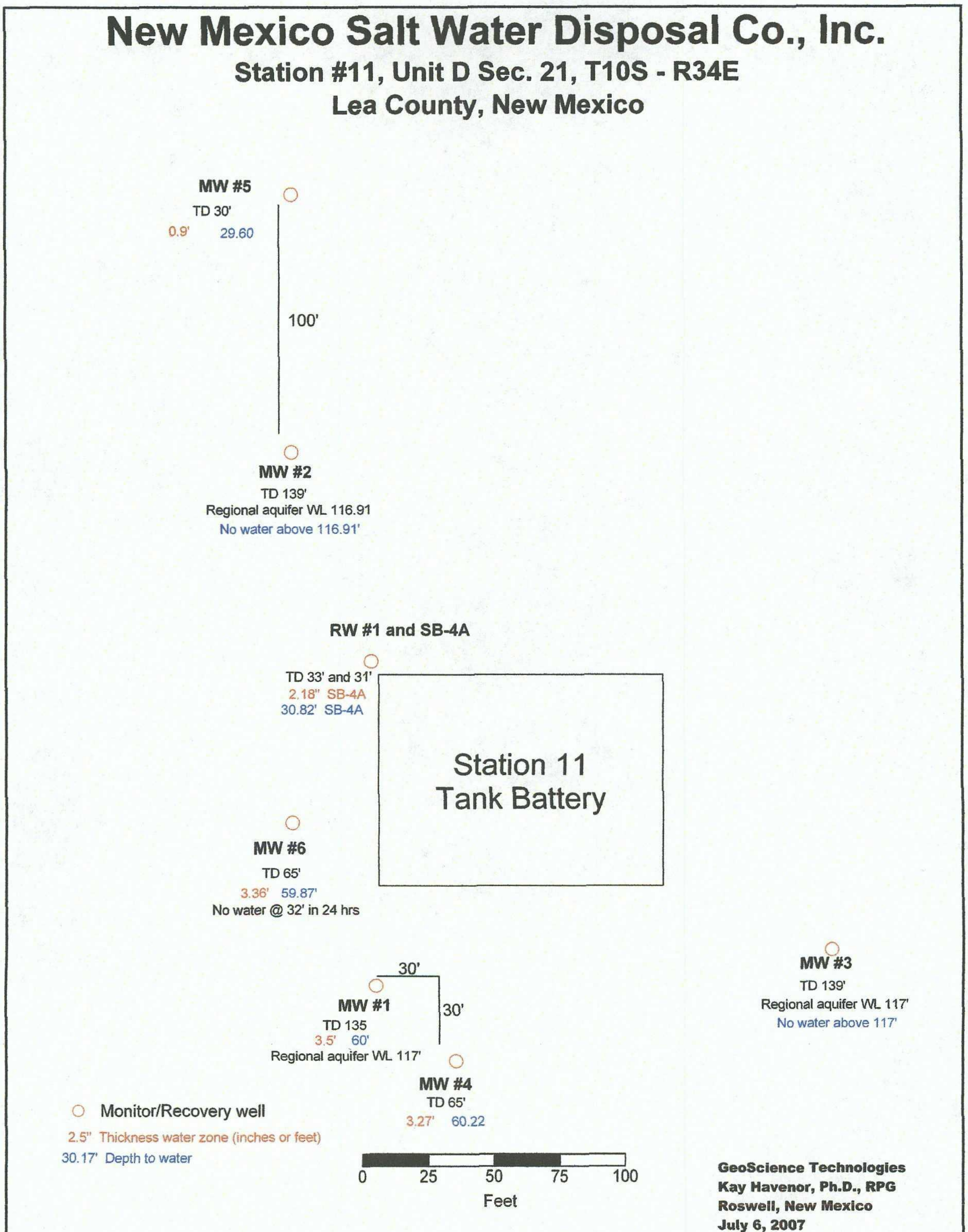


Figure 2 Monitor well locations, depth to water and water zone thickness

An annotated cross-section including MW-1, MW-2, and MW-3 from Barnhill (2007) is shown below as Figure 3, p. 7, and is helpful in following these discussions.

Monitor Wells - Second Phase

The second phase of monitor well construction was precipitated, in part, by the occurrence of 2 ft of water on top of the Cretaceous shale in MW-1 at 61 ft to 63 ft. The drilling of this second phase began April 14, 2009 under the direction and supervision of Mr. Barnhill.

MW-4 was drilled to south of Station 11 to TD 65'. No water was encountered in the interval observed in SB-4A. A test in the clay at 30.30 ft showed the hole was dry. Produced water was found from 60.22' to 63.49' (3.27 ft thick) in sand overlying the disconformity on top of the Cretaceous shale (fat clay) and into the top of the shale. Lab chlorides jn the water sample were 33,000 mg/l. The borehole log for MW-4 is shown in Figure 4, p. 8.

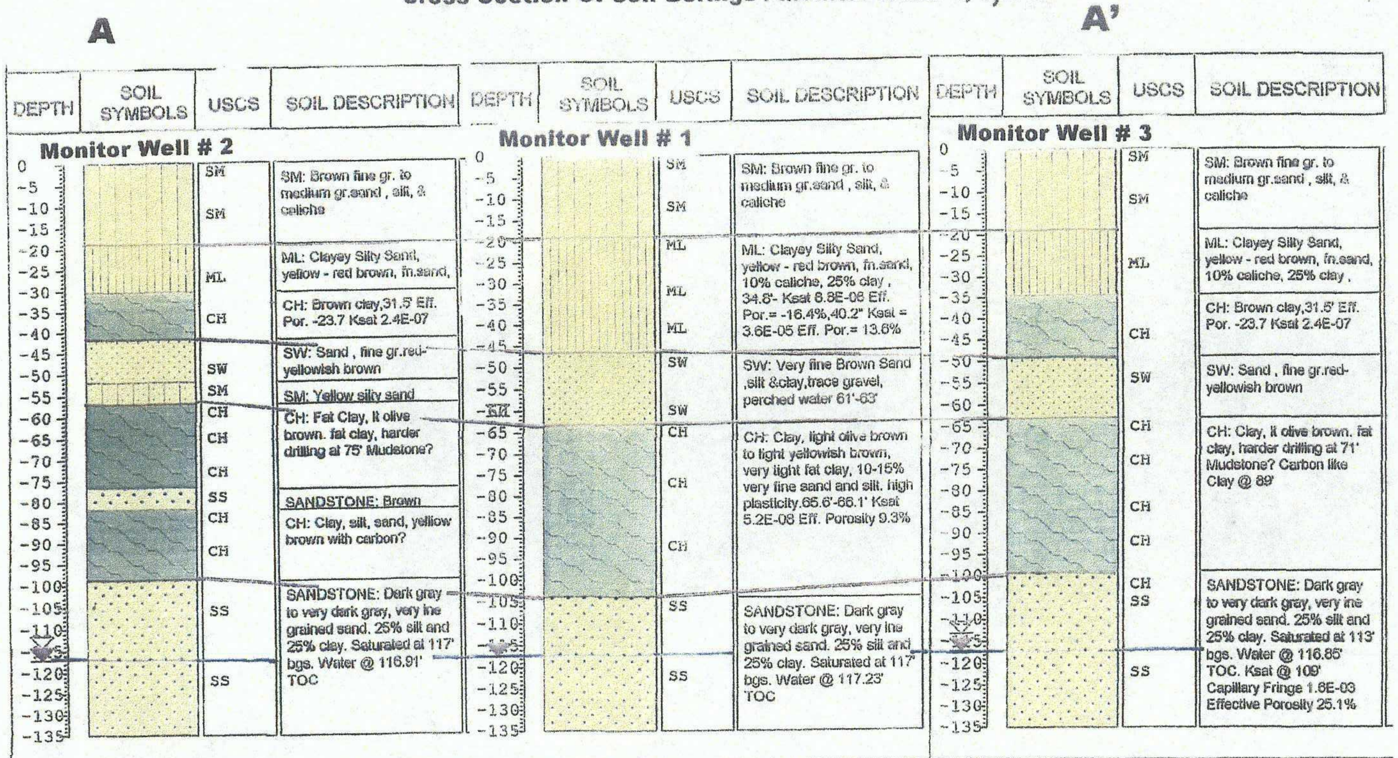
MW-5 was drilled 100 ft north of MW-2 as shown in Figure 2, p. 4. The well encountered 0.9 ft of water interval from 29.6 ft to 30.5 ft. Drilling was not taken deeper to prevent potential communication with deeper zones. Lab chlorides on the water sample were 28,000 mg/l. The borehole log for MW-5 is shown in Figure 5, p. 9.

MW-6 was drilled west of Station 11 (see Figure 2, p. 4) to a depth of 67 ft. Drilling was halted for 24 hours to test for water from 30 ft to 32 ftr. Water observed at this depth in MW-5 was not found in this well. Water was encountered at 59.87 ft in sand overlying Cretaceous shale and its disconformity at 63 ft.. TD was at 65 ft in Cretaceous shale. The top of the water was reported at 59.87 ft. Lab chlorides on the water sample were 20,000 mg/l. The borehole log for MW-6 is shown in Figure 6, p. 10.

Monitor wells MW-1, MW-2, and MW-3, as shown by Barnhill (2007) in cross-section, Figure 3, p. 7, provide important hydrogeological information relating to this immediate area as regards structural attitude, sedimentary depositional environment, and the Cretaceous local aquifer water table. These wells penetrate the Cretaceous shale that forms the aquiclude above the water-bearing sandstone beneath.

New Mexico Salt Water Disposal Company
Station # 11
Section 21, Township 10 South, Range 34 East, N.M. P. M.
Lea County, New Mexico

Cross Section Of Soil Borings / Monitor Wells 1, 2, & 3



Scale: 1" inch = 30' feet (Vertical and Horizontal)
Clayton M. Barnhill, PG
CMB Environmental & Geological Services Inc.
July 2007

Figure 3 Cross-Section MW-2, MW-1, MW-3 (Barnhill, 2007)

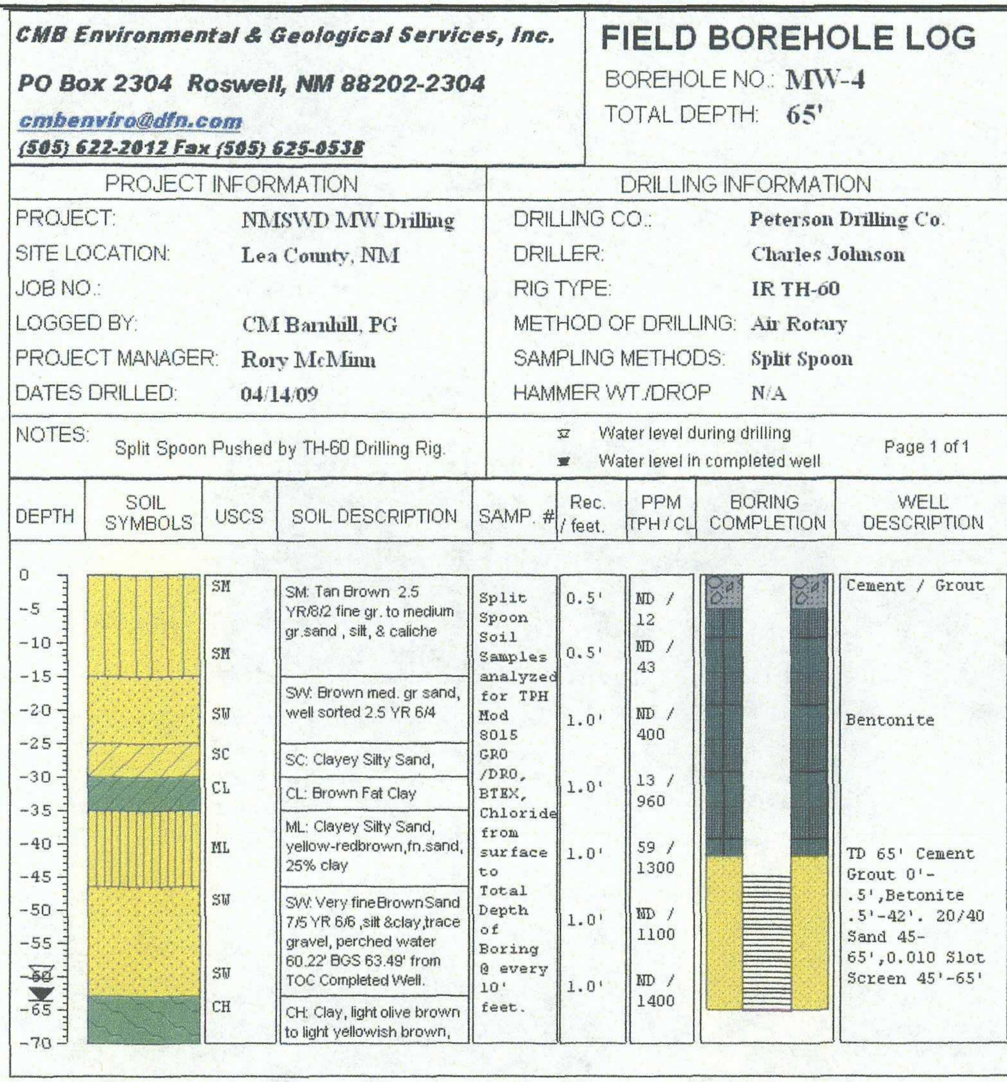
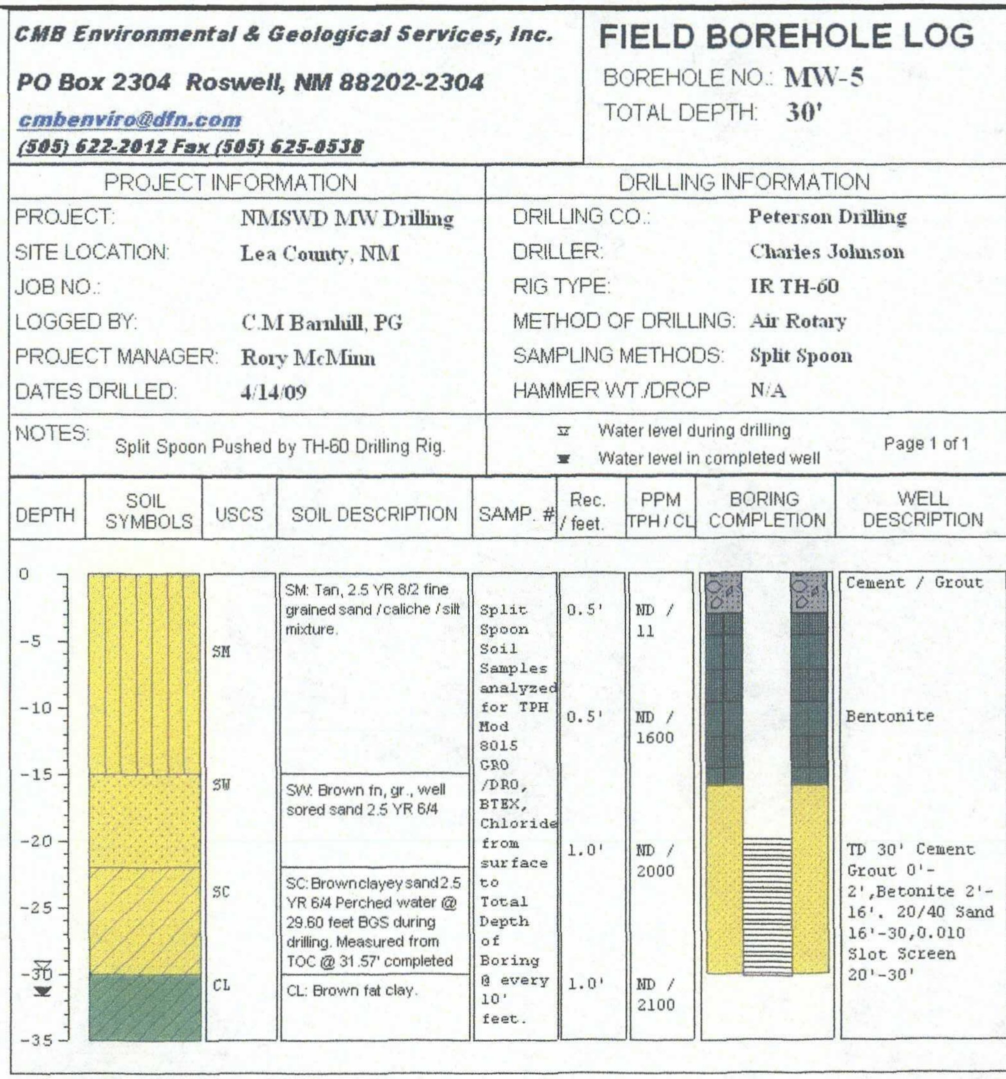


Figure 4 Borehole log MW-4 (Barnhill, 2009)



CMB Environmental & Geological Services, Inc.

PO Box 2304 Roswell, NM 88202-2304

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(505) 622-2012 Fax (505) 625-0538

FIELD BOREHOLE LOG

BOREHOLE NO.: **MW-5**

TOTAL DEPTH: **30'**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	NMSWD MW Drilling	DRILLING CO.:	Peterson Drilling
SITE LOCATION:	Lea County, NM	DRILLER:	Charles Johnson
JOB NO.:		RIG TYPE:	IR TH-60
LOGGED BY:	C.M Barnhill, PG	METHOD OF DRILLING:	Air Rotary
PROJECT MANAGER:	Rory McMinn	SAMPLING METHODS:	Split Spoon
DATES DRILLED:	4/14/09	HAMMER WT./DROP	N/A

NOTES: Split Spoon Pushed by TH-60 Drilling Rig.

▽ Water level during drilling
▼ Water level in completed well

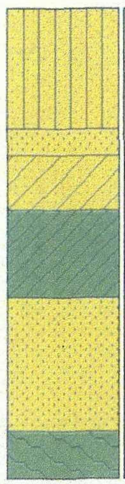
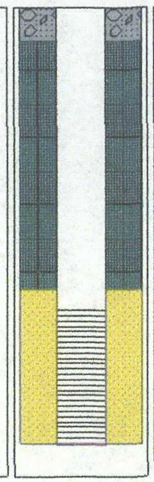
Page 1 of 1

DEPTH	USCS	SOIL DESCRIPTION	SAMP. #	Rec. / feet.	PPM TPH / CL	WELL DESCRIPTION
0 to -15	SM	SM: Tan, 2.5 YR 8/2 fine grained sand / caliche / silt mixture.	Split Spoon Soil Samples analyzed for TPH Mod 8015 GRO /DRO, BTEX, Chloride from surface to Total Depth of Boring @ every 10' feet.	0.5'	ND / 11	Cement / Grout
				0.5'	ND / 1600	Bentonite
-15 to -22	SW	SW: Brown fn, gr., well sored sand 2.5 YR 6/4				
-22 to -30	SC	SC: Brown clayey sand 2.5 YR 6/4 Perched water @ 29.60 feet BGS during drilling. Measured from TOC @ 31.57' completed		1.0'	ND / 2000	TD 30' Cement Grout 0'-2', Betonite 2'-16'. 20/40 Sand 16'-30, 0.010 Slot Screen 20'-30'
-30 to -35	CL	CL: Brown fat clay.		1.0'	ND / 2100	

Figure 5 Borehole log MW-5 (Barnhill, 2009)

CMB Environmental & Geological Services, Inc. ***PO Box 2304 Roswell, NM 88202-2304*** ***cmbenviro@dfn.com*** ***(505) 622-2012 Fax (505) 625-0538***	**FIELD BOREHOLE LOG** BOREHOLE NO.: MW-6 TOTAL DEPTH: 65'

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	NMSWD MW Drilling	DRILLING CO.:	Peterson Drilling Co.
SITE LOCATION:	Lea County, NM	DRILLER:	Charles Johnson
JOB NO.:		RIG TYPE:	IR TH-60
LOGGED BY:	CM Barnhill, PG	METHOD OF DRILLING:	Air Rotary
PROJECT MANAGER:	Rory McMinn	SAMPLING METHODS:	Split Spoon
DATES DRILLED:	04/14/09	HAMMER WT./DROP	N/A
NOTES:	Split Spoon Pushed by TH-60 Drilling Rig.	▽ Water level during drilling ▼ Water level in completed well	Page 1 of 1

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	Rec. / feet.	PPM TPH / CL	BORING COMPLETION	WELL DESCRIPTION
0		SM	SM: Tan Brown 2.5 YR/8/2 fine gr. to medium gr.sand , silt, & caliche	Split Spoon Soil Samples analyzed for TPH Mod 8015 GRO /DRO, BTEX, Chloride from surface to Total Depth of Boring @ every 10' feet.	0.5'	ND / 22		Cement / Grout
-10		SM			0.5'	ND / 20		
-20		SW	SW: Brown med. gr sand,		1.0'	63 / 630		Bentonite
-25		SC	SC: Clayey Silty Sand, yellow - brown , fn.sand,					
-30		CL	CL: Brown Fat Clay, No Perched water at 32' Set temp monitor well at 30' BGS and left open 24 hr.,		1.0'	ND / 3500		
-40		ML			1.0'	ND / 1700		TD 65' Cement Grout 0'-.5',Betonite .5'-42'. 20/40 Sand 45-65',0.010 Slot Screen 45'-65'
-45		SW	SW: Very fine Brown Sand 7/5 YR 6/6, silt & clay,trace gravel, perched water 59.87' BGS 63.23' from TOC Completed Well.		1.0'	ND / 160		
-60		SW			1.0'	53 / 1700		
-65		CH	CH: Clay, light olive brown to light yellowish brown,					

Depth scale: 0, -5, -10, -15, -20, -25, -30, -35, -40, -45, -50, -55, -60, -65, -70

Figure 6 Monitor well MW-6 (Barnhill, 2009)

Geology Revealed by First and Second Phase Borings

Monitor well elevations, Figure 7, p. 12, illustrate the Station 11 area is close to 4,218 ft MSL. MW-1 is mounded 3-feet higher than the surrounding wells and is less than 10 ft south of the intersection of a N-S road into an E-W road. The contouring ignores the roads and the likely man-made mound related to the construction immediately north of the well. The regional ground surface in Section 21 is known to slope east at 25 feet per mile, approximately 1/4°. Station 11 is essentially a flat area. The USGS topographic quadrangle map shown in Barnhill (2004) marks the elevation of the southwest corner of Station 11 tank battery to be 4217 ft MSL.

Two horizons provide excellent structural reference for all three first phase wells. The uppermost horizon is at the base of the Quaternary sand, silt, caliche horizon to about 19 ft as highlighted by Barnhill (2007), shown here in Figure 3, p. 7. This marker is the top of a beveled Ogallala Formation overlain by Quaternary sediment. The marker is essentially flat. The lowermost marker is the groundwater table for the local area's groundwater in Cretaceous age sediments. Figure 3 demonstrates the Cretaceous water table as essentially flat. The water levels on July 7, 2007 were: MW-2 = 116.91 ft, MW-1 = 117.23 ft, and MW-3 = 116.85 ft, a maximum variation of only 0.28 ft (3.36 in). Figure 3 shows the ground's surface, the eroded surface of the Ogallala Formation, the lowermost bed of Cretaceous sandstone, and the water table in each of the wells, all of which are quasi-parallel with only a 0.38 ft gradient from MW-2 to MW-1

Beneath the clayey, brown sand, silty unit and brown clay unit of the Ogallala Formation (at 42 ft in MW-2) is the first sand in which produced water occurs, but only in MW-1. Both MW-2 and MW-3 are dry in that interval. This sand is the same zone in which produced water also has been found in MW-4, and MW-6, p. 8 and 10, respectively. In all three of these wells (MW-1, MW-4, and MW-6) produced water is only in the most basal part of the Ogallala sand that is disconformable on top of Cretaceous shale. These three wells are located to the west and southwest of Station 11 tank (Figure 2, p. 4). Figure 3, p. 7, illustrates that the depths of this sand in MW-1 and MW-3 are essentially the same, but MW-2, located on the northwest corner of Station 11 tank battery, is structurally higher.

The sand at 42 ft in MW-2 was not penetrated in MW-5, located 100 ft north, because it stopped at TD 30 ft. The top of the MW-2's *clay at* 30 ft overlays sand (42 ft to 57 ft). The clay is also present in MW-5 at 30 ft and is the bed that traps and holds the very thin occurrence of produced water shown at 29.60 ft on the borehole log, Figure 5, p. 9. The water zone in MW-5 extends into the clay layer to 30.5 ft, a water column thickness of 0.9 ft. Lab chlorides on the water measured 28,000 mg/l.

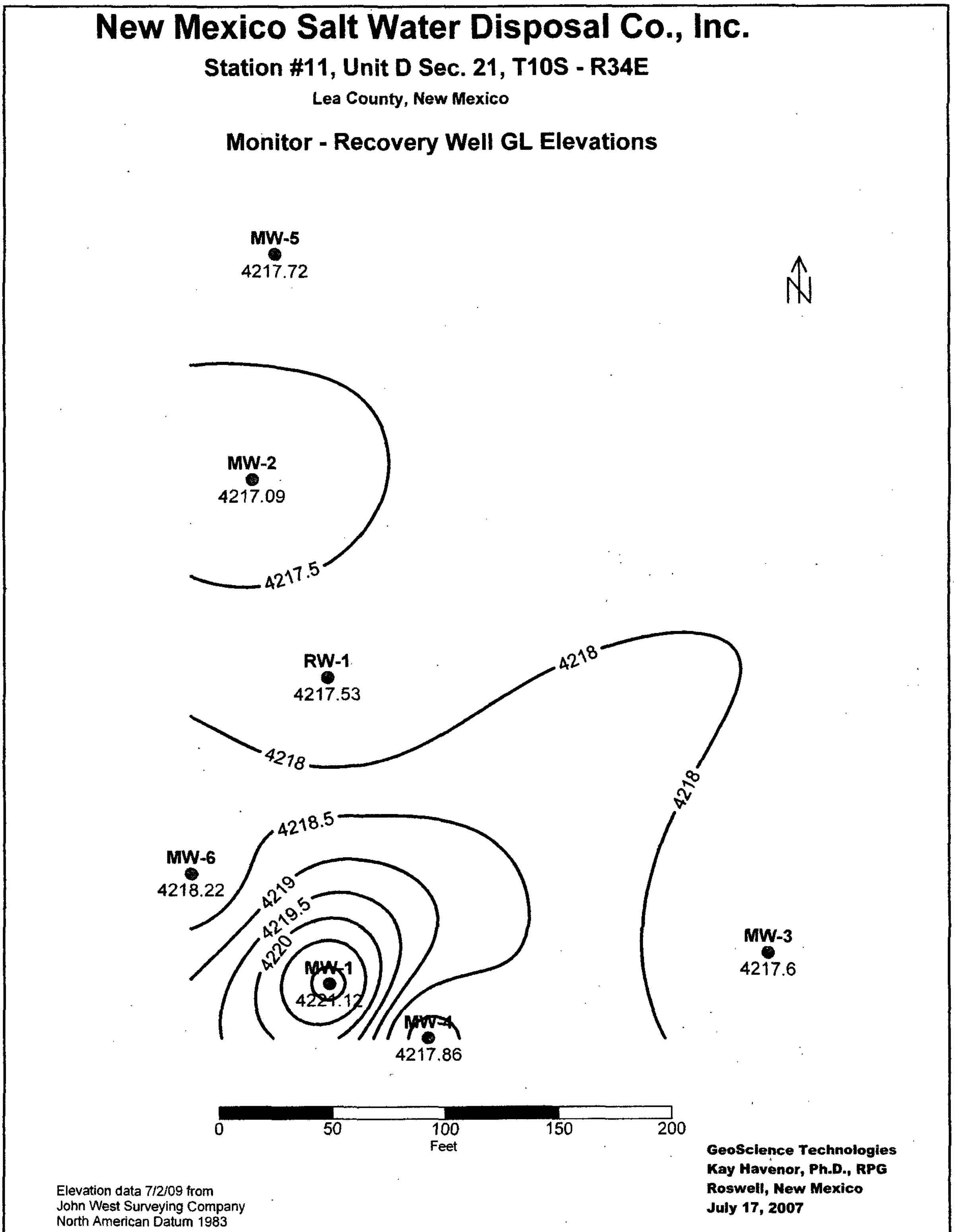


Figure 7 Topographic contour map from well elevations. Surface modifications not shown.

The 40 ft thick shale beneath the Ogallala and the Cenozoic-Paleozoic disconformity is on top, the aquiclude, of the water bearing sandstone in MW-1, MW-2, and MW-3, as shown above in Figure 3, p. 7. MW-4 and MW-6 were only drilled to 65 ft, but both have the same shale underlying their trapped water zone in the 60 ft range. It is a reasonable geological projection that the shale zone is present with consistent thicknesses in MW-4, MW-6, and beneath Station 11 as evidenced by its presence in MW-2 and MW-3.

Shallow Stratigraphy and Structure of the Study Area

Fluids must move through soil, sediment and rock to penetrate into the subsurface. The fate of the fluid's movement is dependent upon many factors including the mass/volume of the fluid, time, and *most* importantly, the formations through which they must move.

Within the immediate study area the surface is covered with 15 ft to 19 ft of Quaternary alluvium, mostly in the form of fine blow sand and caliche. The underlying Tertiary Ogallala Formation extends from about 19 ft to a depth ranging from 57 ft in MW-2 to a maximum 63 ft depth in the remaining wells. The Ogallala aquifer is not present in this greater study area as mapped by Ash, 1963. The Ogallala Formation is present, but all fresh water in the greater part of T10S-R34E is derived from the Ash's (1963) Cretaceous unit mapped with the symbol Kcl. The Cretaceous unit is an erosional remnant upon which Ogallala was later deposited.

A disconformity is present and identified as such from a split-spoon samples in MW-4 across 63 ft. The zone has excellent correlativity to all the sands found in that interval in the other wells. The disconformity is the Cretaceous-Ogallala contact and is a time break of some 42 million years. A significant change of lithology is apparent below the formation contact.

Figure 3, p. 7, shows that MW-1 is located in a structurally lower position than the tops of the correlative sands in MW-2 and MW-4, especially at the base of MW-1's Cretaceous shale at 104 ft.. The slight structural depression developed as a slight reduction in the thickness of the Cretaceous sand beneath the shale at 104 ft in MW-1. This slightly lower structural position in MW-1 reflects upward into the overlying Ogallala. It forms the sag, or sump, into which 3.5 ft of produced water accumulated in the basal Ogallala sand in MW-1. This is significant because it shows 1) the upper Cretaceous shale is a strong aquiclude preventing downward movement of produced water from Station 11, and 2) the trapped water at this horizon is isolated to a small area around the southwest corner of Station 11. This additionally shows the volume of water in the sump is relatively small. The contaminated thickness in the lower Ogallala thins slightly from MW-1 to both MW-4 on the south and MW-6 on the north (Figure 2, p. 4). The produced water is absent in both MW-3, approximately 165 ft west, and MW-2, approximately 140 ft north.

The log plot of MW-1 in Figure 3, p. 7, appears to be anomalous immediately above the 46 ft top of sand. In the adjoining wells, MW-2 and MW-3, the sand at 46 ft is overlain by a brown clay. Comparison of the graphic plot of that interval with the on-site data recorded during drilling discloses that a sandy, silty brown clay is actually present from 39 ft to 46 ft. The unit is not as strong in clay as the correlative zones in all the other wells, but it is present. It also provides a possible conduit to allow produced water from the surface to reach the 60 ft interval in MW-1.

Drilling Testing Information

Soil boring and monitor well development details aid the understanding of the data being reviewed. MW-1 was at 63 ft on June 12, 2007 when the driller noted clay on the bit when he tripped out of the hole. Upon returning to bottom there was 2 ft of water which they sampled. The hole was drilled to 65 ft in fat clay and millimeter thin stringers of sandstone and mudstone. It is important to note that the recorded 2 ft were not logged as sand and clay, but as sandstone and mudstone. At temporary TD of 65' the drilling was suspended by the contractor and was shut-down for five days. Recovery well RW-1 was completed before resuming drilling in MW-1. The lithology encountered at 63 to 65 ft in MW-1 was reconfirmed with slightly more detailed sample descriptions and finished drilling to TD at 135 ft.

Monitor wells MW-2 and MW-3 were drilled into the Cretaceous sandstone aquifer with no observed water zones above the basal sandstone. Both were completed in the Cretaceous sandstone.

Five monitor wells, MW-1, MW-2, MW-3, MW-4, and MW-6, penetrated the local Ogallala Formation into the top few feet of the Cretaceous shale. The first three listed penetrated the 40 ft thick upper shale unit of the Cretaceous in which the hydraulic conductivity is very low, $K_{sat} = 5.2^{-8}$. MW-5 was drilled into the Ogallala Formation, TD 30 ft, where it encountered 0.9 ft of water in the Cretaceous shale (fat clay) beneath a clayey Ogallala sand.

Three monitor wells were drilled beneath the Cretaceous shale into the lower part of the underlying Cretaceous sandstone. This sandstone has a measured water level 14 ft to 17 ft below the base of the overlying shale aquiclude. MW-2 encountered heaving sediment in the basal part of the sandstone layer at about 133 ft. The formation was drilled from 133 ft to 135 ft, and then ratholed to 139 ft, into what may be the top of the Triassic Dockum Formation.

The Cretaceous water in MW-2 is effectively confined by the overlying shale, but is not artesian because the sandstone is not water filled and therefore has no driving hydraulic head. The Cretaceous waters do not have high chlorides content, but range from 538 to 648 mg/l in MW-1, MW-2, and MW-3. The chloride levels are all above EPA MCL levels of 250 mg/l.

Area Windmills

Two windmills tap the Cretaceous sandstone aquifer in the local area. The Lucky windmill in Section 20 is 1-mile southwest of Station 11 and the Sand windmill is 1.3 miles north in Section 9. The chlorides in the two wells were 638 and 548 mg/l respectively. The Lucky windmill wells and one additional unsampled well located in the NW/4 of Section 27, about 1.75 miles southeast of Station 11, are classified in the USGS groundwater data base as producing from the Cretaceous System (210CRCS). The Sand well is not in the USGS well records.

The productive capacity of the Lucky and Sand windmills was described by Barnhill (personal communication) as extremely weak when sampled in May 2009. When asked to explain, Mr. Barnhill reflected that it was about enough water to allow the cows to get a drink, illustrating a finger size stream from the windmill at Lucky well and from the solar powered electric pump at Sand well.

Bailing from the bottom of the Cretaceous sandstone aquifer in the Station 11 MW-3 completed well yielded approximately 15 gallons of fresh water from 117 ft. The well completion field notes indicated "slow recovery!" That suggests the visual pumping discharge described by Mr. Barnhill at the Lucky and Sand windmill wells was reasonable.

Windmill Contamination

USGS water levels have been reported in the "Cretaceous System local aquifer" Lucky and the ranch well southeast in Section 27. Total depths of the ranch well and Lucky well are not reported in the USGS files. The OSE records suggest the Lucky well is at least 101 ft deep. The last reported water level in the Lucky windmill well was 1981 at a depth of 34.11 ft. The water analysis of water taken from the Sandy windmill is geochemically inconsistent with the Lucky windmill data. No information is available on the Sandy windmill as to depth or water level. The Sandy well has therefore been disregarded in this analysis. Cretaceous water analyses from the Station 11 monitor wells MW-1, MW-2 and MW-3 were reported by Barnhill (2007) and are geochemically consistent with the water from Lucky windmill, except for nitrate levels. No Ogallala aquifer is reported in the sections surrounding Station 11, or in most of this township, by Ash (1963).

The water level in the Lucky windmill is at a height approximately the same as the top of the first significant fat clay encountered about 30 ft in all the Station 11 monitor wells, except possibly MW-1. The 34 ft deep water level in the Lucky windmill was not observed in the Station 11 wells, except for MW-5. The difference undoubtly has to do with the professional installation of the monitor wells, their casing, screening, and grouting to prevent water zone mixing. That cannot be assumed for the windmill well. The Lucky's well depth, at a minimum, puts the hole into the Cretaceous local aquifer, as the water chemistry very clearly confirms.

The Station 11 well lithology logs, water levels and analyses shows the aquifer beneath Station 11 is not artesian. The water level is about 15 ft beneath the top of the sandstone host. Lack of evidence otherwise requires we assume the Lucky windmill is similar. There is also evidence, discussed below, that some communication exists between MW-6 and the Lucky well at the 60 ft level. That communication presents conditions that must be met in MW-6, namely that the incoming volume must be extremely small to match the amount of water accurately measured in MW-6. It would further require that water being pumped from the Lucky borehole would stand and maintain a water level around 34 ft over many years. USGS water level records from 1970 to 1981 show water levels from 37.01 ft to 34.11..

To evaluate the local rancher's expressed concern that produced water releases from Station 11 have contaminated the Lucky stock water supply, a sample of water from the Lucky windmill was taken at the same time as from MW-4, MW-5, MW-6. Samples from MW-1, MW-2, and MW-3 had previously been collected and analyzed. Those analyses permit comparisons of bromide and nitrate to evaluate possible migration of contamination from Station 11 to the Lucky area one-mile southwest.

Bromide and nitrates are each normally less than 10 mg/l in groundwater, except in special circumstances not known to be present in this region. Nitrate in fresh water is characteristically indicative of septic systems, livestock feeding, and commercial farming, none of which exist in the Station 11 or Lucky windmill area, except livestock watering at the latter. Bromide is generally in oil/gas related produced water in high quantities. Livestock presence is not physically excluded from the Station 11 area except from the fenced tank battery.

Unfortunately, the laboratory failed to analyze nitrates in the MW-5 sample submitted, but it was analyized in the Lucky windmill well plus MW-4 and MW-6. EPA limits (MCL) for nitrate as N in public drinking water is 10 mg/l. The EPA has no MCL for bromide, but it is considered as dangerous over 10 mg/l. Table 1 shows the concentrations found in the Lucky windmill, MW-4, MW-5, and MW-6.

Table 1 Bromide and nitrate-N concentrations in Lucky windmill and monitor wells.

Compound in mg/l	Lucky	MW-4	MW-5	MW-6
Nitrate as N	15.9	<2.50	NA	49.4
Bromide	<2.50	940	512	609

The hydrogeochemical argument is relatively simple. Nitrate is not found in oil/gas produced water. Bromide is uncommon in fresh waters. Nitrate source is present in the Lucky windmill at contamination levels. Professional well construction of the Station 11 monitor wells is specifically engineered to prevent subsurface water contamination via the well bore except from a specific horizon. Common construction of ranch water wells, including many domestic wells, does not have the grouting and/or isolation to prevent contamination via the open borehole.

The Lucky well analysis shows it has 15.9 mg/l nitrate–N in its well water produced from the Cretaceous groundwater aquifer. MW-4 has below measurable nitrate in water taken from the lower Ogallala at TD 65 ft. MW-6 shows 49.4 mg/l nitrate-N from the bottom of the 65 ft grouted and surface isolated well. The Lucky windmill well is the only potential source of nitrate and it is assumed to be the up-gradient well. The higher level of nitrate in MW-6 can be directly related to concentration caused by H_2O adsorption and the resulting concentration of nitrates as very small volumes of water have moved from Lucky to the MW-6 site for decades. The volumes constitute seepage rather than flow. The Lucky windmill is one-mile southwest of Station 11.

The Lucky windmill has below detectable bromide whereas MW-4, and MW-6 have 940 mg/l and 609 mg/l respectively. The high oil/gas produced water concentrations of bromide are not seen in the Lucky windmill. The hydrogeochemistry demonstrates that water movement, albeit small, is from Lucky windmill to the MW-6 site. Were there any water from Station 11 moving into the Lucky windmill there would be unquestionably high concentrations of bromide as well as highly elevated chlorides and sodium. Water from Lucky windmill is and has moved into the MW-6 site through the sand along the top of the Cretaceous disconformity at 63 ft. No bromides, and no high sodium-chlorides (elevated above that seen in the Cretaceous sandstone) demonstrates that water is not moving from the Station 11 area to the Lucky windmill. An additional consideration to these indicated movements is that of time. With no driving flow of water, and the observed minuscule, isolated volumes, the rate of movement of either fresh or produced water through the Ogallala sandy horizons present in this environment would be truly of geological proportions.

The initial round of soil borings (SB-1, SB-2, SB-3), at the corners of Station 11, found no shallow indications of water, but did record *soil* chlorides above 250 mg/kg (ppm). As has been noted, the 250 ppm value is the EPA's MCL limits in water for safe consumption by humans. New Mexico has no health or environmental standards for soil chlorides. If soil chloride standards were set at 250 mg/kg there would be large areas, especially in southern New Mexico, where soils in their native/natural state would be in extreme violation.

Septic systems are an excellent example of using soils as filters to purify waste water. The filtering and ion exchange processes essentially adsorb ions and/or particles as well as exchange ions such as Na/K, but generally excepting nitrates. However, there no known water/rock (mineral) interaction that will remove chloride from groundwater.

The chloride content of the 61 - 63.5 ft produced water in MW-1 was 21,000 mg/l whereas the underlying regional aquifer water was 550 mg/l. The separation of the two zones is effected by the 40 ft+ Cretaceous shale (fat clay horizon) above the Cretaceous aquifer sand. The water samples from the Cretaceous aquifer in MW-2, and MW-3, plus the more distant Lucky windmill, individually and collectively confirm that the Cretaceous shale has effectively prevented any downward migration into the Cretaceous aquifer from the thin, dispersed and areally isolated produced water shows at Station 11. Unfortunately, the Cretaceous sandstone aquifer beneath Lucky windmill has nitrate contamination.

Conclusions

Four shallow borings, SB-1, 2, 3, and 4, were drilled to a maximum depth of 16 ft. No water, BTEX or TPH was detected, but laboratory analyses found soil chlorides to be above 250 ppm (mg/l). Although 250 mg/l chloride is an EPA MCL for drinking water, New Mexico has no standard for *soil* chloride concentrations.

Because of the >250 mg/l chlorides in soil samples, the SLO required additional soil borings. Four new borings were drilled close to the original soil borings near the corners of Station 11. SB-1A, SB-2A and SB-3A were drilled to 36 ft into a clay layer without encountering any water. SB-4A was drilled at the northwest corner of Station 11 to a TD of 31 ft in clay. Water was noted in the clay from 30.82 ft to 31 ft, a thickness of 2.16 inches. Chloride content of the water was 45,000 mg/l.

The SB-4A water zone in clay was inappropriately referred to by Barnhill (2004) as a "perched aquifer." This writer, following geological concepts, disagrees with the SB-4A zone being classified as an aquifer. It should more appropriately have been described as "A very thin water saturated zone was found within a tight silty fat clay drilled from 27 to 31 ft BGS." Less than 2.2 inches of water in a fat clay does not constitute an aquifer or groundwater protected by the OCD's abatement regulations.

Three monitor wells plus a recovery well immediately next to SB-4A were ordered by the OCD. MW-1, MW-2, and MW-3 were drilled at locations shown on Figure 2, p. 4. Two monitor wells were drilled to TD 135 ft. MW-3 was drilled to TD 139 ft. Water levels were found in all three wells at about 117 ft in Cretaceous sandstone. No contamination was found in the Cretaceous aquifer water. The USGS classifies other wells in this aquifer in the immediate area as Cretaceous local aquifer (Cretaceous System (210CRCS)) (Ash, 1963).

Water was found during the drilling of MW-2 in Ogallala sand from 63 ft to 65 ft, directly on top of the Cretaceous shale. The hole was cased and drilling continued to TD 135 ft in the Cretaceous aquifer sandstone where the well was completed. No contamination was found in the fresh water at TD. The Cretaceous clay above the aquifer sandstone is an effective aquiclude to downward fluid migration.

Recovery well RW-1 was drilled to TD 33 ft and completed. During drilling it reported no water in the Ogallala sand penetrated. After completion a sample of water was collected for chemical analysis. The fat clay that is present throughout the study area beneath the Ogallala sand will act as a barrier to any downward migration toward the Cretaceous sandstone aquifer. Again, the 40 ft thick Cretaceous shale that is found about 60 ft deep presents an excellent example of a groundwater barrier to downward migrating water.

Hydrogeochemistry demonstrates that the Lucky windmill has no contamination from Station 11 produced water migrating to or entering the well. That is verified by the absence of any measurable bromide content that might have migrated from MW-6 or through subsurface paths. The hydrogeochemistry further confirms that some water moved from the Lucky windmill, which was contaminated by nitrates, into the area where MW-6 was developed.

All of the wells in the study area are underlain by the Cretaceous shale, an aquiclude, that prevents downward migration of water and contaminates into the Cretaceous sandstone aquifer. In most cases the fat clay horizons in the Ogallala Formation will trap any aqueous contaminates and prevent most fluids from going deeper. Where the upper Ogallala fat clay is silty to sandy, as in MW-1, the top of Cretaceous shale will continue to shield the local aquifer.

The local Ogallala Formation has no indication of groundwater accumulations. The only known groundwater in the area is in the Cretaceous that disconformably underlies the Ogallala Formation. No Ogallala aquifer is present in most of T10S-R34E, especially the greater area around Station 11.

The mechanical problems that resulted in produced water releases at Station 11 have all been corrected. With the construction of six monitor wells, and the RW-1 recovery well, the local area is more than adequately positioned to monitor any possible future releases, should such occur.

The small amounts of water found during drilling pose no threat to any potable waters in the greater area. Bailer tests in the recovery and monitor wells all indicate no hydraulic drive, or influx of fluid that is present to enable lateral flow. The recovery well RW-1 only yielded about a liter of produced water into the hole in approximately one year. All wells, monitor and recovery, have exhibited poor recoveries, hence insufficient volume and or/drive to create a threat to any fresh water supplies. The most important hydrogeological conclusion concerning the greater Station 11 area is that there is no protectable groundwater above the aquiclude isolated Cretaceous aquifer.

The previous corrections of the mechanical problems that caused produced water releases at Station 11 are to be further enhanced by NMSWDC's installation of a liner and berms with larger capacity that will hold 150% of the capacity of the storage tanks. Additionally, the verification of no effect, or potential affect(s), on any fresh water supply demonstrates that natural attenuation processes have/will insure that no imminent nor future threat is present due to the Station 11 releases. Monitoring could continue for a reasonable time to insure the minuscule water volumes observed remain harmless. There is no threat of potable water being impaired. It is recommended that no further action be required by the SLO or OCD at Station 11.

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Statement of Qualifications

Kay C. Havenor

Ph.D. Geoscientist
Certified Professional Geologist AIPG #673
Registered Geologist Arizona #30438
Registered Professional Geologist Texas #5806

Professional Experience

Field, subsurface and research geology; regional structural, stratigraphy, oil and gas, hydrodynamics, environmental and hydrogeological investigations, with primary emphasis in Arizona, New Mexico, West Texas, and other portions of the western United States, Canada and Mexico. Mining experience in New Mexico and western Mexico. Professionally active in geology from1958 to present. Geological consulting and independent oil/gas and groundwater activities from 1962 to the present. Oil and gas production operator (Havenor Operating Company), Texas and New Mexico.

Geological research, exploration and development, extensive field experience in drilling, completion, testing, and evaluation of wells for hydrocarbons and water. Non-drilling geological field mapping, surface and subsurface exploration in New Mexico, Texas, Arizona, Colorado, Mexico and British Columbia includes geologic surface mapping, stratigraphic analysis, base metal prospecting, mining, environmental, groundwater, and geologic hazards evaluation.

Environmental and preconstruction site evaluations, dairy and cheese plants monitoring, discharge plans, isotopic determinations of nitrate sources. Hydrogeochemical forensics, hydrogeochemical and isotopic water mapping.

Adjunct Faculty Geology, Eastern New Mexico University, 1992 to the present.

Present and recent consulting areas include investigation and mapping of groundwater in West Texas and southeastern New Mexico. Surface and subsurface geology of Ouachita overthrust area of portions of Terrell and Val Verde Counties, Texas. Structure, stratigraphy and hydrogeology of the northern Tularosa Basin, Otero County, New Mexico. Structure and subsurface stratigraphy of Mehsana area, Cambay Basin, Guarat, India. Produced water disposal in southeastern New Mexico.

Education

Colorado College, Colorado Springs, Colorado, 1953-1957
BS Geology, magna cum laude

University of Arizona, Tucson, Arizona, 1957-1958
MS Geology
Graduate Teaching Fellow

MS thesis on The Pennsylvanian System of Arizona

University of Arizona, Tucson, Arizona, 1992 and 1995
Ph.D. Geoscience 1996
Graduate Teaching Assistant
Emphasis in hydrogeology, remote sensing, environmental geology.
Dissertation: The hydrogeologic framework of the Roswell groundwater basin, Chaves, Eddy, Lincoln, and Otero Counties, New Mexico

Professional Affiliations

Geological Society of America, Senior Fellow
American Association of Petroleum Geologists, Member
American Institute of Professional Geologists, #673, Charter Member
former State Chapter Newsletter Editor
Roswell Geological Society
former President, Vice-president, Secretary, and Treasurer
Arizona Hydrological Society
Arizona Geological Society
New Mexico Geological Society
Sigma Xi

Publications in geology

Foster, R. W., Hawks, W. L., Parkhill, T. A., Smith, C. T., and Havenor, K. C., 1968. Mineral Resource Evaluation of State Lands in East-Central New Mexico: New Mexico Bureau of Mines and Mineral Resources, pp. 71 p., 5 tables, 26 figs.

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GeoScience Technologies

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Expert Witness Summary

Qualified as an expert witness in various areas, including geoscience, hydrogeology, hydrology, paleoclimatology, hydrogeochemistry, groundwater, oil and natural gas, and economics thereof in hearings/trials before:

New Mexico Oil Conservation Commission
New Mexico State Engineer
US District Court, Albuquerque, New Mexico
Fifth Judicial District Court of New Mexico
Twelfth Judicial District Court of New Mexico

Appendix E- Water Analysis Reports

- Northwest Background Well
- East Leak Source Well
- Local Water Wells Map and Analysis

CARDINAL Laboratories

PHONE (575) 393-2326 ° 101 E. MARLAND ° HOBBS, NM 88240

Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	12/29/2010	Sampling Date:	12/27/2010
Reported:	02/03/2011	Sampling Type:	Water
Project Name:	NMSWD NW BACKGROUOND MW	Sampling Condition:	** (See Notes)
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	CROSSROADS, NM		

Sample ID: PURGE @ 4.25 GALS (H021620-01)

BTEX 8021B mg/L **Analyzed By: CMS**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Benzene*	**0.002**	0.001	12/30/2010	ND	0.050	101	0.0500	1.73	
Toluene*	**0.003**	0.001	12/30/2010	ND	0.049	98.1	0.0500	1.38	
Ethylbenzene*	<0.001	0.001	12/30/2010	ND	0.049	97.8	0.0500	0.494	
Total Xylenes*	**0.003**	0.003	12/30/2010	ND	0.143	95.5	0.150	1.60	

Surrogate: 4-Bromofluorobenzene (PIL *114 %* *80-120*

Chloride, SM4500Cl-B mg/L **Analyzed By: CK**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Chloride	**14400**	4.00	12/30/2010	ND	108	108	100	0.00	

Celey D. Keene

Celey D. Keene, Lab Director/Quality Manager

CARDINAL Laboratories

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Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	12/22/2010	Sampling Date:	12/22/2010
Reported:	12/29/2010	Sampling Type:	Water
Project Name:	NMSW DISPOSAL 6" LEAK	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	CROSSROADS		

Sample ID: LEAK SOURCE EAST (H021594-01)

BTEX 8260B mg/L Analyzed By: CMS

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Benzene*	**0.011**	0.001	12/28/2010	ND	0.019	94.1	0.0200	0.212	
Toluene*	**0.003**	0.001	12/28/2010	ND	0.018	92.4	0.0200	5.42	
Ethylbenzene*	<0.001	0.001	12/28/2010	ND	0.020	98.6	0.0200	0.253	
Total Xylenes*	<0.003	0.003	12/28/2010	ND	0.058	97.0	0.0600	2.49	

Surrogate: Dibromofluoromethane	*77.4 %*	*80-120*
Surrogate: Toluene-d8	*105 %*	*80-120*
Surrogate: 4-Bromofluorobenzene	*107 %*	*80-120*

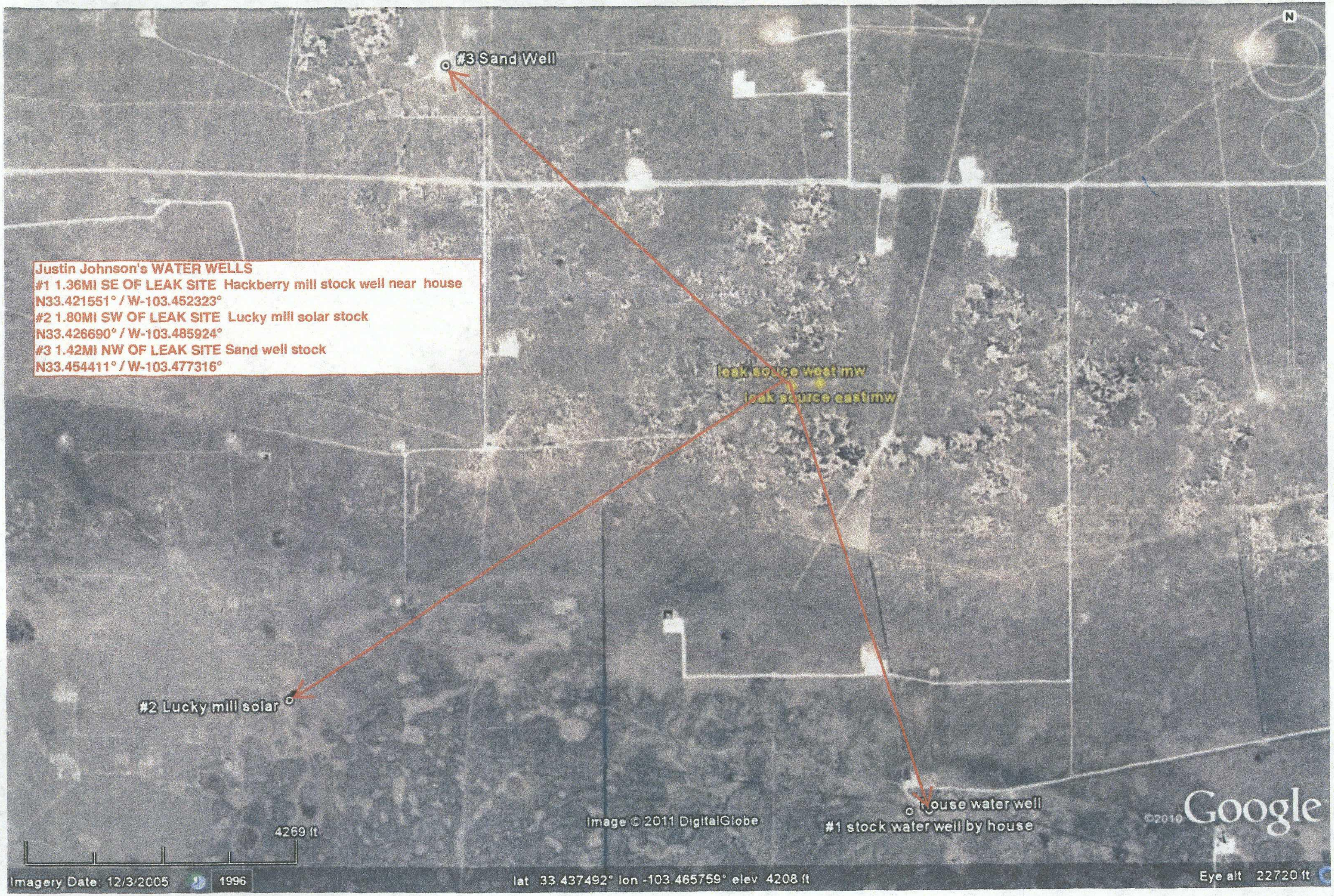
Chloride, SM4500Cl-B mg/L Analyzed By: HM

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Chloride	**66000**	4.00	12/23/2010	ND	108	108	100	0.00	

Cardinal Laboratories *=Accredited Analyte

Celey D. Keene

Celey D. Keene, Lab Director/Quality Manager



#3 Sand Well
Justin Johnson's WATER WELLS
#1 1.36MI SE OF LEAK SITE Hackberry mill stock well near house
N33.421551° / W-103.452323°
#2 1.80MI SW OF LEAK SITE Lucky mill solar stock
N33.426690° / W-103.485924°
#3 1.42MI NW OF LEAK SITE Sand well stock
N33.454411° / W-103.477316°
leak souce west mw
leak source east mw
#2 Lucky mill solar
house water well
#1 stock water well by house
Image © 2011 DigitalGlobe
©2010 Google
4269 ft
Imagery Date: 12/3/2005
1996
lat 33.437492° lon -103.465759° elev 4208 ft
Eye alt 22720 ft

FIG. 11

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April 15, 2011

ROY R. RASCON

WHOLE EARTH ENVIRONMENTAL, INC.

2103 ARBOR COVE

KATY, TX 77494

RE: NMSWD

Enclosed are the results of analyses for samples received by the laboratory on 04/05/11 8:05.

Cardinal Laboratories is accredited through Texas NELAP for:

Method SW-846 8021	Benzene, Toluene, Ethyl Benzene, and Total Xylenes
Method SW-846 8260	Benzene, Toluene, Ethyl Benzene, and Total Xylenes
Method TX 1005	Total Petroleum Hydorcarbons

Certificate number T104704398-08-TX. Accreditation applies to solid and chemical materials and non-potable water matrices.

Cardinal Laboratories is accreditated through the State of Colorado Department of Public Health and Environment for:

Method EPA 552.2	Haloacetic Acids (HAA-5)
Method EPA 524.2	Total Trihalomethanes (TTHM)
Method EPA 524.4	Regulated VOCs (V2, V3)

Accreditation applies to public drinking water matrices.

This report meets NELAP requirements and is made up of a cover page, analytical results, and a copy of the original chain-of-custody. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Celey D. Keene

Celey D. Keene

Lab Director/Quality Manager

CARDINAL Laboratories

PHONE (575) 393-2326 ° 101 E. MARLAND ° HOBBS, NM 88240

Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	04/05/2011	Sampling Date:	04/04/2011
Reported:	04/15/2011	Sampling Type:	Water
Project Name:	NMSWD	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	NMSWD - JUSTIN JOHNSON		

Sample ID: MILL #1 STOCK (H100666-01)

Bicarbonate 310.1M **mg/L** ***Analyzed By: HM***

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Alkalinity, Bicarbonate	**148**	5.00	04/08/2011	ND	964	96.4	1000	28.6	

BTEX 8260B **mg/L** ***Analyzed By: CMS***

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Benzene*	<0.001	0.001	04/05/2011	ND	0.020	99.2	0.0200	9.45	
Toluene*	<0.001	0.001	04/05/2011	ND	0.019	96.3	0.0200	8.55	
Ethylbenzene*	<0.001	0.001	04/05/2011	ND	0.020	102	0.0200	9.14	
Total Xylenes*	<0.003	0.003	04/05/2011	ND	0.056	93.9	0.0600	8.01	

Surrogate: Dibromofluoromethane	*122 %*	*80-120*
Surrogate: Toluene-d8	*87.8 %*	*80-120*
Surrogate: 4-Bromofluorobenzene	*70.4 %*	*80-120*

Calcium, 200.7 **mg/L** ***Analyzed By: JM***

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Calcium	**85.7**	0.500	04/11/2011	ND	5.09	102	5.00	1.56	GAL

Carbonate 310.1M **mg/L** ***Analyzed By: HM***

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Alkalinity, Carbonate	**8.00**	0.00	04/08/2011	ND	ND		0.00		

Chloride, SM4500Cl-B **mg/L** ***Analyzed By: HM***

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Chloride	**64.0**	4.00	04/08/2011	ND	108	108	100	0.00	

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Celey D. Keene

Celey D. Keene, Lab Director/Quality Manager

CARDINAL Laboratories

PHONE (575) 393-2326 ° 101 E. MARLAND ° HOBBS, NM 88240

Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	04/05/2011	Sampling Date:	04/04/2011
Reported:	04/15/2011	Sampling Type:	Water
Project Name:	NMSWD	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	NMSWD - JUSTIN JOHNSON		

Sample ID: MILL #1 STOCK (H100666-01)

Conductivity 120.1 — **uS/cm** — **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Conductivity	**700**	1.00	04/08/2011		1420	101	1410	0.00	

Magnesium, 200.7 — **mg/L** — **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Magnesium	**11.5**	0.500	04/11/2011	ND	25.6	102	25.0	1.55	GAL

pH Units — **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
pH	**7.93**	0.100	04/08/2011		7.04	101	7.00	0.00	

Potassium, 200.7 — **mg/L** — **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Potassium	**1.80**	0.500	04/14/2011	ND	10.6	106	10.0	2.87	GAL

Sodium, 200.7 — **mg/L** — **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Sodium	**36.5**	0.500	04/11/2011	ND	8.72	108	8.10	2.16	GAL

Sulfate 375.4 — **mg/L** — **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Sulfate	**97.0**	10.0	04/11/2011	ND	39.9	99.8	40.0	0.254	

TDS 160.1 — **mg/L** — **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
TDS	**423**	5.00	04/07/2011	ND				1.30	

Total Alkalinity 310.1M — **mg/L** — **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier

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Celey D. Keene, Lab Director/Quality Manager

CARDINAL Laboratories

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Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	04/05/2011	Sampling Date:	04/04/2011
Reported:	04/15/2011	Sampling Type:	Water
Project Name:	NMSWD	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	NMSWD - JUSTIN JOHNSON		

Sample ID: MILL #1 STOCK (H100666-01)

Total Alkalinity 310.1M **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Alkalinity, Total	**156**	4.00	04/08/2011	ND	790	96.3	820	28.6	

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Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	04/05/2011	Sampling Date:	04/04/2011
Reported:	04/15/2011	Sampling Type:	Water
Project Name:	NMSWD	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	NMSWD - JUSTIN JOHNSON		

Sample ID: MILL #2 STOCK (H100666-02)

Bicarbonate 310.1M **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Alkalinity, Bicarbonate	**190**	5.00	04/08/2011	ND	964	96.4	1000	28.6	

BTEX 8260B **mg/L** **Analyzed By: CMS**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Benzene*	<0.001	0.001	04/05/2011	ND	0.020	99.2	0.0200	9.45	
Toluene*	<0.001	0.001	04/05/2011	ND	0.019	96.3	0.0200	8.55	
Ethylbenzene*	<0.001	0.001	04/05/2011	ND	0.020	102	0.0200	9.14	
Total Xylenes*	<0.003	0.003	04/05/2011	ND	0.056	93.9	0.0600	8.01	

Surrogate: Dibromofluoromethane	*123 %*	*80-120*
Surrogate: Toluene-d8	*89.7 %*	*80-120*
Surrogate: 4-Bromofluorobenzene	*73.0 %*	*80-120*

Calcium, 200.7 **mg/L** **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Calcium	**247**	2.50	04/11/2011	ND	5.09	102	5.00	1.56	GAL

Carbonate 310.1M **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Alkalinity, Carbonate	<0.00	0.00	04/08/2011	ND	ND		0.00		

Chloride, SM4500Cl-B **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Chloride	**530**	4.00	04/08/2011	ND	*108*	*108*	*100*	*0.00*	

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Analytical Results For:

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ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	04/05/2011	Sampling Date:	04/04/2011
Reported:	04/15/2011	Sampling Type:	Water
Project Name:	NMSWD	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	NMSWD - JUSTIN JOHNSON		

Sample ID: MILL #2 STOCK (H100666-02)

Conductivity 120.1 **uS/cm** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Conductivity	**2200**	1.00	04/08/2011		1420	101	1410	0.00	

Magnesium, 200.7 **mg/L** **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Magnesium	**32.6**	2.50	04/11/2011	ND	25.6	102	25.0	1.55	GAL

pH Units **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
pH	**7.44**	0.100	04/08/2011		7.04	101	7.00	0.00	

Potassium, 200.7 **mg/L** **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Potassium	**3.70**	2.50	04/14/2011	ND	10.6	106	10.0	2.87	GAL

Sodium, 200.7 **mg/L** **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Sodium	**122**	2.50	04/11/2011	ND	8.72	108	8.10	2.16	GAL

Sulfate 375.4 **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Sulfate	**185**	10.0	04/11/2011	ND	39.9	99.8	40.0	0.254	

TDS 160.1 **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
TDS	**1320**	5.00	04/07/2011	ND				1.30	

Total Alkalinity 310.1M **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier

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Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	04/05/2011	Sampling Date:	04/04/2011
Reported:	04/15/2011	Sampling Type:	Water
Project Name:	NMSWD	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	NMSWD - JUSTIN JOHNSON		

Sample ID: MILL #2 STOCK (H100666-02)

Total Alkalinity 310.1M **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Alkalinity, Total	**156**	4.00	04/08/2011	ND	790	96.3	820	28.6	

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Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	04/05/2011	Sampling Date:	04/04/2011
Reported:	04/15/2011	Sampling Type:	Water
Project Name:	NMSWD	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	NMSWD - JUSTIN JOHNSON		

Sample ID: MILL #3 STOCK (H100666-03)

Bicarbonate 310.1M mg/L **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Alkalinity, Bicarbonate	**185**	5.00	04/08/2011	ND	964	96.4	1000	28.6	

BTEX 8260B mg/L **Analyzed By: CMS**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Benzene*	<0.001	0.001	04/05/2011	ND	0.020	99.2	0.0200	9.45	
Toluene*	<0.001	0.001	04/05/2011	ND	0.019	96.3	0.0200	8.55	
Ethylbenzene*	<0.001	0.001	04/05/2011	ND	0.020	102	0.0200	9.14	
Total Xylenes*	<0.003	0.003	04/05/2011	ND	0.056	93.9	0.0600	8.01	

Surrogate: Dibromofluoromethane	*127 %*	*80-120*
Surrogate: Toluene-d8	*87.3 %*	*80-120*
Surrogate: 4-Bromofluorobenzene	*70.4 %*	*80-120*

Calcium, 200.7 mg/L **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Calcium	**333**	2.50	04/11/2011	ND	5.09	102	5.00	1.56	GAL

Carbonate 310.1M mg/L **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Alkalinity, Carbonate	<0.00	0.00	04/08/2011	ND	ND		0.00		

Chloride, SM4500Cl-B mg/L **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Chloride	**400**	4.00	04/08/2011	ND	108	108	100	0.00	

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Analytical Results For:

WHOLE EARTH ENVIRONMENTAL, INC.
ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	04/05/2011	Sampling Date:	04/04/2011
Reported:	04/15/2011	Sampling Type:	Water
Project Name:	NMSWD	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	NMSWD - JUSTIN JOHNSON		

Sample ID: MILL #3 STOCK (H100666-03)

Conductivity 120.1 **uS/cm** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Conductivity	**2530**	1.00	04/08/2011		1420	101	1410	0.00	

Magnesium, 200.7 **mg/L** **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Magnesium	**43.9**	2.50	04/11/2011	ND	25.6	102	25.0	1.55	GAL

pH Units **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
pH	**7.68**	0.100	04/08/2011		7.04	101	7.00	0.00	

Potassium, 200.7 **mg/L** **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Potassium	<2.50	2.50	04/14/2011	ND	10.6	106	10.0	2.87	GAL

Sodium, 200.7 **mg/L** **Analyzed By: JM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Sodium	**145**	2.50	04/11/2011	ND	8.72	108	8.10	2.16	GAL

Sulfate 375.4 **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Sulfate	**615**	10.0	04/11/2011	ND	39.9	99.8	40.0	0.254	

TDS 160.1 **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
TDS	**1820**	5.00	04/07/2011	ND				1.30	

Total Alkalinity 310.1M **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier

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Celey D. Keene, Lab Director/Quality Manager

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Analytical Results For:

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ROY R. RASCON
2103 ARBOR COVE
KATY TX, 77494
Fax To: (281) 394-2051

Received:	04/05/2011	Sampling Date:	04/04/2011
Reported:	04/15/2011	Sampling Type:	Water
Project Name:	NMSWD	Sampling Condition:	Cool & Intact
Project Number:	NONE GIVEN	Sample Received By:	Jodi Henson
Project Location:	NMSWD - JUSTIN JOHNSON		

Sample ID: MILL #3 STOCK (H100666-03)

Total Alkalinity 310.1M **mg/L** **Analyzed By: HM**

Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier
Alkalinity, Total	**152**	4.00	04/08/2011	ND	790	96.3	820	28.6	

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Celey D. Keene, Lab Director/Quality Manager

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Notes and Definitions

GAL	Analysis subcontracted to Green Analytical Laboratories, a subsidiary of Cardinal Laboratories.
ND	Analyte NOT DETECTED at or above the reporting limit
RPD	Relative Percent Difference
**	Samples not received at proper temperature of 6°C or below.
***	Insufficient time to reach temperature.
-	Chloride by SM4500Cl-B does not require samples be received at or below 6°C
	Samples reported on an as received basis (wet) unless otherwise noted on report

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Celey D. Keene

Celey D. Keene, Lab Director/Quality Manager

CARDINAL Laboratories

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

101 East Marland, Hobbs, NM 88240
(575) 393-2326 FAX (575) 393-2476

Company Name: WEE Inc
Project Manager: Roy R. Rascon
Address:
City: State: Zip:
Phone #: Fax #:
Project #: Project Owner:
Project Name: NMSWD
Project Location: Justin Johnson
Sampler Name: Roy R. Rascon

BILL TO
P.O. #:
Company:
Attn:
Address:
City:
State: Zip:
Phone #:
Fax #:

Lab I.D. (FOR LAB USE ONLY)	Sample I.D.	(G)RAB OR (C)OMP.	# CONTAINERS	MATRIX: GROUNDWATER	WASTEWATER	SOIL	OIL	SLUDGE	OTHER:	PRESERV: ACID/BASE:	ICE / COOL	OTHER:	SAMPLING: DATE	TIME	ANALYSIS REQUEST: BTEX	CATS & ANS
H100666-1 A-C	A-C #1 Mill Stock	G	3	X						X	X		4-4-11	220	X	X
2	#2 mill Stock	G	3	X						X	X		4-4-11	315	↓	↓
3	#3 mill Stock	G	3	X						X	X		4-4-11	339	↓	↓

PLEASE NOTE: Liability and Damages. Cardinal's liability and client's exclusive remedy for any claim arising whether based in contract or tort, shall be limited to the amount paid by the client for the analyses. All claims including those for negligence and any other cause whatsoever shall be deemed waived unless made in writing and received by Cardinal within 30 days after completion of the applicable service. In no event shall Cardinal be liable for incidental or consequential damages, including without limitation, business interruptions, loss of use, or loss of profits incurred by client, its subsidiaries, affiliates or successors arising out of or related to the performance of services hereunder by Cardinal, regardless of whether such claim is based upon any of the above stated reasons or otherwise.

Relinquished By: Roy R. Rascon Date: 4-5-11 Time: 9:05 Received By: Jodi Henson

Relinquished By: Date: Time: Received By:

Delivered By: (Circle One)
(Sampler) - UPS - Bus - Other: 0.0°C

Sample Condition
Cool: ☑ Yes ☐ No
Intact: ☑ Yes ☐ No

CHECKED BY: (Initials) JH

Phone Result: ☐ Yes ☐ No Add'l Phone #:
Fax Result: ☐ Yes ☐ No Add'l Fax #:
REMARKS: PLEASE Email to All

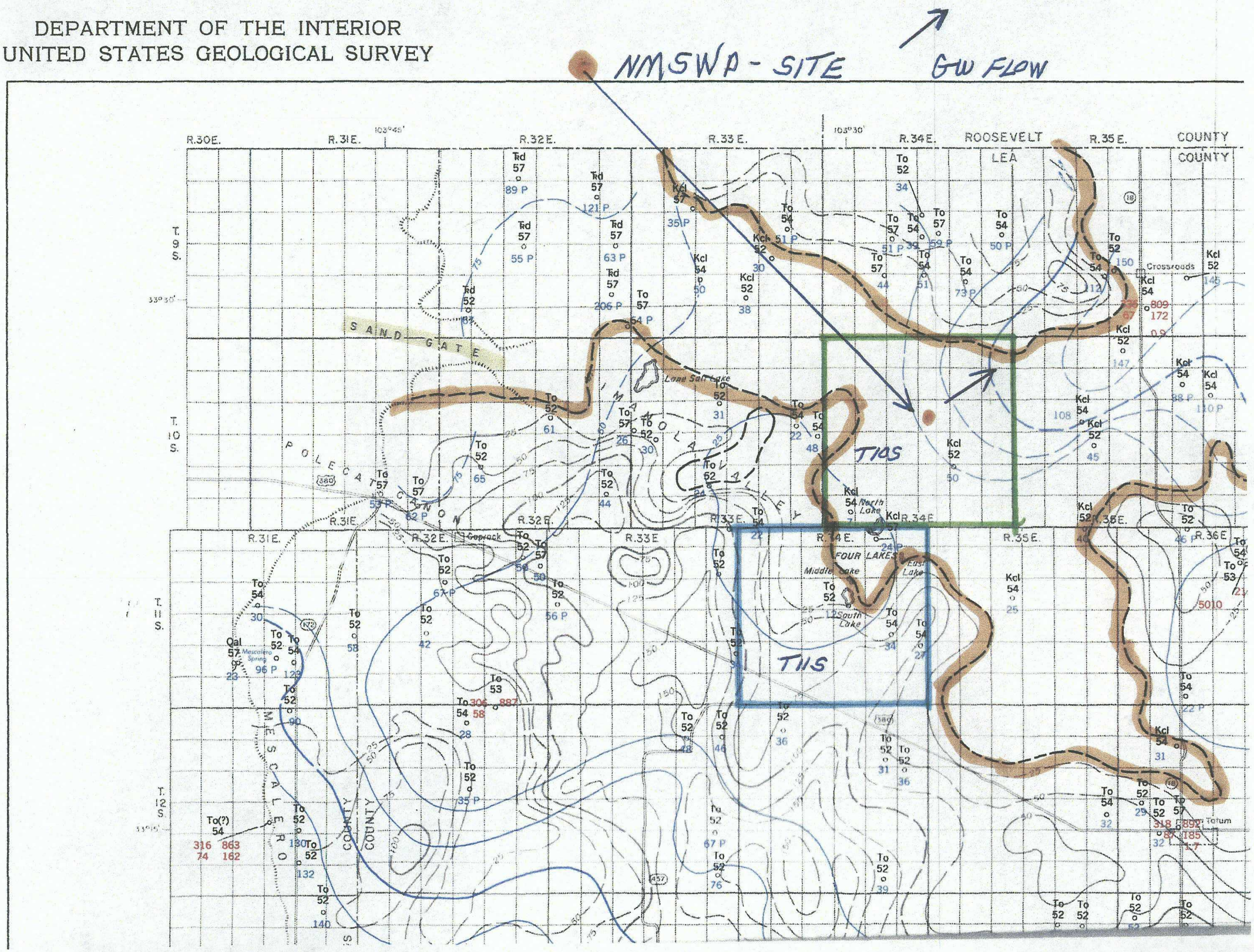
† Cardinal cannot accept verbal changes. Please fax written changes to 505-393-2476

#26

Appendix F Water Well Records and Map

Map
Ts 10s-34e
Ts 11s-34e

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



New Mexico Office of the State Engineer
Water Column/Average Depth to Water

No records found.

Basin/County Search:

Basin: Lea County

PLSS Search:

Township: 10S **Range:** 34E

Average Depth to Water: **48 feet**

Minimum Depth: **25 feet**

Maximum Depth: **85 feet**

Record Count: 23

Basin/County Search:

Basin: Lea County

PLSS Search:

Township: 11S   Range: 34E

New Mexico Office of the State Engineer
Water Column/Average Depth to Water

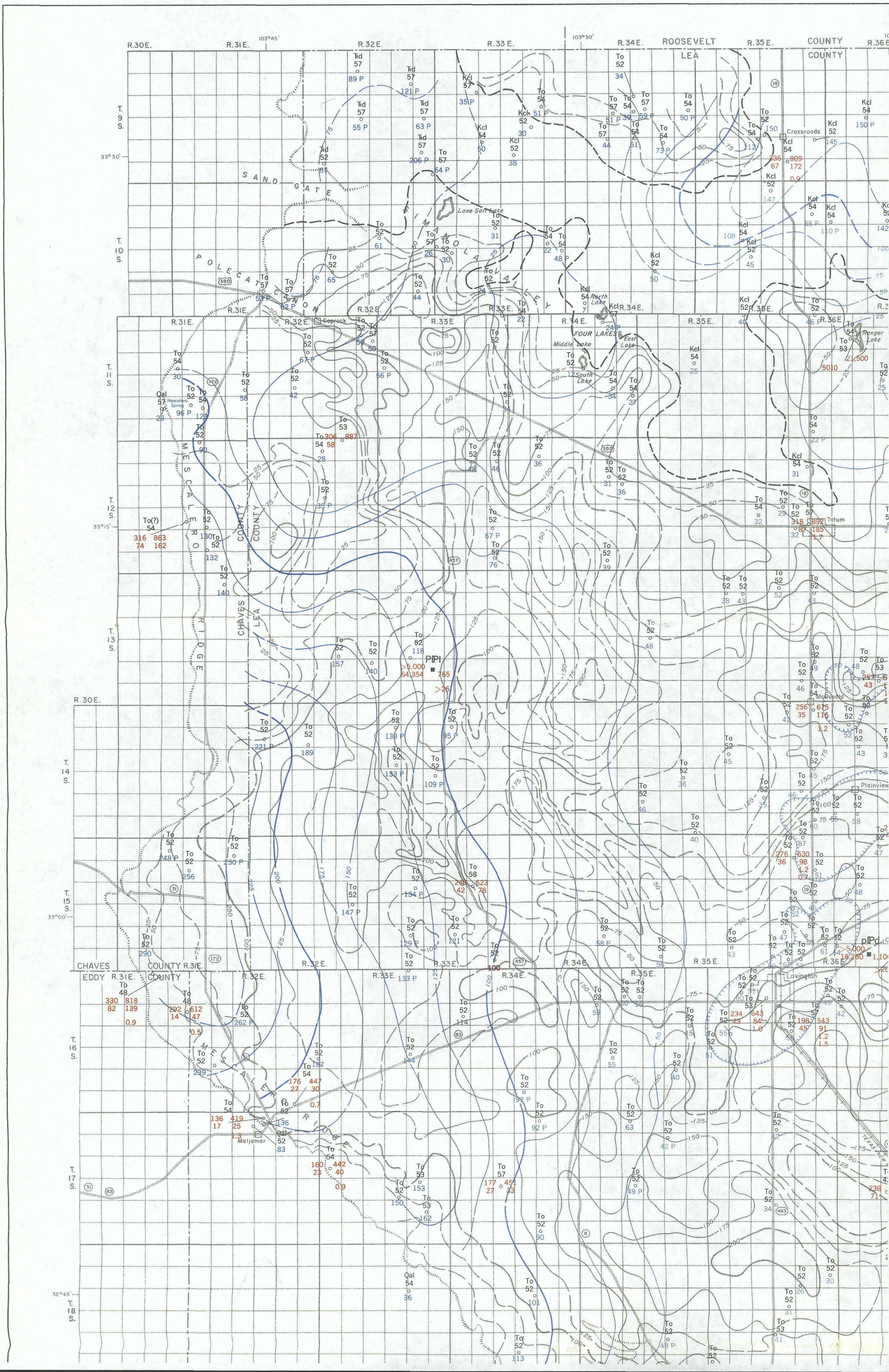
(quarters are 1=NW 2=NE 3=SW 4=SE)

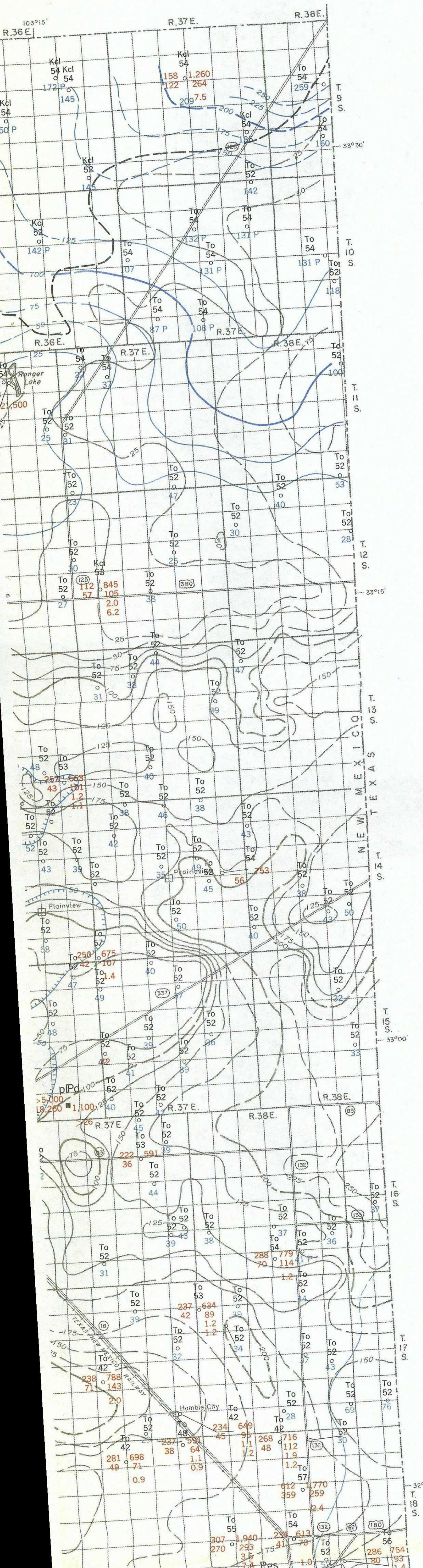
(quarters are smallest to largest) (NAD83 UTM in meters) (In feet)

POD Number	Sub basin	Use	County	Q 64	Q 16	Q 4	Sec	Tws	Rng	X	Y	Depth Well	Depth Water	Water Column
L 00371		PRO	LE	1	3	2	23	11S	34E	641408	3691556*	76		
L 00394		PRO	LE	1	1	2	25	11S	34E	643035	3690371*	100		
L 03137		PRO	LE		3	3	16	11S	34E	637470	3692208*	85	45	40
L 03137 APPRO		PRO	LE		3	3	16	11S	34E	637470	3692208*	85	45	40
L 05023		PRO	LE		2	2	07	11S	34E	635415	3695003*	140	85	55
L 05024		PRO	LE		4	3	28	11S	34E	637918	3688997*	90	30	60
L 05345		PRO	LE		1	1	32	11S	34E	635912	3688568*	70	40	30
L 06122		PRO	LE		3	1	17	11S	34E	635844	3692990*	73	43	30
L 06133		PRO	LE		1	1	19	11S	34E	634300	3691762*	90	45	45
L 06239		PRO	LE		2	2	35	11S	34E	641951	3688646*	72	25	47
L 06372 (E)		PRO	LE		3	1	16	11S	34E	637458	3693013*	124	80	44
L 06394 (E)		PRO	LE		1	1	03	11S	34E			110	80	30
L 06445 (E)		PRO	LE		3	2	18	11S	34E	635041	3692978*	95	60	35
L 06458 (E)		PRO	LE		1	2	08	11S	34E	636622	3695021*	90	32	58
L 06784		STK	LE				21	11S	34E	638097	3691202*	61	25	36
L 10196		STK	LE		4	1	29	11S	34E	636297	3689779*	60		
L 10197		STK	LE		1	4	26	11S	34E	641538	3689447*	50		
L 10198		STK	LE		1	2	05	11S	34E			60		
L 10199		STK	LE		2	2	21	11S	34E	638684	3691821*	51		
L 10200		STK	LE		3	3	17	11S	34E	635858	3692185*	60		
L 10201		STK	LE		2	3	07	11S	34E	634623	3694178*	80		
L 10202		STK	LE		4	4	28	11S	34E	638723	3689008*	70		
L 11021		PRO	LE	1	3	3	24	11S	34E	642224	3690762*	100		

***UTM location was derived from PLSS - see Help**

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY





EXPLANATION

AQUIFERS

Era	System	Series	Symbol	Description
CENOZOIC	QUATERNARY	Recent	Qal	**Alluvium** — *Sand and gravel; may include some redeposited material from Ogallala formation and the underlying Cretaceous and Triassic rocks*
CENOZOIC	TERTIARY	Pliocene	To	**Ogallala formation** — *Irregularly-bedded sand, grit, and local gravel conglomerate cemented by lime or caliche, and local beds of sand, clay, and limestone; may include some redeposited material from the underlying Cretaceous and Triassic rocks*
MESOZOIC	CRETACEOUS	Lower Cretaceous(?)	Kcl	**Clay and limestone** — *Yellow and blue clay with thin stringers of brown, and gray, limestone; probably equivalent to the Tucumcari shale*
MESOZOIC	TRIASSIC	Upper Triassic	₸d	**Dockum group, undivided** — *Maroon, red, and gray irregularly-bedded sandstone, bright- and dark-red shale and sandy shale, and purplish limestone pebble beds*
PRE-MESOZOIC	PERMIAN		Pgs	**Grayburg formation and San Andres limestone, undivided** — *Sandy dolomite with interbedded dolomitic sand; porous white limestone; known only from logs of oil wells*
PRE-MESOZOIC	PENNSYLVANIAN AND PERMIAN (CARBONIFEROUS)		PℙI	**Limestone** — *White to light gray crystalline limestone with vuggy porosity and occasional green shale partings; known only from logs of oil wells*
PRE-MESOZOIC	PRE-PENNSYLVANIAN		pℙd	**Dolomite** — *Sandy porous dolomite and vuggy crystalline dolomite; known only from logs of oil wells*

○ Water well

■ Oil and gas well location near center of field

Spring

Aquifer — To
57 — *Year sampled*

Hardness as $CaCO_3$ (ppm) — 198
543 — *Specific conductance (micromhos at 25°C)*

Chloride (ppm) — 45
91 — *Sulfate (ppm)*
1.2 — *Fluoride (ppm)*
1.5 — *Sodium-adsorption ratio*

150

Depth to water, in feet, below land surface datum. Static-level measurement unless the figure is followed by the capital letter "P" which indicates that the measurement was made while the well was being pumped.

Data are grouped around the source-of-water symbol. Undetermined information is noted by the absence from the designed position in the group of data.

——— 25 - - - -

Line connecting points of approximately equal depth to water below land-surface datum as of 1952
Dashed where inferred; interval 25 feet

——— 150 - - -

Line connecting points of approximately equal saturated thickness of the deposits of Cenozoic age as of 1952
Dashed where inferred; interval 25 feet

- - - - - - - - - -

Approximate boundary of bedrock highs that interrupt the water table in the deposits of Cenozoic age

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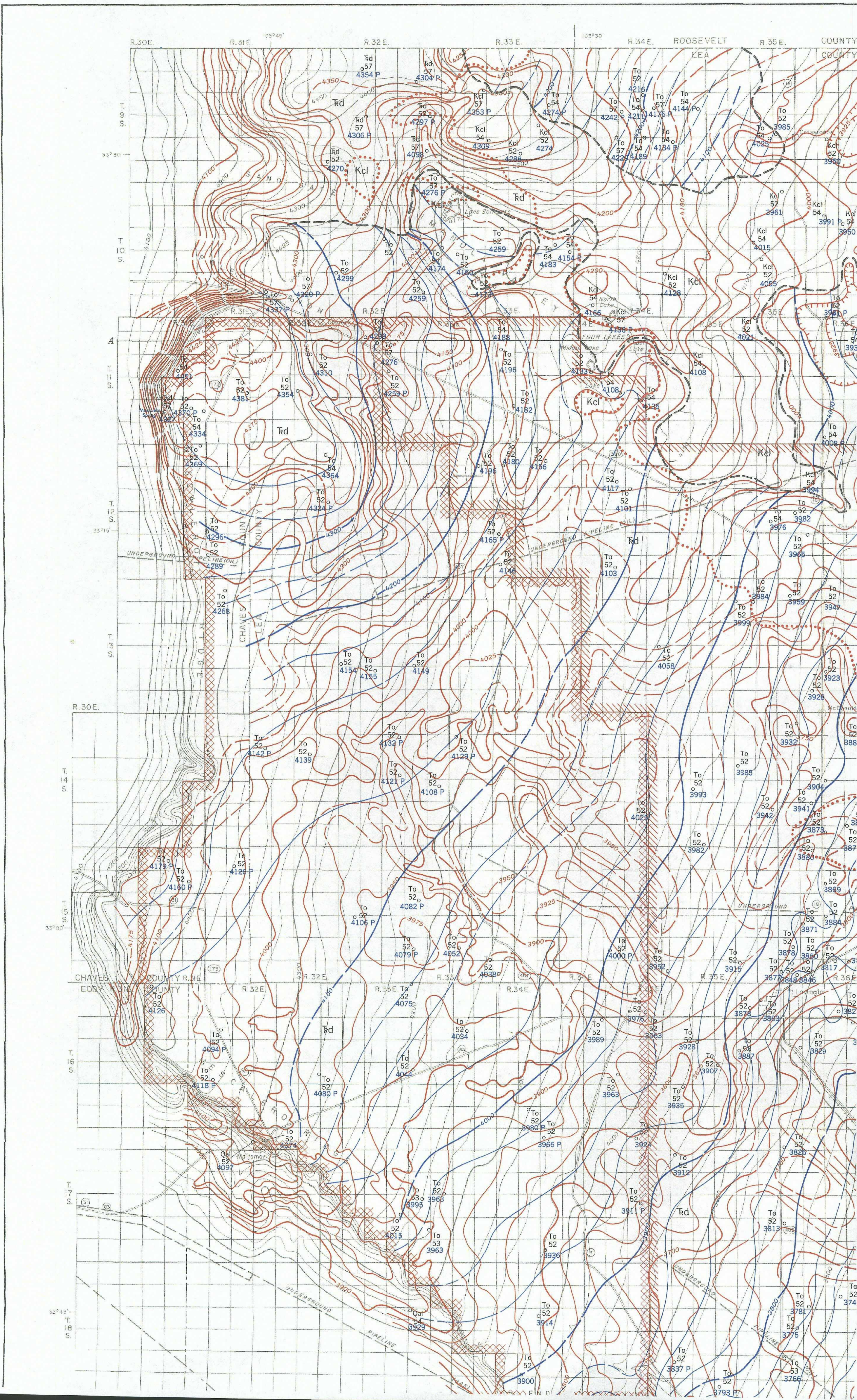

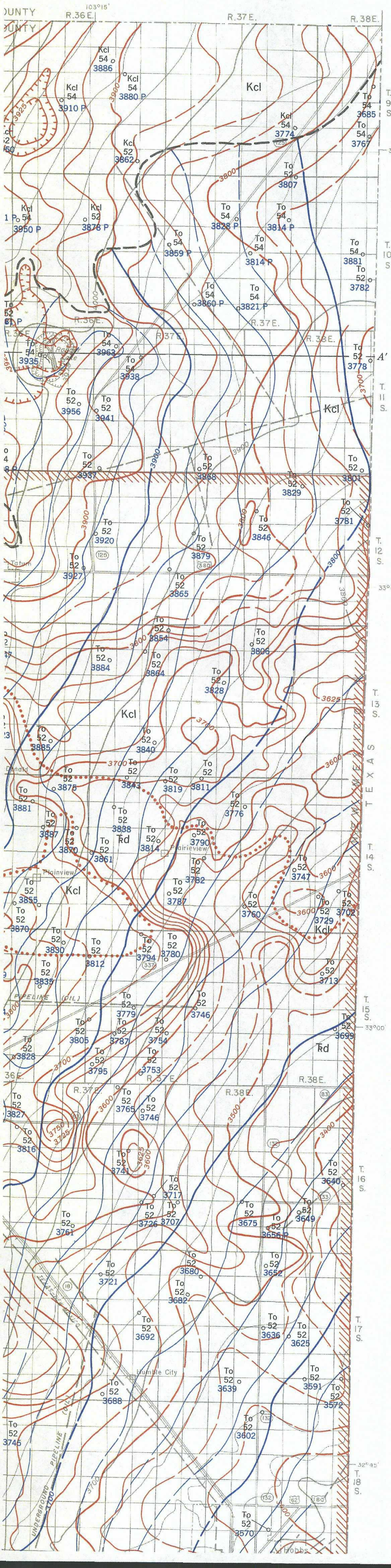

EXPLANATION

AQUIFERS

CENOZOIC

QUATERNARY

Recent

Qal

Alluvium

Sand and gravel; may include some redeposited material from Ogallala formation and the underlying Cretaceous and Triassic rocks

TERTIARY

Pliocene

To

Ogallala formation

Irregularly-bedded sand, grit, and local gravel conglomerate cemented by lime or caliche, and local beds of sand, clay, and limestone; may include some redeposited material from the underlying Cretaceous and Triassic rocks

MESOZOIC

CRETACEOUS

Lower Cretaceous (?)

Kcl

Clay and limestone

Yellow and blue clay with thin stringers of brown, and gray, limestone; probably equivalent to the Tucumcari shale

TRIASSIC

Upper Triassic

T̶d

Dockum group, undivided

Maroon, red, and gray irregularly-bedded sandstone, bright- and dark-red shale and sandy shale, and purplish limestone pebble beds

GEOLOGIC UNITS DIRECTLY BELOW THE ROCKS OF CENOZOIC AGE

MESOZOIC

CRETACEOUS

Lower Cretaceous (?)

Kcl

Clay and limestone

Yellow and blue clay with thin stringers of brown and gray, limestone; probably equivalent to the Tucumcari shale

TRIASSIC

Upper Triassic

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Dockum group, undivided

Maroon, red, and gray irregularly-bedded sandstone, bright- and dark-red shale and sandy shale, and purplish limestone pebble bed

Spring

Water well

Aquifer — To
Year sampled — 52
3494

Altitude of water level, in feet above mean sea level. Static-level measurement unless the figure is followed by the capital letter "P" which indicates that the measurement was made while the well was being pumped.

Data are grouped around the source-of-water symbol. Undetermined information is noted by the absence from the designated position in the group of data.

4025

Contour drawn on the water table in the deposits of Cenozoic age as of November-December, 1952

Dashed where approximately located; contour interval 25 feet; datum is mean sea level

Approximate boundary of bedrock highs that interrupt the water table in the deposits of Cenozoic age

4150

Contour drawn on the post-Mesozoic erosional surface

Dashed where approximately located; contour interval 25 feet; datum is mean sea level

Buried contact

Area included in declared Underground Water Basin, prior to Oct. 1, 1952

Area added to declared Basin on Oct. 1, 1952