1R - 415

REPORTS

DATE:

2005

August 2005

Amended Corrective Action Plan

Lovington Abo 1G Release Site

IR-415

R.T. HICKS CONSULTANTS, LTD.

901 RIO GRANDE BLVD. NW, SUITE F-142, ALBUQUERQUE, NM 87104

R. T. HICKS CONSULTANTS, LTD.
901 Rio Grande Blvd NW ▲ Suite F-142 ▲ Albuquerque, NM 87104 ▲ 505.266.5004 ▲ Fax: 505.266-0745

August 31, 2005

Wayne Price
NMOCD Environmental Bureau
1220 South St. Francis Drive
Santa Fe, New Mexico 87505
Via E-mail and Federal Express

RE: Amended Corrective Action Plan
Abo 1G Pipeline Release NMOCD Case #1R0415
Section 1, 17S, 36E, Unit G

Dear Wayne:

On behalf of Rice Operating Company, R.T. Hicks Consultants, Ltd. is pleased to submit the attached Amended Corrective Action Plan for the above-referenced site.

If you have any questions or concerns about the enclosed report, please let us know. Thank you for your time.

Sincerely,
R.T. Hicks Consultants, Ltd.

Katie Lee

Katie Lee
Staff Scientist

Copy: Rice Operating Company

R. T. HICKS CONSULTANTS, LTD.
901 Rio Grande Blvd NW ▲ Suite F-142 ▲ Albuquerque, NM 87104 ▲ 505.266.5004 ▲ Fax: 505.266-0745

Instructions for Accessing the HYDRUS-1D files on the enclosed CD

The HYDRUS 1-D problems must be copied onto your computer before they can be run with HYDRUS 1-D.

HYDRUS 1-D can be downloaded for free at:
http://www.pc-progress.cz/Pg_Hydrus_Downloads.htm

If you have questions or comments, please call our office, 505-266-5004.

August 31, 2005

Amended Corrective Action Plan

LOVINGTON ABO
1G RELEASE SITE

Prepared for:

Rice Operating Company
122 West Taylor
Hobbs, NM 88240

R.T. HICKS CONSULTANTS, LTD.
901 RIO GRANDE BLVD. NW, SUITE F-142, ALBUQUERQUE, NM 87104

1.0 SUMMARY

1. ROC mobilized to the Abo 1-G release site on November 10, 2003 and drilled three borings. The ROC field procedures were consistent with industry practice and with previously-submitted ROC characterization plans (e.g. junction box plan). Approximately 40 samples were collected.

2. In November 2005, Hicks Consultants completed a sampling boring and monitor well adjacent to SB-1 in accordance with an NMOCD-approved workplan. Approximately 15 samples were collected from the boring.

3. In July 2005, ROC implemented a deep soil sampling (about 130 samples) and surface soil sampling program (about 70 samples) to provide better characterization of the 1992 release and the 2003 release.

4. Chloride concentration data show a center of mass at depths of 3 to 6-feet below grade and a second mass at depths of 12- to 20-feet below grade. While the chloride from both spills is generally present at points near the source of the releases; at greater distances or release margins, the effects of only one of the releases may be present.

5. Samples from the bore holes, the deep soil sampling and the surface sampling yielded peak chloride concentrations of approximately 8,500 ppm, 1,500 ppm, and 1,400 ppm at respective depths of 0 feet, 4- to 6-feet below grade and 14- to 16-feet below grade. Area weighted average chloride concentrations were approximately 2,400 ppm, 850 ppm, and 475 ppm at these same respective depths.

6. Laboratory analyses confirm that regulated petroleum hydrocarbons are not present above screening levels employed by the PST Bureau of the New Mexico Environment Department.

7. Five potential remedies were evaluated using HYDRUS-1D and a simple mixing model to predict ground water chloride concentrations in an imaginary monitoring well with a 10-foot screened interval that is located at the edge of the release. Simulation experiments predict that only the simple vegetative cap remedy will cause ground water to exceed the 250 ppm chloride standard in the imaginary monitoring well.

8. A simple vegetative cap is sufficient to prevent impairment of ground water that would be produced from a windmill with a 40-foot screened interval located at the edge of the spill.

9. Ease of construction, long-term viability and other environmental considerations cause us to recommend the following remedy:
   a. Excavate and stockpile the areas of high-chloride surface soil that do not currently support vegetation.
   b. Excavate, characterize and segregate by chloride concentration the uppermost 2-feet of the vadose zone that overlies about 35% of the subsurface chloride load. This translates to removal of material where the average chloride concentration over the thickness of the impact is greater than about 1000 mg/kg.
   c. Blend clean soil (imported or excavated from the site) with higher chloride stockpiles to create a mixture that will support vegetation (i.e. about 1000 ppm chloride).
   d. Place a 1-foot thick clay barrier in the excavation in 6-inch lifts such that the saturated hydraulic conductivity of this clay barrier is less than 5×10^{-6} cm/sec.
   e. Place at least 2-feet of the blended stockpiled soil and any imported soil over the clay barrier and over the remaining unexcavated portion of the spill to create a small swale that will shed excess precipitation.
   f. Seed the site with native plants and fence the area to enhance re-vegetation

The selected remedy protects fresh water, human health and the environment. It complies with NMOCD rules and we believe it provides the greatest net environmental benefit.

2.0 BACKGROUND

The Abo 1G Discharge Site is located about 6 miles southeast of the center of Lovington, New Mexico. Plate 1 is a 1:24,000 topographic map showing the location of the site relative to Route 18, the Hobbs-Lovington Highway. Plate 2 is a 1:6,000 image (2004) of the site location and nearby features such as the Navajo Lovington Refinery and the Lovington-Hobbs highway.

Figure 1. View of Abo 1G Leak site

In 2003, a line near the pick-up truck in Figure 1 ruptured and produced water flowed south. This 2003 release was the impetus for the investigations described herein. This final corrective action plan summarizes all of the data available for the site and recommends a remedy to protect fresh water, public health and the environment.

On October 18, 2003, Rice Operating Company (ROC) prepared a Release Notification report that estimated a pipeline failure released 190 barrels of produced water and ROC recovered 130 barrels. The pipeline failure released produced water with little or no hydrocarbons. Plate 3a is the same image as Plate 2 at a 1:600 scale. This image shows the geometry of the 2003 release, which affected about 31,000 square feet of rangeland. ROC is also aware that a 10 barrel release near this same location occurred on June 3, 2003 and this earlier release impacted a 2,400 square foot area near SB-1. In August 2005, ROC conducted an internal records search and discovered a release report dated October 21, 1992. This report documents a release of produced water that covered about 17,000 square feet at this same location. Plate 3b is an aerial photograph taken between 1996-1999 at the same scale as Plate 3a showing our interpretation of the extent of the 1992 release. Plate 3a & 3b demonstrates that both spills occurred at essentially the same location. The 1992 report suggests that the release was principally water with little or no hydrocarbons and ROC recovered about 500 barrels of the release. This search of older records became feasible in mid 2005 due to the efforts of ROC to categorize and organize their older files in various storerooms.

ROC mobilized to the site on November 10, 2003 and drilled three borings. The field procedures employed by ROC were consistent with industry practice and with previously-submitted ROC characterization plans (e.g. junction box plan). In November 2004, Hicks Consultants completed a sampling boring and monitor well adjacent to SB-1 in accordance with an NMOCD-approved workplan. In July 2005, ROC implemented a deep soil sampling and surface soil sampling program to provide better characterization of the 1992 release and the 2003 release. Plate 4 is a sketch map that shows the outline of the 1992 and 2003 spills (based upon the imagery), 2003 borings, the 2004 monitor well and the 2005 trench samples. In 2005, ROC also collected surface soil samples on a 25-foot grid, which are not displayed on Plate 4.

Hicks Consultants used the data collected by ROC, the data from our 2004 field program and obtained additional data from public sources as input to the HYDRUS-1D vadose zone fate and transport model. Hicks Consultants employed the results of the modeling to develop a remedy to protect ground water quality and to restore the ground surface.

3.0 RESULTS OF FIELD PROGRAMS & INVESTIGATIONS

Next to the pipeline rupture, ROC drilled SB - 01 in 2003 to a depth of 45-feet. From field inspection, the site has several inches of sandy soil covering a highly-fractured caliche horizon. We examined borehole samples and the on-site cuttings log from SB-01 and concluded that the subsurface is composed of 24-feet of thin caliche layers within sands and silts. Interbedded with these caliche-rich sands and silts are silty clays. Below this uppermost 24-feet is 20-feet of sand and silt.

The lithologic log of MW-1 confirms the observations of 2003 for SB-1. Lithologic logs for both borings are included in Plates 5 & 6. Plate 5 also displays the calculated chloride load for the boring. The lithology of MW-1 is primarily a very fine-grained sand silt interbedded with a complex series of caliche beds. Layers featuring some caliche exist from 0.5- to 10-feet bgs, 33- to 44-feet bgs, and 53- to 60-feet bgs. In addition to these zones, three well indurated layers of caliche exist at 0.5- to 3-feet bgs, 15- to 17-feet bgs, 20- to 22-feet bgs, and 35- to 36-feet bgs. There also exists a well indurated layer of sandstone at 67- to 68-feet bgs.

We have no site specific or regional data on the moisture content of the vadose zone. Such data are generally rare. As described in a later section of this report, we used HYDRUS-1D to simulate an initial water content of the unsaturated zone.

We conclude that the vadose zone is about 90-feet thick and is composed of a caliche-rich upper horizon underlain by sand with minor amounts of silt.

Characteristics of Saturated Zone

In well L-1716 , about 1 mile west of the release site, the driller's log reports "water sand" from 45-feet to 70-feet underlain by 7-feet of "calcium sand" before penetrating water bearing units. At well L-5014, approximately 5 miles north of the site, the driller log identifies caliche from 2- to 28-feet below surface. Below this upper strata is sand and sandy clay to a depth of 190-feet. From 190- to 205-feet below surface, the driller reports a clay zone. This 15-feet of clay is underlain by 10-feet of clay and gravel. The driller penetrated the Dockum Group red beds at 215-feet below grade. For monitoring wells in the Lea Refinery, one mile to the northeast, driller's logs report a 4-foot caliche bed overlying more than 100-feet of very fine to fine grained sands. At the Lea Refinery, April 1996 water levels are 90-feet below grade (H+GCL, 1996). These well logs are included in Appendix A.

The saturated Ogallala Aquifer, which underlies the location, is dominantly sand. The saturated thickness of the aquifer is about 130-feet. The screened interval of wells in the area range from 20-feet to more than 100-feet. According to the USGS (http://water.usgs.gov/GIS/metadata/usgswrd/ofr98-548.html#Identification_Information), the hydraulic conductivity of the High Plains Aquifer ranges from less than 25-feet/day to greater than 300-feet per day with an average hydraulic conductivity of 60-feet/day. At this location, where saturated gravel units are restricted to the base of the Ogallala, we estimate the hydraulic conductivity is about 50-feet per day. Geologists who drilled monitoring wells at the Lea Refinery estimated the saturated hydraulic conductivity as ranging from 25- to 75-feet per day. At the Lea Refinery, the hydraulic gradient is 0.004 feet/foot to the southeast. The resultant ground water flux is probably about 10 cm per day.

Basin Environmental obtained samples from LA MW-1 on December 3, 2004, March 1, 2005 and June 16, 2005. The results of these samples are presented in Appendix B. The results show no evidence of ground water impact. Please note that the results of all analysis are in general agreement. The TDS result from the March 1, 2005 sampling was analyzed outside of the "hold time", but reproducibility of the results shows that all samples are representative of ground water quality.

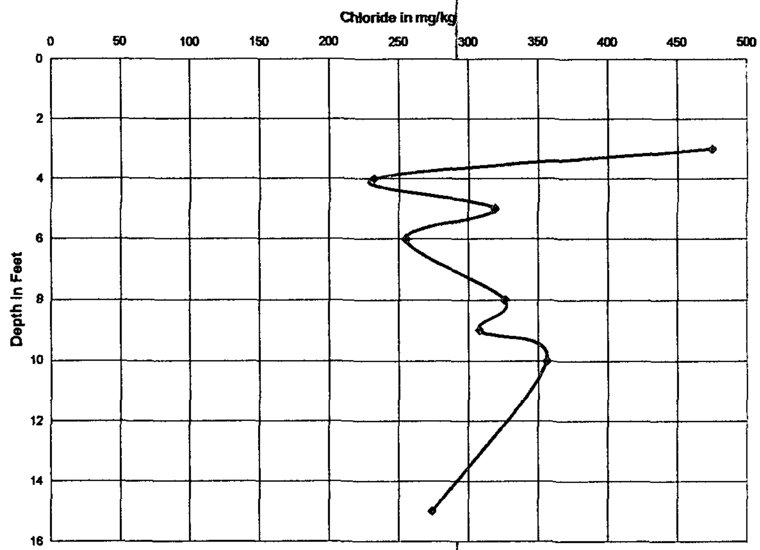


Figure 2. SB-2 Field Chloride concentrations

Chloride Distribution in the Vadose Zone

Appendix C presents the analyses of field samples from the vadose zone during the 2005 field events. Earlier submissions present the analytical data for soils from previous sampling campaigns.

Soil boring SB-2 is uphill from the spill site and we considered this a "background" location, however the term "ambient" is more accurate. At this soil boring, the chloride near the ground surface is 475 ppm. From 4-feet below grade to the total depth of 15-feet, chloride in this caliche-rich horizon ranges between 230 and 356 ppm (Figure 2). Other scientists suggest that "background" chloride concentration in Lea County soil can be less than 100 ppm. At this site, caliche dominates the upper vadose zone and oil and gas activities may have released small amounts of chloride to the environment for decades in the form of small spills that are subsequently re-distributed by wind. At this release site, the ambient chloride concentration in the upper vadose zone is about 300 ppm. In the deep vadose zone, below about 45-feet, chloride concentrations are less than 100 ppm (See Plates 5 and 6). We believe these low chloride concentrations below 45-feet are due to the sand lithology combined with our hypothesis that anthropogenic chloride originating from decades of oil and gas production has penetrated only 41-feet of the vadose zone.

Plate 7 compares the chloride concentration versus depth for SB-1 and SB-3 (November 2003) with MW-1 (November 2004). These three borings, which provide the deepest vertical characterization for the site, show two distinct chloride masses - one from 3- to 6-feet below land surface and a second mass at 12- to 20-feet below land surface. These soil borings show a decline in chloride concentrations to ambient levels (i.e. 300 ppm) at 45-feet, 9-feet and about 40-feet below land surface respectively. Because the water table lies about 90-feet below land surface, this observed decrease of chloride concentrations to background suggests that the release did not create saturated conditions between ground surface and ground water.

As stated in earlier submissions to NMOCD, the patterns for SB-1 and MW-1 shown in Plate 7, which are closest to the pipeline rupture, confirm that the October 2003 release was not the first release at or near this site. An earlier release appears as chloride concentrations above 1,000 ppm between 12- and 20-feet below grade and the October release appears as the high chloride between 3- and 6-feet depth. We stated in our earlier reports that we did not believe that the chloride concentrations between 12- and 20-feet in SB-1 and MW-1 were caused by the 10-barrel release of June 2003. As suggested earlier in this report, the recent examination of ROC files identified the source of this deeper center of mass as a 1992 release.

Plate 8 shows the results of the deep soil sampling at the 12 sampling trenches, 3 soil borings and the monitor well. In general, chloride concentration profiles of points closest to the junction box (Points A, C, E, G and SB-1 and LA MW-1) demonstrate both the shallow and the deeper chloride masses. Points further away may demonstrate only the most recent spills (Points H, I, J and SB-3). Other points (B and K) have a chloride profile showing relatively low concentrations near the surface and higher concentrations at intermediate depths (8- to 14-feet bgs). The site has little relief and is located in an active oil field with considerable human activity. We believe that over the course of the last 15 years, small topographic changes due to rainfall events, human activities, and the variation in source location and flows of the different releases explains the variation in chloride distribution at the site.

4.0 SIMULATION MODELING EXPERIMENTS

4.1 HYDRUS-1D CALIBRATION INPUT DATA

Because the chloride center of mass at SB-1/LA MW-1 (from the 1992 release) resides at a depth of about 15-feet below land surface, chloride movement is not temporarily perturbed by upward wicking due to evapotranspiration or individual rainfall events. This mass resides above and within the well indurated caliche at 15- to 17-feet bgs. We compared the observed chloride transport rates at these depths and within these known lithologies with the predictions of the model, then adjusted the input characteristics to calibrate the HYDRUS-1D simulation.

The density of chloride measurements from the ROC November 2003 field program is quite good and clearly defines the location of the chloride center of mass at the SB-1 location. The data from the November 2004 event at MW-1 does not allow us to identify the center of chloride mass with the same degree of precision, but for the purposes of our modeling experiment, the data are more than sufficient.

Plate 9 is similar to Plate 7 but more clearly shows that peak measured chloride concentration of the upper chloride center of mass has migrated approximately two feet downward during the 12-month period (November 2003 to November 2004) that separates these two deep sampling programs. We believe that the recent rain events may have temporarily created saturated flow in the upper soil profile moving the chloride into the sand and caliche layer below the upper fractured caliche.

The minimum chloride concentration between the two masses was at a depth of approximately 8-feet bgs in November 2003 and was located at approximately 11-feet bgs in November 2004. The chloride at these depths is within a very fine-grained sand silt featuring little caliche. Considering sampling depth approximations, this suggests a chloride migration rate of two to three feet per year.

The recent precipitation did not affect the downward migration of the peak chloride concentration at 15-feet in the same manner. As Plate 9 implies, the peak chloride concentration is at a depth of 16-feet in 2004, suggesting a migration rate of approximately one foot per year. At 35- to 36-feet bgs we note virtually identical chloride concentrations from both drilling events. At this depth, a hard caliche layer exists and the downward migration of chloride is less than 1-foot per year.

At the 35- to 36-foot depth the low moisture content of the caliche creates extremely low vertical hydraulic conductivities, thus these units act as barriers to vertical flow. Below this caliche layer, chloride concentrations decline to ambient levels.

We conclude that the recent precipitation events have resulted in movement of the upper chloride mass downwards about 2-feet. The minimum chloride concentration has migrated downwards two to three feet. The lower mass of chloride has migrated downwards about one foot through the caliche at this horizon. A lower rate of chloride migration is present at the 35- to 36-foot caliche layer. The rates of chloride migration, when weighted by thickness of soil material, suggest a rate of chloride migration of about one to two feet per year.

The data for the calibration included our acquisition and installation of weather data for Hobbs, New Mexico from October 1, 2003 to November 6, 2004. This data is collected approximately 12 miles south of the spill site because the data from the Lovington Airport is not complete for these dates and this is the closest available weather data to the site. We then began our simulations using weather data for October 2003, when the release actually occurred. We then added the 46 year weather record from the Pearl, New Mexico weather station to create a representative atmospheric file for the HYDRUS-1D simulations.

Our 2004 monitor well boring program allowed us to collect a very detailed description of the vadose zone for the MW-1 boring (See Plate 6). This improved vadose zone profile data was used in all simulations.

Table 1 summarizes the data employed in the final calibration simulation, attached. Appendix D is a CD with the data in a format that will allow the reader to verify the results of the simulations using HYDRUS-1D or a similar code.

4.2 HYDRUS-1D MODEL CALIBRATION

To calibrate the model, we installed the chloride concentration data obtained by ROC at SB-1 in their November 2003 field event as the initial condition. We then ran the model for one year with the November to November Hobbs weather data discussed above. We made slight adjustments to the hydraulic properties in order to calibrate the model predictions to the chloride migration observed in the 2004 MW-1 field data.

Plate 10 adds the predicted chloride concentrations of the calibrated simulation, (line marked with diamonds) to the observed field data shown in Plate 9.

To obtain the match shown in Plate 10 (i.e. to calibrate our HYDRUS-1D simulation) we adjusted the hydraulic properties of the caliche and sand zones such that the center of the upper chloride mass migrated about 1.5 feet downwards from November 2003 to November 2004. In the calibration simulation, the minimum chloride concentration observed at about 8-feet bgs in SB-1 migrated slightly over one foot downwards. The center of the lower chloride mass (15 feet bgs in SB-1) migrated 1.1-feet in the same time interval, about 10 percent more than observed.

We used extremely conservative dispersion coefficients for our calibration, which would tend to over-estimate the resultant chloride concentration in ground water. As stated earlier, we believe that the rate of movement of chloride in the upper ten feet of the soil profile is affected by the weather, such as large rainfall events, rather than the long-term climate of the site. Compounding the effects of day-long rainfall events is the difficulty of accounting for the hydraulic properties of the uppermost fractured caliche bed. These fractures act as aids to flow in saturated conditions and as a hindrance to flow during the unsaturated conditions between severe precipitation events. After infiltrated water (and entrained chloride) passes beyond this uppermost vadose zone, unsaturated flow is the dominant type of transport. Climate, not weather, is the principal influence of this rate of flow.

Because we see a match between the 2004 field chloride concentrations and the predicted chloride concentration of calibrated simulation, we believe that HYDRUS-1D is a reasonable representation of the flow regime. Vertical migration rates and preservation of the two separate chloride concentrations are a good match to field data. In our calibrated HYDRUS-1D simulation, the center of the upper chloride mass migrated about 1.5-feet downwards from November 2003 to November 2004. The minimum chloride concentration has migrated slightly over one foot downwards. The center of the lower chloride mass migrated 1.1-feet in the same time interval, about 10 percent more than observed. We believe that the rate of movement of the lower chloride mass demonstrates a good agreement of the model with the field data because these short-term influences are not active at this depth.

4.3 SIMULATION AND DESIGN OF CORRECTIVE ACTION

Before design of a final corrective action for the site, we evaluated the following possible remedies:

1. Vegetation Cap without any excavation and chloride exportation.

2. Excavation and placement of chloride impacted surface soil beneath a synthetic liner which covers 100% of the site, then covering the liner with imported topsoil and vegetation cap.

3. Excavation and exportation of 35% of the chloride load, which translates to removal of material where the average chloride concentration over the thickness of the impact is greater than about 1,000 mg/kg.

4. Excavation and placement of chloride impacted surface soil beneath synthetic liner strips that would cover 35% of the total spill area, then covering the lined and unlined portions of the spill site with imported topsoil and vegetation cap.

5. The selected remedy:
   a) Excavate and stockpile the areas of high-chloride surface soil that do not currently support vegetation.
   b) Excavate, characterize and segregate by chloride concentration the uppermost 2-feet of the vadose zone that overlies about 35% of the subsurface chloride load. This translates to removal of material where the average chloride concentration over the thickness of the impact is greater than about 1,000 mg/kg (see Plate 6).
   c) Blend clean soil (imported or excavated from the site) with higher chloride stockpiles to create a mixture that will support vegetation (i.e. about 1,000 ppm chloride).
   d) Place a 1-foot thick clay barrier in the excavation in 6-inch lifts such that the saturated hydraulic conductivity of this clay barrier is less than 5×10^{-6} cm/sec.
   e) Place at least 1.5 feet of the blended stockpiled soil and any imported soil over the clay barrier and over the remaining unexcavated portion of the spill to create a small swale that will shed excess precipitation.
   f) Seed the site with native plants and fence the area to enhance re-vegetation.

For the preliminary design of all remedies we employed field-calibrated HYDRUS-1D simulations. We followed the following protocol to calculate and install an average chloride load from the releases. We compiled all of the chloride concentration data from the trench samples, the bore hole samples, and the surface samples. As this data is from different depths at the various locations, we linearly interpolated depth discrete samples for each of the trench sites and each of the bore holes to create complete chloride profiles at each site. We gave these profiles an area weighting allowing for the calculation of an averaged chloride concentration profile representative of the entire spill area. This profile was used in the HYDRUS-1D modeling.

We calibrated the mixing model to the observed conditions in ground water. To do this, we assumed that the pore water in the capillary fringe (from 0- to 8-feet above the water table) equaled the ambient water quality documented by the existing monitoring well, which is about 100 ppm and compared the model output for the first 10 years of the simulation with the observed ground water data. We selected the period 0-10 years for the calibration because we are confident that only true "background" chloride in soil water (from 50- to 90- feet below land surface) is entering the aquifer during this time. In other words, we are confident that chloride from the 1992 release does not enter ground water from years 0-10 in our simulation experiment.

To determine the area of the spill that overlies 35% of the chloride load, we employed the same area-weighting protocol discussed above to map the area planned for the clay barrier. Using this method, we identified a clay barrier strategy that covers 35% of the chloride load by creating a barrier over two areas. The largest area is defined by trenches A, B, and D and MW-1 (see Plate 11). A smaller area defined by SB-3 and trench I completes this cover strategy.

Table 2 summarizes the output of the simulation experiments. HYDRUS-1D predicts that only the vegetative cap remedy allows chloride concentrations above the state standard of 250 mg/L for the imaginary well with a 10-foot screen located at the edge of the spill site. Because of the simulation methodology will exaggerate the chloride concentration in ground water, we are confident that the predicted maximum chloride in the imaginary well is what we say: a maximum concen-

Table 2. Simulation experiment outputs

Remedy	Maximum Chloride Concentration (mg/l)			Duration of ground water chloride conentration above 250 mg/l (yrs.)	Time from present to Max. Concentration (yrs.)
	10 ft screen	*40 ft screen*	*100 ft screen*	*10 ft screen*	
Vegetative Cap only	405	188	137	19	29
Synthetic Barrier over 100% of the spill area, cover with topsoil and vegetative cap	100	100	100	0	Not Applicable
Excavtion and Exportation of 35% of the chloride load	243	140	116	0	29
Excavation of surface chloride and placement of synthetic barriers over 35% of the spill area and	243	140	116	0	29
Excavation of upper 3-feet. Replace with 1-foot of clay underlying 1.5 foot of loam and	243	140	116	0	29

tration. At other sites, we have found that chloride is distributed throughout the underlying aquifer provided that geologic barriers to flow, such as silt-clay horizons, do not exist. At this site, MW-1 did not detect such barriers within the uppermost 30-feet of the saturated zone and the screened interval of nearby supply wells is 20- to 100-feet. Table 2 includes an evaluation of different mixing zones.

For the selected remedy, the simulated response of an imaginary monitoring well located at the edge of the spill that draws from an aquifer with a 10-foot thick mixing zone is shown below in Figure 3. After year 10, the chloride from the 1992 begins to enter ground water. After year 50, the released chloride from below the vegegative cap has effectively moved through the vadose zone. Released chloride that lies below the clay barrier is effectively sequestered in the vadose zone for more than a century. The maximum predicted chloride concentration in ground water caused by the slow release from beneath the clay barrier is less than 105 ppm, which is observed more than 410 years from now.

Although installation of a synthetic liner over 100% of the spill area permanently sequesters the chloride in the upper vadose zone and results in a better simulation result, we did not select this option. This remedy demands that the liner maintain integrity for hundreds of years. We favored the clay liner remedy which allows a very slow release of chloride to ground water that remains compliant with NMOCD Rules.

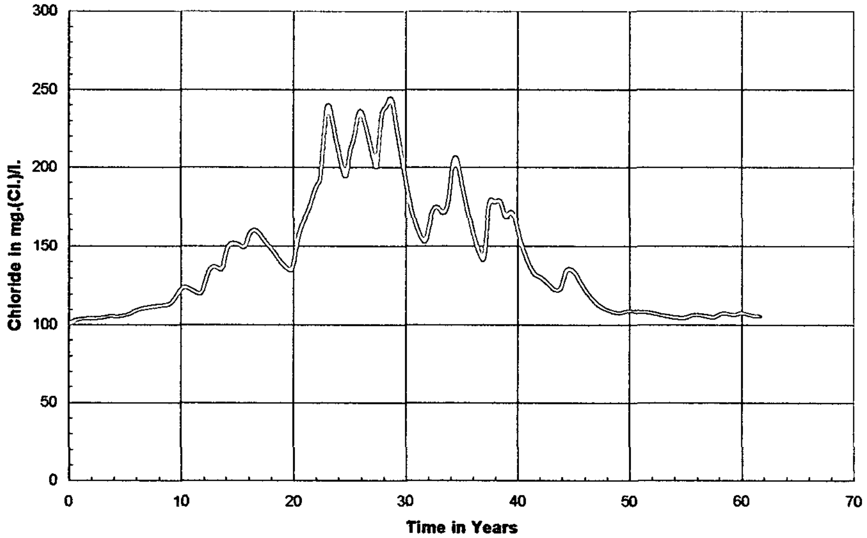


Figure 3. Chloride concentration in the aquifer for the Abo 1G Release Site, averaged chloride load from entire site, vegetation, 35% clay cap

4.4 SCHEDULE

Sixty days after NMOCD approval of this remedy, we will submit detailed plans and specifications for this remedy. The plans will include hydraulic conductivity testing of the material selected for the clay barrier, a plot plan showing the area to be capped with clay, a detailed description of the proposed field methods, a quality assurance plan for the remedy, and a post-remedy monitoring plan. Thirty days after NMOCD approval of the detailed plans, ROC will begin field activities to implement the remedy, with completion of the remedy 60 days after NMOCD approval of the detailed plans.

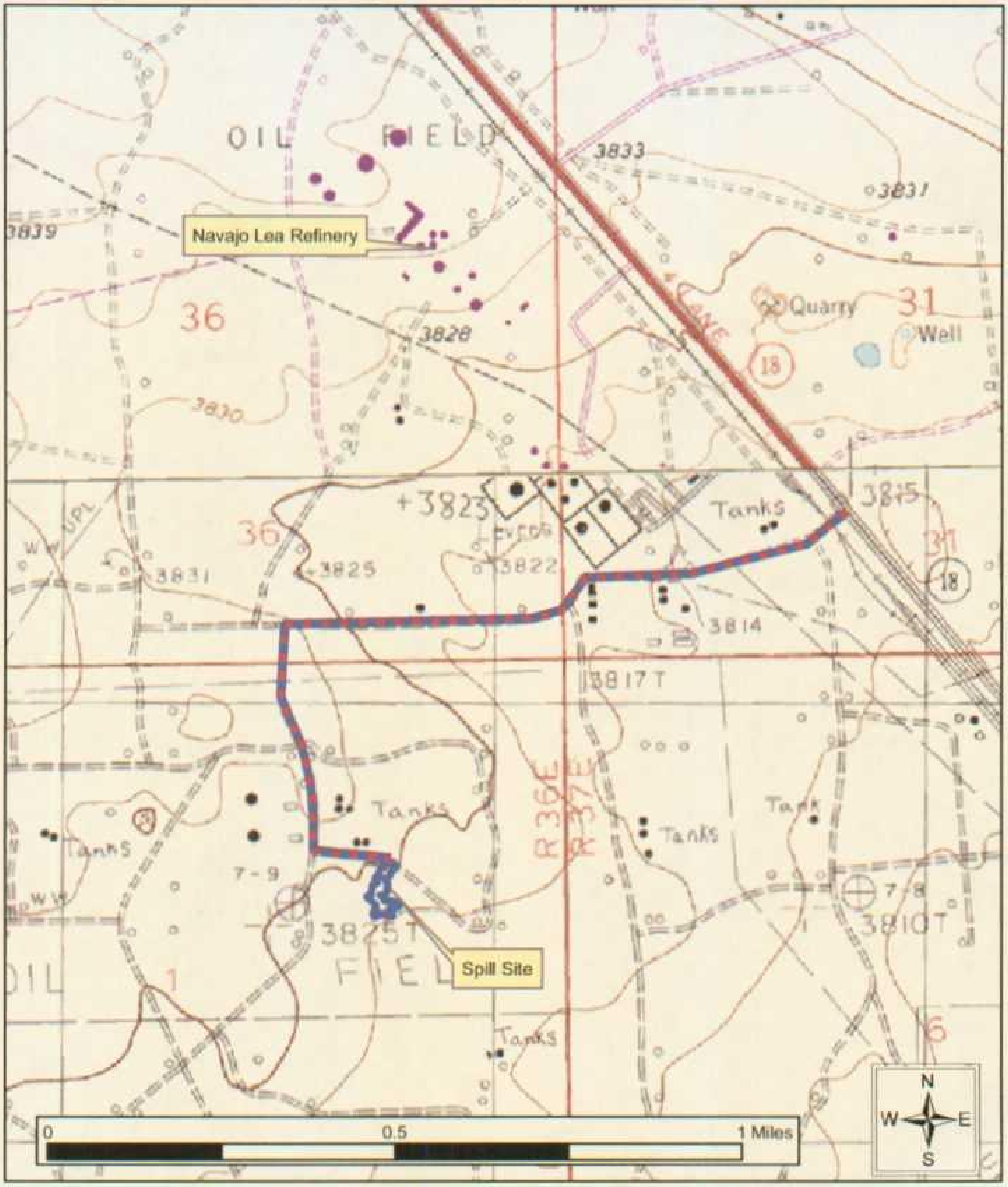
TABLES

Table 1: Input Parameters for Simulation Modeling

Input Parameter	Source
1. Vadose Zone Thickness - 91 feet	Appendix A well logs
2. Vadose Zone Texture - Plate 6	Samples and attached well logs
3. Dispersion Length - < 10%	Professional judgment
4. Soil Moisture	HYDRUS-1D initial condition simulation
5. Chloride in release - 19,994 ppm	Samples of produced water
6. Height of spill on land surface -1.0 inches	Calculated from chloride load at sampling location SB-3 and chloride in released water
7. Length of release parallel to ground water flow - 477 ft	Field Measurements
8. Climate - Arid	Pearl Weather Station near Hobbs Airport
9. Background Chloride in Ground Water - 100 ppm	Professional judgment
10. Ground Water Flux - 10 cm/day	Calculated from published data and the Lea Refinery Report
11. Aquifer Thickness - 10 feet	NMOCD suggestion

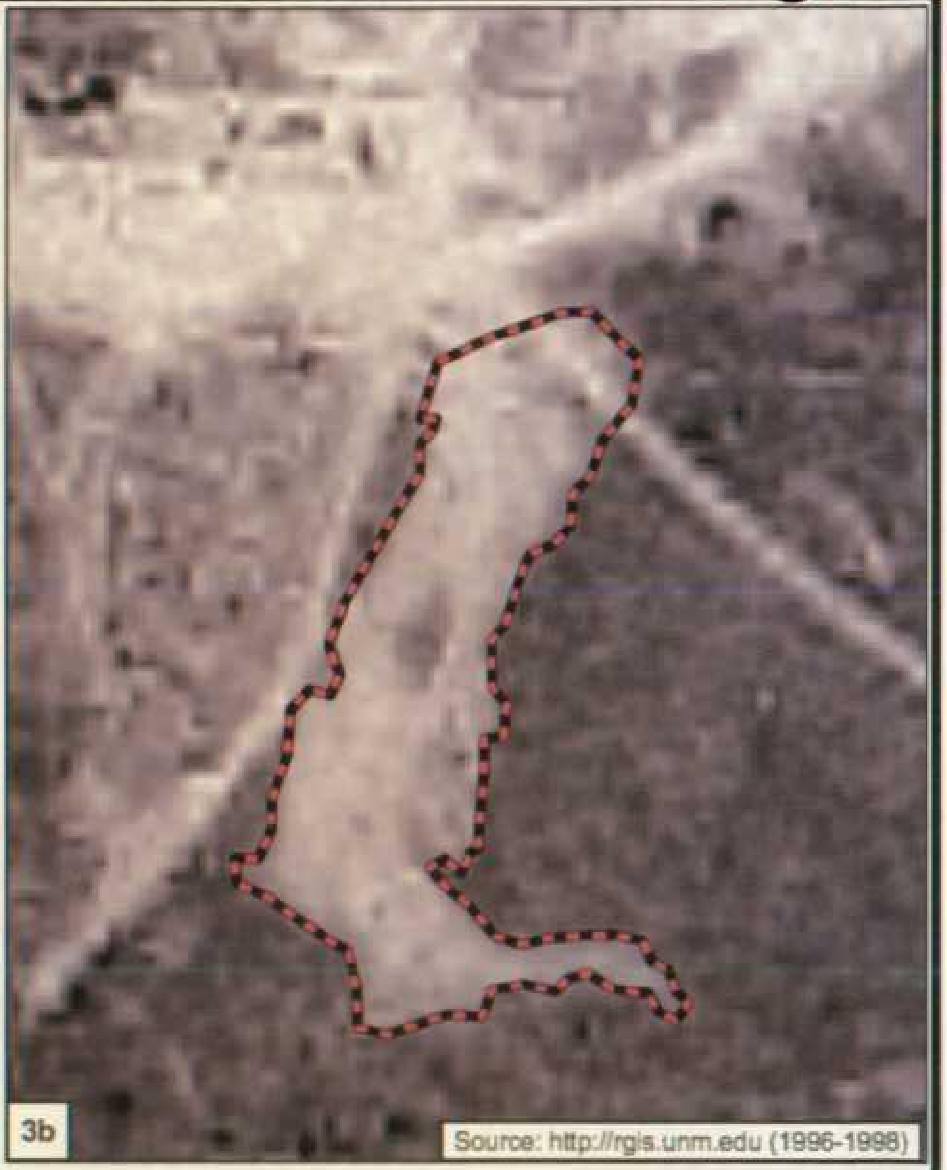
PLATES

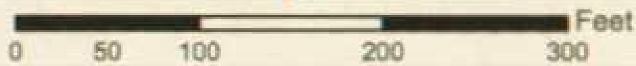
Directions: From Lovington, NM, proceed on Highway 18 for approximatly 5.3 miles. Head southwest on an unnamed dirt road (0.5 miles southeast of the Navajo Lea Refinery. Proceed on the dirt road for approximately 0.8 miles. Head south on an unamed dirt road for approximately 0.3 miles. Head east on an unnamed dirt road immediatley south of a tank battery. Proceed east for approximately 550 feet. The spill site is on the south side of the road.



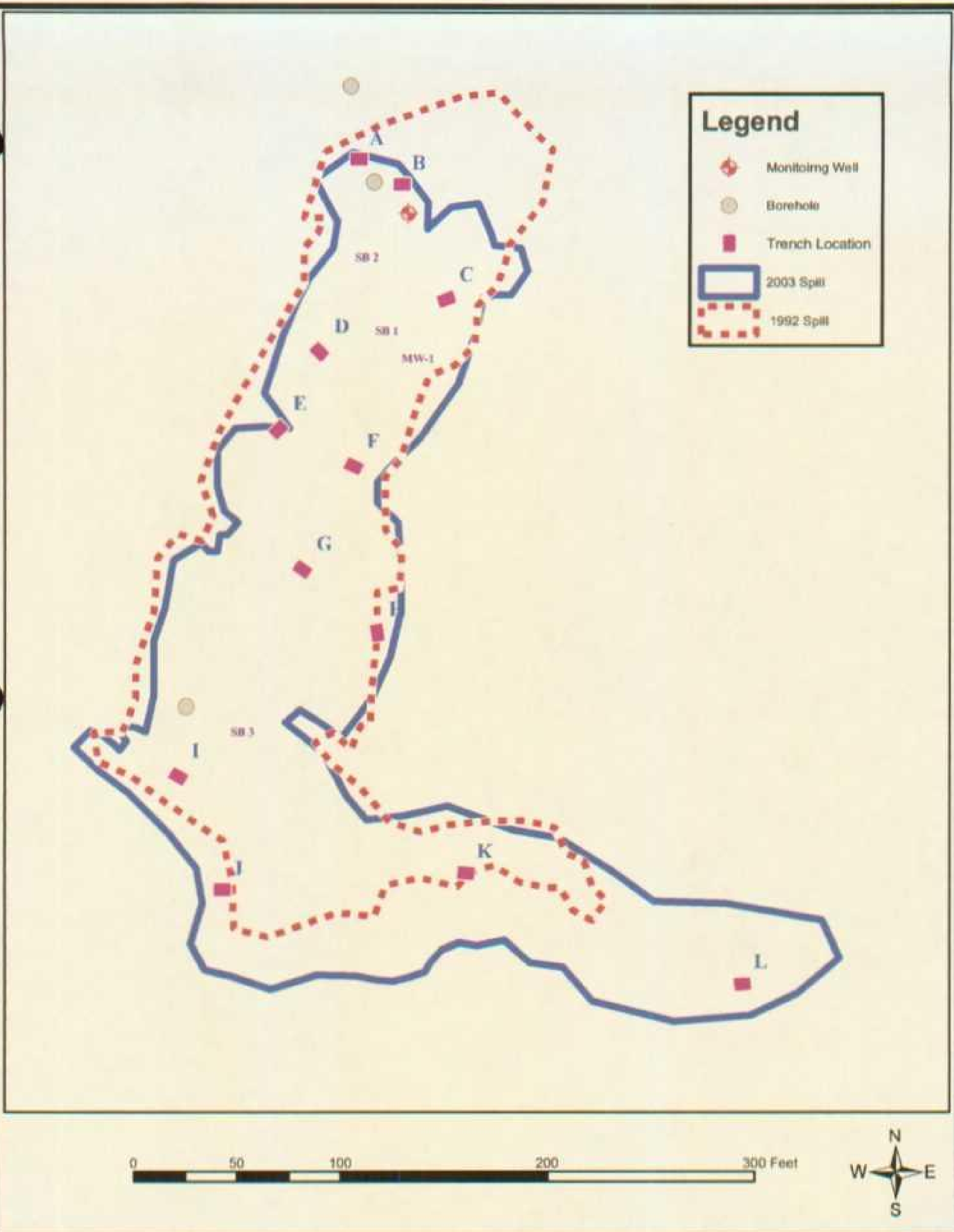
R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Site Location Map (USGS Lovington SE 7.5' Quad)	Plate 1
	ABO 1G Realease Site, OCD Case #1R0415	August 2005

R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Location of Realese and Sourrounds	Plate 2
	ABO 1G Realease Site, OCD Case #1R0415	August 2005





R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Geometry of 2003 and 1992 Releases	Plates 3a & 3b
	ABO 1G Realease Site, OCD Case #1R0415	August 2005



R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Geometry of 1992 & 2003 Releases with Trenches, Soil Borings & Monitoring Well	Plate 4
	ABO 1G Realease Site, OCD Case #1R0415	August 2005

Depth	Lithologic Description	Measured Soil Chloride Concentration mg/kg	Bulk Density of Sample kg/m3	Thickness of Column (ft)	Calculated Chloride Mass in Column (kg/m2)
0 feet	0-1 ft Top Soil				
10 feet	1-22 ft Caliche	525	1858	10	3.23
20 feet		1088	1858	11	7.37
30 feet	22-31 ft Sand & Caliche	1161	1858	5	3.57
		636	1858	4	1.57
40 feet	31-45 ft Sand	573	1858	7	2.47
		236	1858	7	1.02
		Calculated Chloride Load			19.22

R.T. Hicks Consultants 901 Rio Grande NW Albuquerque, NM	**RICE** *Operating Company*	Plate 5
	Soil Bore #1 - Calculation of Chloride Load, Abo Leak, Lea County, New Mexico	Aug-05

Logger:	David Hamilton	Client:	Well ID:
Driller:	Eades Drilling	ROC	
Drilling Method:	Air Rotary	Project Name:	
Start Date:	11/5/2004	Abo Apache LA 1-G Release Site	LA MW-1
End Date:	11/6/2004	Location:	
		Section 1, 17S, 36E, Unit 1G	

Depth (feet)	Description	Comments	Well Construction
0.0	Surface, 0 - .5 feet	Hard drilling	Cement, 0-3 feet
2.0	Frac. caliche, sand, clay, .5 - 3 feet, tan		
4.0	Sand and caliche, 3 - 5 feet, tan		Hydrated bentonite, 3-87 feet
6.0 – 8.0	Very fine grained sand, silt, some caliche, 5 - 10 feet, tan		
10.0 – 12.0	Very fine grained sand, silt, little caliche, 10 - 15 feet, tan		
14.0	Indurated caliche, 15 - 17 feet		
16.0 – 18.0	Very fine grained sand, silt, little caliche, 17 - 20 feet		
20.0	Thin caliche layers in sand, 20 - 22 feet		
22.0 – 32.0	Very fine grained sand, silt, 22 - 33 feet, tan with reddish tinge	Samples fell out of spoon, collected with shovel	
34.0 – 42.0	Very fine grained sand, silt, caliche, 33 -44 feet, light tan. Well indurated caliche layer from 35 to 36 feet		
44.0 – 50.0	Very fine grained sand, silt, 44 - 53 feet, tan		
52.0 – 58.0	Very fine grained sand, silt, some caliche, 53 - 60 feet, tan		
60.0 – 64.0	Very fine grained sand, silt, 60 - 67 feet, tan		
66.0	Indurated sand, silt, 67 - 68 feet	Hard drilling	
68.0 – 98.0	Very fine grained sand, silt, 68 - 100 feet tan. Slightly redder below 83 feet	Soil moist at 100 feet	Sand, 87-122 feet
100.0 – 122.0	Very fine grained sand, silt, 100 - 122 feet	Hole was drilled with water below 100 feet due to borehole collapse	

Field data

Depth	Chloride mg/kg	PID
6.0	1245	6.3
11.0	553	7.3
16.0	1307	5.2
21.0	805	8.2
26.0	741	1.1
31.0	493	0.8
36.0	566	0.6
41.0	126	3.3
46.0	83	2.0
51.0	49	1.0
61.0	59	2.4
71.0	50	2.9
81.0	59	3.7
91.0	55	2.7

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Albuquerque, NM 87104
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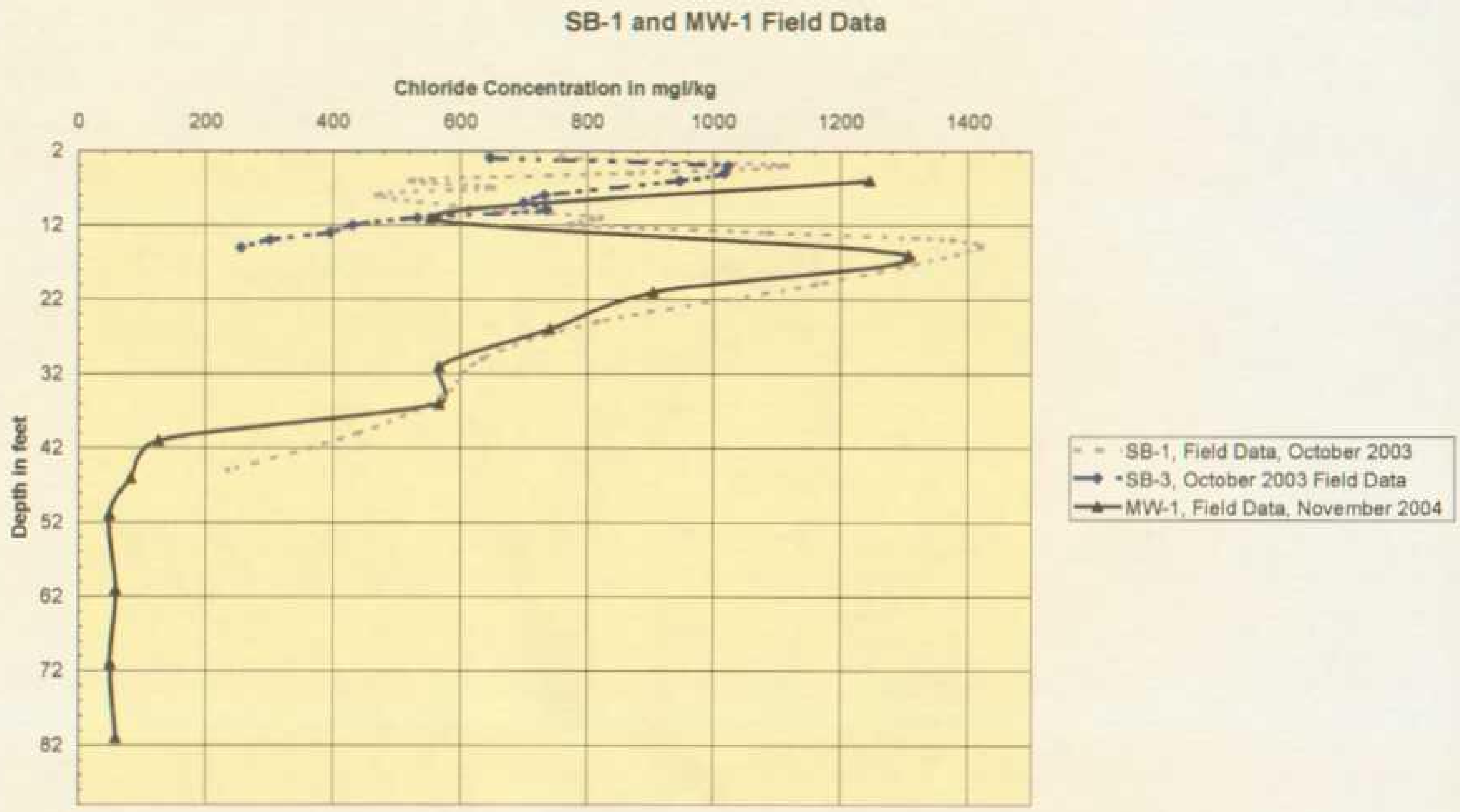
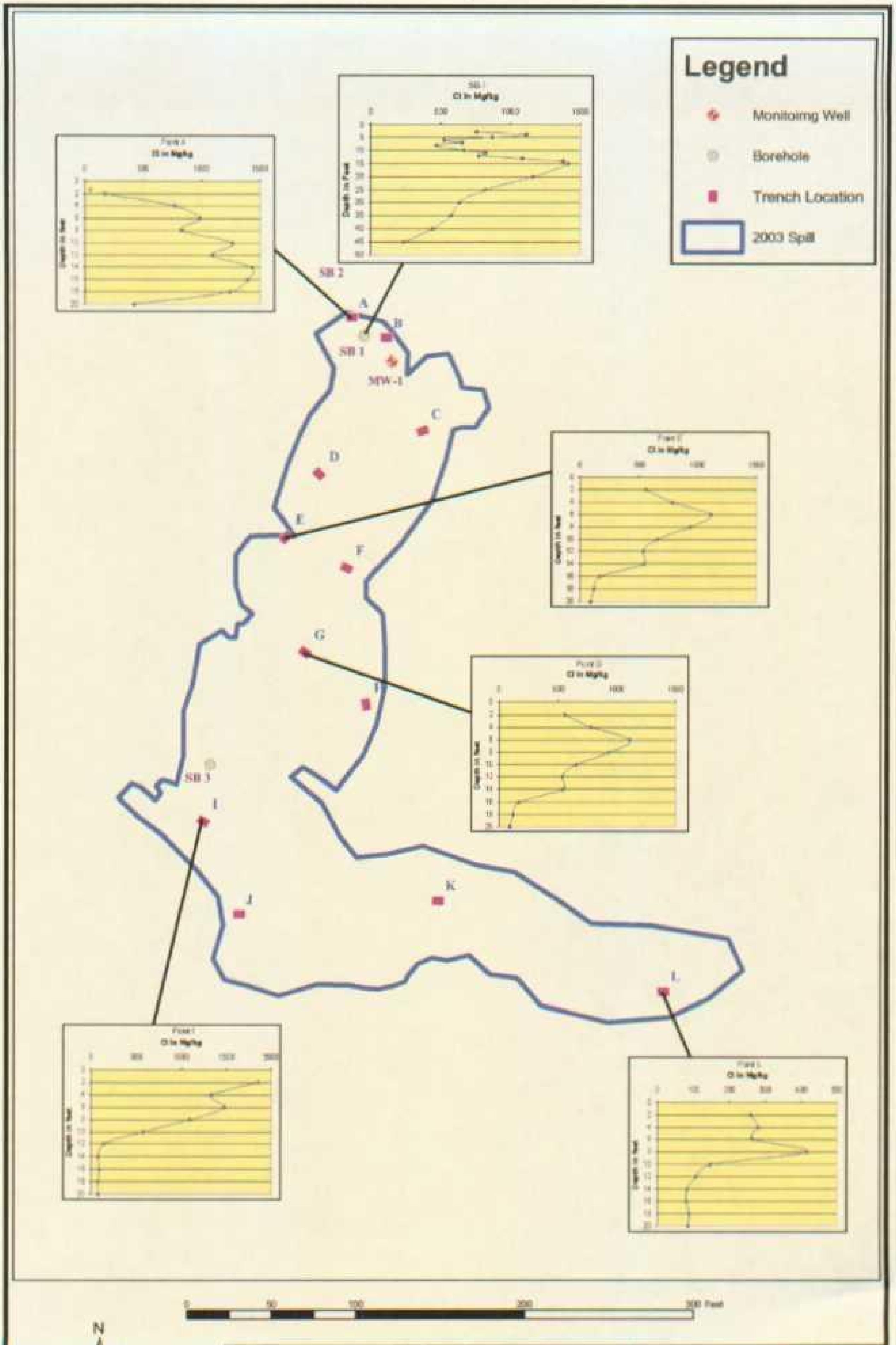
ROC Lovington Abo 1-G Site — Plate 6

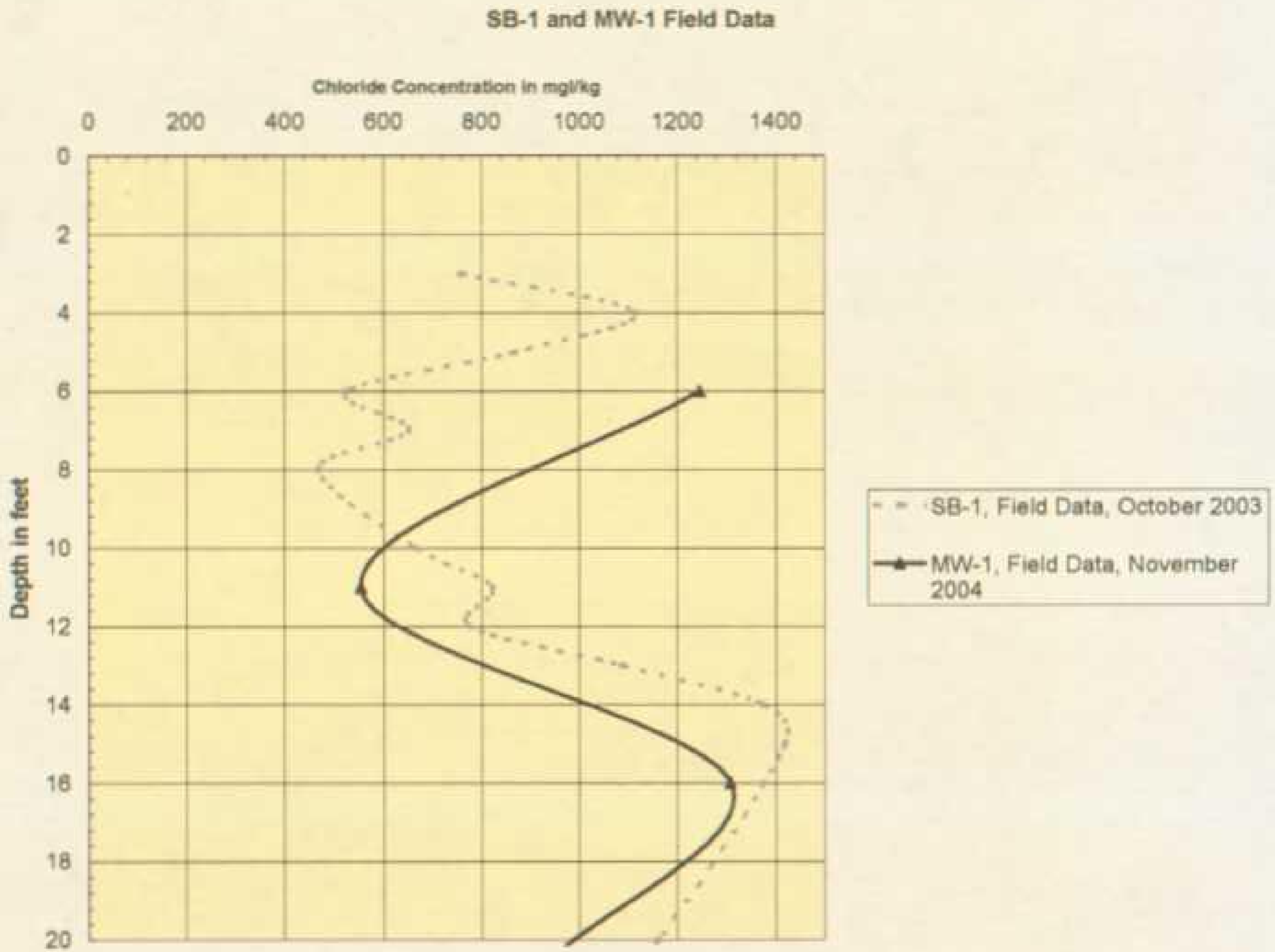
Monitoring Well Boring — August 2005



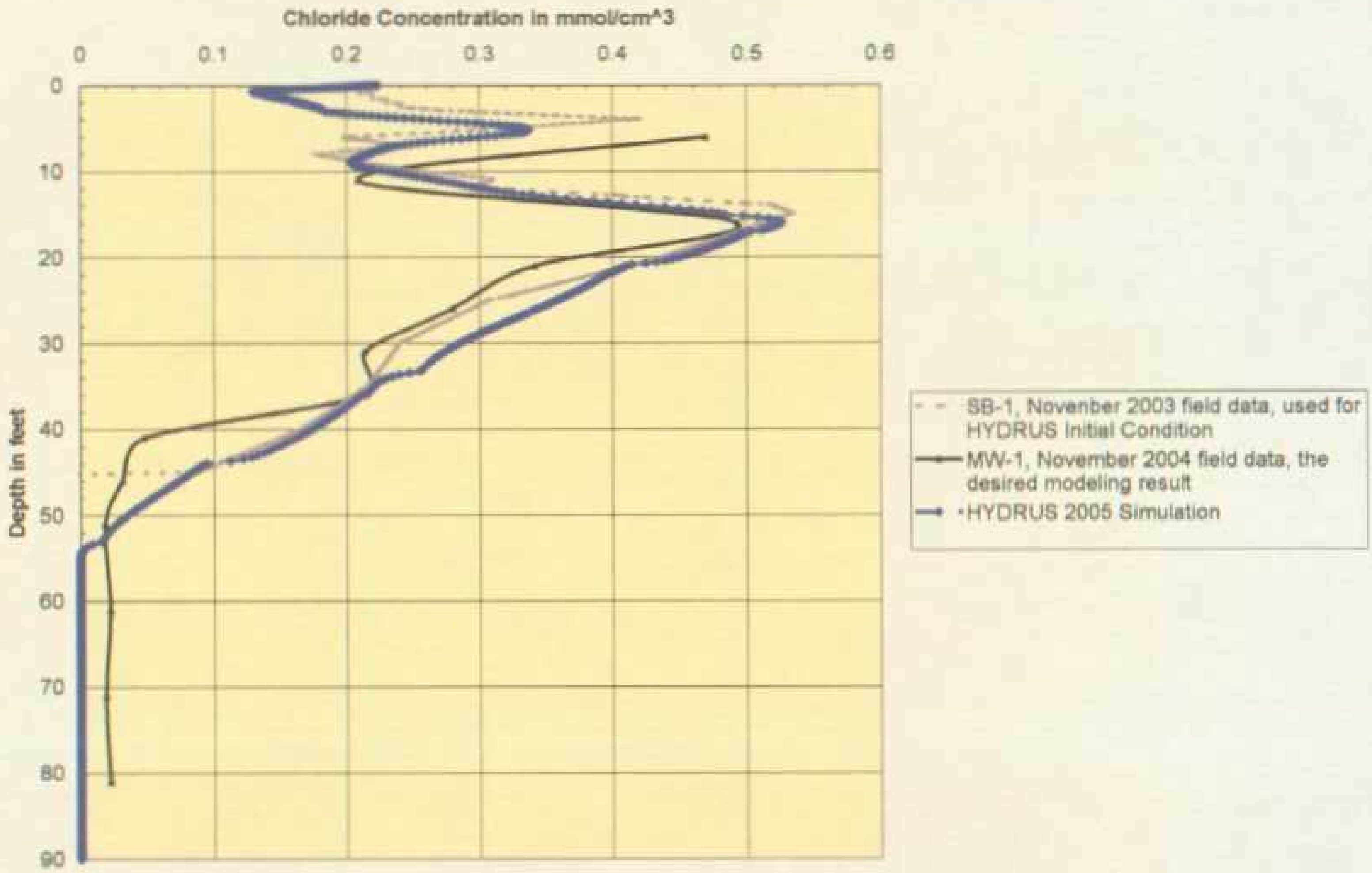
R.T. Hicks Consultants, Ltd. 901 Rio Grande Blvd. NW, Suite F-142 Albuquerque, New Mexico 87104	Chloride Loading in SB-1 and MW-1 Field Data	Plate 7
	Abo 1G Release Site, NMOCD Case #1RO415	Aug-05



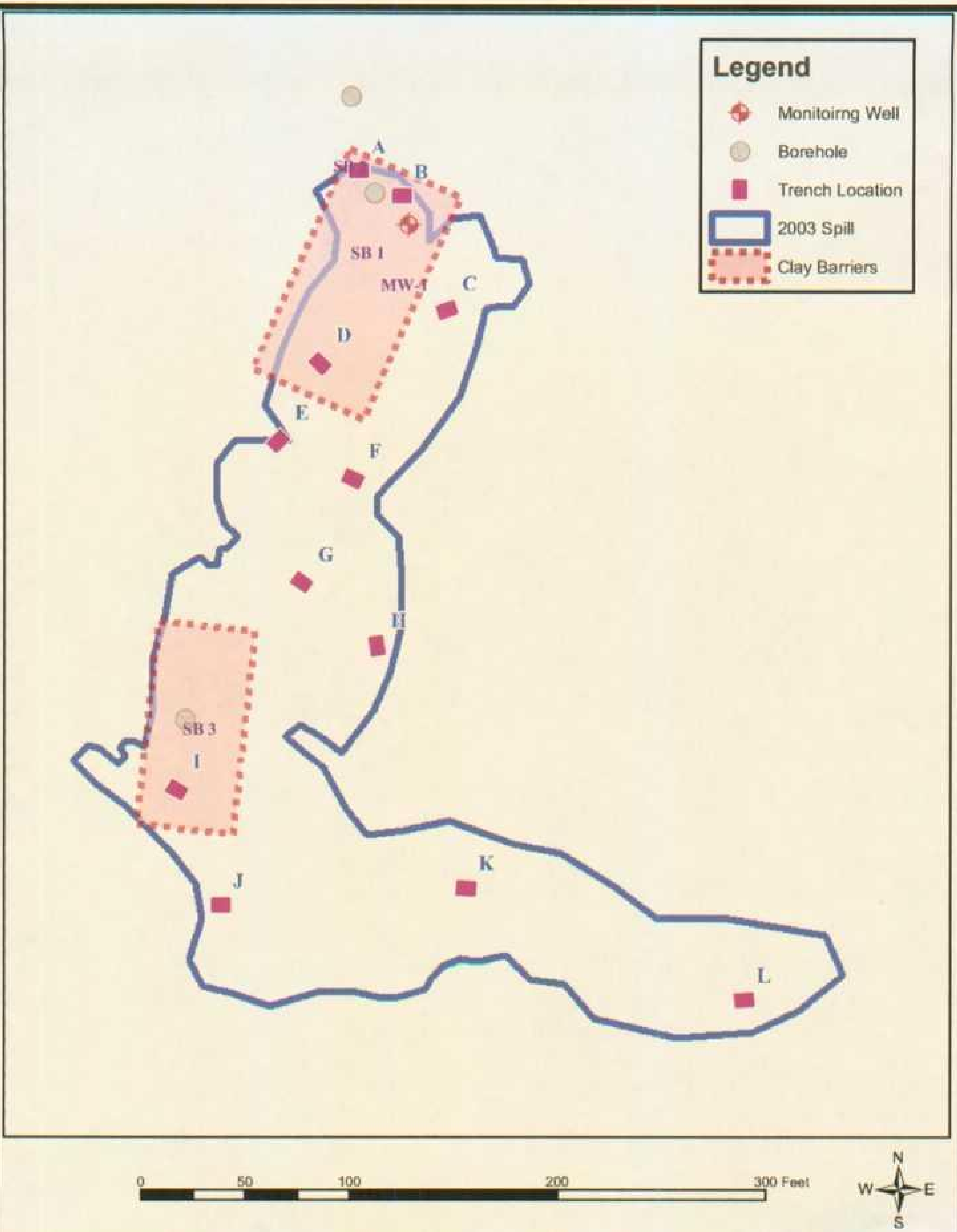
R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Geometry of 2003 Release with Trenches, Soil Borings & Monitoring Well and selected graphs	Plate 8
	ABO 1G Realease Site, OCD Case #1R0415	August 2005



R.T. Hicks Consultants, Ltd. 901 Rio Grande Blvd. NW, Suite F-142 Albuquerque, New Mexico 87104	Detail of Chloride Loading in SB-1 and MW-1 Field Data	Plate 9
	Abo 1G Release Site, NMOCD Case #1RO415	Aug-05



R.T. Hicks Consultants, Ltd. 901 Rio Grande Blvd. NW, Suite F-142 Albuquerque, New Mexico 87104	Comparison of HYDRUS 1D Modeling with Field Data	Plate 10
	Abo 1G Release Site, NMOCD Case #1RO415	Aug-05



R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004	Areas Proposed for Clay Barriers	Plate 11
	ABO 1G Realease Site, OCD Case #1R0415	August 2005