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REPORTS

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Soil Restoration Plan for Township 19S Range 37E Section 7 Spill

RICE OPERATING COMPANY

HOBBS , NEW MEXICO

Prepared for:

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1.0 EXECUTIVE SUMMARY

Rice Operating Company (ROC) is the service provider (operator) for the Eunice-Monument-Eumount (EME) Saltwater Disposal System and has no ownership of any portion of pipeline, well, or facility. The EME System is owned by a consortium of oil producers, System Partners, who provide all operating capital on a percentage ownership/usage basis. Major projects require System Partner authorization of expenditures (AFE) approval and work begins as funds are received.

During a routine inspection on December 29, 2000, Rice Operating Company (ROC) discovered a pipeline failure in Section 7, Township 19S, Range 37E. The pipeline is regularly inspected and the last inspection was in October 2000. Because cooling tower blowdown water from the Linam Ranch Gas Plant comprises a significant portion of the water in the pipe, we believe the chloride concentration of the released water is less than 10,000 mg/L. Soil sampling data support this estimate of water quality.

Under contract to ROC, R.T. Hicks Consultants, Ltd. evaluated existing reports, collected additional field data, met with the surface landowner and then developed this soil restoration plan. The principal findings of our study are:

1. The spill released wastewater containing chloride and minor amounts of hydrocarbons to a 1-acre area of land belonging to the State of New Mexico and Mr. Jimmy Cooper.

2. The soil affected by the spill is low-permeability clay-loam, 4-12 feet thick and underlain by caliche.

3. Background chloride concentration in the native soil is about 200-500 parts per million (ppm) (Assaigai laboratory analysis by EPA Method 300 in Pit 3).

4. The average chloride concentration in soils obviously affected by the release is 1500 ppm (EPA Method 300).

5. Sodium from the released wastewater has replaced calcium in the clay soils, causing swelling and further reduction in the natural permeability.

6. Chloride concentration in soils decreases with depth. Near surface soil samples contain twice as much chloride as samples obtained from immediately above the caliche horizo, which occurs at appoximately 3.5-6 feet below ground surface.

7. Depth to groundwater at the site is about 60 feet.

8. The nearest down gradient water supply well is more than 2 miles from the release.

Our evaluation of the data relating to the spill allow us to conclude:

A. The release has not impaired groundwater quality. Simulation modeling using the HYDRUS unsaturated flow model show that migration of chloride to groundwater will require more than three years under average precipitation conditions.

B. The addition of gypsum to the soil will cause restoration of the calcium/sodium ratio in the clays and thereby return the soil to its natural permeability.

C. Application of supplemental water to the soil after chemical amendment (gypsum addition) will flush the chloride below the top caliche horizon. At this depth, the chloride will not migrate up.

D. Over many years, the flushed chloride will slowly drain to the water table. The rate of drainage is very slow relative to the natural movement of groundwater in the underlying Ogallala aquifer. We currently believe that the resultant water quality in the Ogallala aquifer will meet New Mexico groundwater standards. Aquifer simulation modeling will test this hypothesis.

We recommend that a small portion of the release, the 0.1 acre of state land, undergo natural restoration. Here we will not add gypsum or supplemental water as described above. We recommend that the southern quarter of the site undergo mechanical restoration through excavation of the impaired soil and importation of clean soil. For the remainder of the release site, we recommend in-place chemical amendment to restore the soil to its productive capacity. We propose the addition of 20-30 tons of gypsumfollowed by the application of up to 2 acre feet of supplemental water.

We recommend monitoring the efficacy of each method over the next 12-24 months to determine which method is most effective for soil restoration of salt water impacted landscapes.

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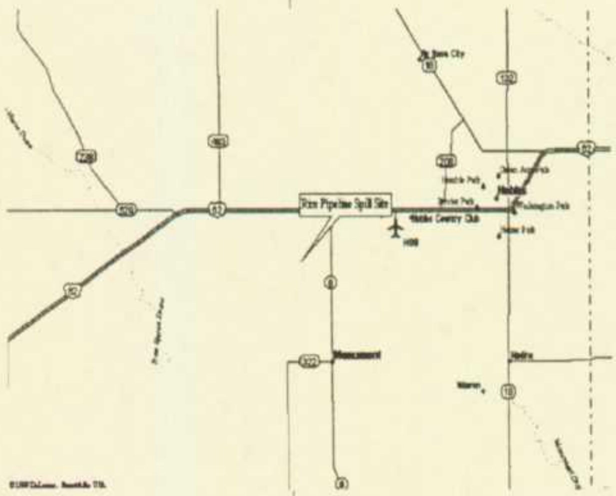
2.0 INTRODUCTION

2.1 DURATION, FLOWRATE AND CHEMISTRY OF RELEASE

The December 2000 release is the second time this pipeline released fluids at this location. At least six years earlier, ROC personnel discovered a small release, which impaired an area of about 20 feet by 15 feet. We believe that this past release was below reporting limits. Interviews with ROC personnel and examination of the surrounding area permit us to conclude that these two incidents are the only releases from the pipeline at the site.

Figure 1: Location of the site



2.2 LOCATION AND ACCESS

The spill site is located in Township 19S Range 37E Section 7. Figure 1 is a location map of release relative to Hobbs, New Mexico. To access the site from Hobbs, drive east on State Road 62 past the Linam Ranch Gas Plant. Turn left (south) on County Road 41 and drive approximately 2 miles, an electrical transfer station is visible on the east side of the road. Turn left and pass the substation. The spill site is on the north side of the dirt road approximately 0.25 miles west of County Road 41. Plate 1 is a topographic map that shows site access from US 62 west of Hobbs. Figure 2 and 3 are photographs of the site.

Figures 2 and 3: Photographs of the site looking northwest from the spill and a view from state land north of the site looking south towards the site.

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2.3 REGULATORY CONSIDERATIONS

Section 3105 of the New Mexico Water Quality Control Commission regulations (20 NMAC 6.2) state that Discharges from ..."Effluent or leachate discharges which are regulated by the Oil Conservation Commission and the regulation of which by the Water Quality Control Commission would interfere with the exclusive authority granted under Section 7-2-12 NMSA 1978 (Oil and Gas Act), or under other laws, to the Oil Conservation Commission" are exempt from WQCC authority.

The Oil and Gas Act (70-2-12NMSA) states that included in the powers of the Oil Conservation Commission is the power..."(21) to regulate the disposition of nondomestic wastes resulting from the oil exploration, development, production or storage of crude oil or natural gas to protect public health and the environment; and (22) to regulate the disposition of nondomestic wastes resulting from the oil field service industry, the transportation of crude oil or natural gas, the treatment of natural gas or the refinement of crude oil to protect public health and the environment...."

The Oil Conservation Commission regulations (19 NMAC 3.SL05.12) state that "(b.) Hazardous or toxic wastes or petroleum products may not be disposed of on the lease of permit premises, and all such materials used in the operations must be removed from the lease area immediately upon termination of the lease or permit. Due care shall be used to prevent leaks and spills of such materials; clean up of any spills and reclamation of the area shall be performed in consultation with the Commissioner." According to the above regulations and statues, produced water pipeline spills are under the jurisdiction of the Oil Conservation Commission.

2.4 EVALUATION CRITERIA OF SOIL RESTORATION ALTERNATIVES

We followed guidance provided by American Petroleum Institute (API) Publication 4663 *Remediation of Salt-Affected Soils at Oil and Gas Production Facilities* (Carty et al., 1997). According to this guidance and commonly accepted agricultural practices, the soil restoration alternatives for spills are:

1. **Passive or natural restoration**, which does not employ human intervention. This remedial method employs natural

processes of precipitation and chemical diffusion to restore the soil within an acceptable time.

2. **Mechanical restoration** employs machinery to remove impacted soils and replaces them with "clean soils." This method has a high success rate but can cause erosion and the introduction of non-native plants from imported soil. Often, this practice may simply move the problem to a different location, outside of the control of the responsible party.

3. **In-place chemical amendment** involves adding materials such as gypsum, surfactants, and water to the soil. The chemicals are necessary to avoid or repair damage to the soil structure. Structural damage to the soil occurs when sodium in the released water replaces calcium within the clay minerals in the soil. This calcium/sodium replacement causes swelling of the clay minerals and closing of soil pores. Open soil pores are essential to a healthy soil. After the sodium/calcium ratio in the soil is repaired by addition of amendments (e.g. gypsum) water application promotes vertical flushing of constituents of concern to a depth that is below the root zone but generally above the water table. This technique is the most widely used method of soil restoration yet can be the most difficult to implement.

Passive restoration may be considered a poor choice because of landowner objections to this alternative. Natural restoration is a viable alternative at sites where:

- Chloride, hydrocarbon and other constituent concentra tions in soil are within tolerance limits of the native vegetation
- Constituent concentrations are 1-2 times background conditions and natural precipitation is sufficient to dilute pore water and flush the constituents below the root zone
- Re-vegetation with salt-tolerant (halophytic) species is acceptable to the surface landowner
- The topography of the site suggests that land disturbance, required by other restoration techniques would result in uncontrollable and unacceptable erosion
- A sensitive habitat (e.g. wetlands) at or near the site would become unacceptably damaged by heavy equipment use or the restoration process associated with mechani

cal or chemical amendment remedies

- The damage is extensive and severe, making mechanical or chemical amendment restoration impractical relative to acquisition of the property

Mechanical restoration is feasible at most sites and is generally acceptable to the landowner. Two basic types of mechanical restoration are common: (1) disposal of affected soil and replacement with new soil and (2) in-place mixing of unaffected soil with affected soil (dilution). Mechanical restoration may be employed with a variety of site conditions. Typically, mechanical restoration is the remedy of choice where:

- The total volume of soil impact is small (e.g. less than 20 cubic yards)
- The depth of spill intrusion is small, permitting effective soil mixing (dilution)
- The spilled material is dominantly hydrocarbons and tilling/mixing is sufficient to promote bio-remediation
- The soils are ill-suited for in-place chemical amendment or natural restoration methods

Evaluation of in-place chemical amendment requires more field analysis and testing than the other alternatives. The Natural Resources Conservation Commission's (formerly the Soil Conservation Service) Soil Surveys contain some information to assist in determining if in-place chemical amendment is an appropriate soil restoration strategy, thereby minimizing the field-testing program. In-place Chemical Amendment is feasible and warrants further investigation if the following are true for the subject site:

- The soil drains relatively well.
- Depth to groundwater is greater than 6 feet below ground surface.
- Depth to an impermeable layer (Redbeds or thick clay) is greater than 6 feet.
- The site is not exceedingly sloped and subject to uncon trolled erosion if disturbed.
- The soil shrink-swell potential is relatively low
- The soil is neither too acidic nor too alkaline

- The site is not a wetland or very near a wetland
- Application of irrigation water for flushing the soil will not result in an unacceptable degradation of groundwater quality.

After meeting with the landowner, we eliminated natural restoration as a presumptive remedy. The landowner expressed confidence in mechanical restoration. Our preliminary evaluation of the site suggested that mechanical restoration and in-place chemical amendment warrant careful consideration.

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3.0 REGIONAL ENVIRONMENTAL SETTING

The majority of the ROC operated EME-SWD pipeline system lies on the southwestern extent of the High Plains, also termed the Llano Estacado, in Lea County, New Mexico. The High Plains is an isolated mesa covering large parts of western Texas and eastern New Mexico. This mesa, which is a deposition surface with little topographic relief, slopes gently towards the south-east (Nicholson and Clebsch, 1961). The Mescalero Ridge, a small escarpment to the west and south of Hobbs, NM, marks the southwestern extent of the High Plains.

3.1 CLIMATE AND PRECIPITATION DATA

The climate of southern Lea County is classified as semiarid/ arid and is characterized by low annual precipitation, low humidity and high average temperatures (Nicholson and Clebsch, 1961). Table 1 presents monthly average climatic data measured at the Pearl, New Mexico weather station located 5.7 miles southwest of and at approximately the same elevation as the Section 07 spill site. The maximum average temperature at Pearl is 92.3 °F, and the minimum average temperature is 26.0 °F. These averages occur in July and December, respectively. Annual precipitation is 13.8 inches with the majority of the precipitation falling during the monsoon season between the months of July and October. Annual snowfall is 5.0 inches (5 inches of snow is equal to approximately 0.5 inches of rain). Average annual pan evaporation measured at the Hobbs FAA Airport is 51.7 inches (Gabin and Lesperance, 1977).

Table 2 provides monthly rainfall data measured at the Lea County Regional Airport from January 2001 to March 2001, the three months following the discovery of the release. The Lea County Regional Airport is located approximately 4.5 miles northeast of the spill site. Although little precipitation fell in January, the airport measured 1.8 inches and 1.08 inches of precipitation in February and March, respectively. The majority of the February precipitation fell during a single storm event on the 27th.

3.2 SOILS

The Lea County Soil Survey states that soil in the area of the spill is Mixed Alluvial Land (MU). The Soil Survey classifies MU as a *Dryland Capability Unit* (VIe-1). This soil unit is generally used for range and wildlife habitat. Field and farm windbreaks can be established including Russian-olive, Rocky Mountain juniper, and Siberian Elm.

The soil surrounding the site is Kimbrough-Lea complex (KU). KU is also *Dryland Capability Unit* (VIIs-1). This unit is used for range and wildlife habitat.

Appendix A presents more detailed descriptions of MU and KU from the Lea County Soil Survey. The appendix also contains tables from the Soil Survey that list physical characteristics and potential uses of MU and KU. Due to soil variability, estimates for the physical properties of MU are not provided.

3.3 REGIONAL HYDROGEOLOGY

Groundwater of the Ogallala aquifer, which underlies the High Plains, is a principal source of water supply in southern Lea County. The aquifer supplies water to agriculture, industry, municipalities, and domestic water users (Nicholson and Clebsch, 1961). The Ogallala aquifer is a water-table aquifer and precipitation is its primary source of recharge. Due to low precipitation and high evapotranspiration rates, the recharge rate of this aquifer is low, 0.25-0.5 inches/year (Nicholson and Clebsch, 1961). Low recharge and extensive groundwater use has depleted areas of the aquifer (Native and Smith, 1987).

The Ogallala aquifer consists of saturated sediments of the Pliocene age Ogallala Formation. The Ogallala Formation consists of fine-grained calcareous sand with some clay, silt and sand (Nicholson and Clebsch, 1961). The Ogallala Formation varies in thickness from a few inches to approximately 300 feet (Nicholson and Clebsch, 1961). Some of the variability of thickness is due to the subsurface topo-graphy of the Dockrum Group, which underlies the Ogallala Formation. The Triassic Dockrum Group consists of the Chinle Formation and Santa Rosa Sandstone and many workers refer to these units as "the red beds." The Santa Rosa Sandstone consists of fine-to-coarse-grains, while red and green clay stone dominate the Chinle Formation (Nicholson and Clebsch, 1961).

An indurated layer of caliche often caps the Ogallala Formation. The caliche is formed by the accumulation of calcium carbonate at some depth beneath the land surface, typically 1-10 feet. Due to its low permeability, areal extent, and thickness, the caliche can be a barrier to the downward movement of water. Water perches on the caliche, accumulating in depressions or small "channels" on the uppermost surface of the caliche. The perched water can migrate to open fractures and solution channels, penetrating the caliche then infiltrating into the Ogallala Formation. The water then flows downward under unsaturated conditions to the water table of the Ogallala aquifer. Plate 2 is schematic showing the influence of the caliche on the vertical migration of water.

Plate 3 is a water-table elevation map of the Ogallala aquifer near the spill site. The general direction of groundwater flow is towards the southeast. We estimate the hydraulic gradient at 0.003 feet per foot. The average flow rate of groundwater in the southern High Plains Ogallala aquifer has been estimated at 0.6 feet/day (Native and Smith, 1987). Hydraulic conductivity values for this portion of the aquifer range from 3 to 260 feet/day with an average value of 31 feet/day, and the specific yield of the aquifer varies between 22% and 4% (Native and Smith, 1987). The saturated thickness of the Ogallala aquifer in the southern High Plains varies between 0 to 300 feet and depth to water ranges from 0 to 460 feet (Native and Smith, 1987). The saturated thickness is controlled by the subsurface topography of the Dockrum Group.

The Ogallala aquifer yields high quality water that can be used for domestic, agricultural, and industrial uses. Table 3 provides chemical data of water sampled from two windmills located northeast of the spill site. Both windmills are screened in the Ogallala aquifer. The average total dissolves solids (TDS) content of water sampled from these windmills is 475 ppm. The Water Quality Control Commission (WQCC) Standard for TDS is 1000 ppm.

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4.0 DESCRIPTION OF INVESTIGATIVE PROGRAMS

4.1 JANUARY 2001 SAMPLING PROGRAM

In response to the pipeline release report on December 29, 2000 to the NMOCD, ROC personnel conducted a preliminary site investigation in January 2001. The purpose of the investigation was to assess the lateral and vertical impact of the release on native soil.

ROC personnel dug and trenched 25 pits and collected soil samples at discrete depths. Plate 4 shows the sample locations and Table 4 provides the sample depths of each location. ROC personnel analyzed the soil samples for chloride using EPA method 9253. They analyzed for chloride because the pipeline that ruptured is used to carry water that contains relatively high concentrations of sodium chloride (NaCl).

4.2 MARCH 2001 FIELD PROGRAM

Hicks Consultants was contracted by ROC to expand the characterization and to recommend a remediation plan for the impacted soil. In March 2001, we implemented a field program that included sampling of surface soil and soil at discrete depths. We outlined the general approach in a letter to the New Mexico Oil Conservation Division (NMOCD) dated March 28, 2001.

Before we collected any samples, we created a rectangular grid that encompassed the area of the spill (Plate 4). We placed the origin of the grid 23-feet south of a fence and 60 feet west of the pipeline release. The fence, used to establish the axis of the sampling grid, runs east/west and separates the Cooper property from State of New Mexico land located to the north. On Plate 4, A-1 marks the origin of the grid. We located grid points east and south of this point using a spacing of 50 feet. Alphabetical letters identify grid points located east of the origin, and numbers distinguish grid points to the south.

4.2.1 SURFACE SOIL SAMPLING

We collected surface samples at each grid point shown in Plate 4 at a depth of two to six inches below ground surface. Samples collected from sample locations (i.e., grid points) with similar vegetation and soil characteristics as adjacent sample locations were combined in the field in order to create composite samples. When creating the composite samples, we used approximately the same mass of sample from each sample location. ROC personnel analyzed the soil samples for chloride using EPA method 9253. Table 5 shows how we created the composite samples.

4.2.2 DEPTH SAMPLING

We constructed three backhoe trenches. We dug each trench to a total depth of 4.5 feet in order to collect soil samples at discrete depths. An indurated layer of caliche encountered at a depth of 4.5 feet prevented sampling at greater depths with the backhoe. From each Pit, we collected soil samples from the following depth intervals: 0-0.25 feet, 0.25-0.5 feet, 0.5-1.0 feet, and 2.5-4.5 feet.

Plate 4 shows the locations of the three pits. Two of the pits were located in areas heavily stained by the spill and where vegetation appeared stressed or dead. We located the third trench (Pit 3) in an area where vegetation appeared to be unaffected by the spill and where surface indication of the spill did not exist. We installed Pit 3 to establish background soil chemistry and to monitor the efficacy of a soil restoration program.

We dug a fourth pit approximately 10 feet west of the pipeline release in a barren area with little to no vegetation. The total depth of this pit was 3.5 feet, where we encountered the uppermost surface of the caliche layer. We collected a single sample from this pit just above the caliche.

We submitted all soil samples from the pits to Assaigai Analytical Laboratories, Inc. (Assaigai) for analysis of benzene, toluene, ethylbenzene, xylenes (BTEX), naphthalene, common alkaline earth and alkali metals (Ca, Mg, K and Na), iron (Fe), Chromium (Cr) and chloride (Cl). Assaigai analyzed for BTEX and naphthalene by EPA method 8260A, metals by EPA method 6010A and chloride by EPA method 300.0. Organic constituents and chloride were extracted from the samples using water. For metals, the laboratory dissolved the soil in acid, yielding a total concentration of metals in both pore water and the solid matrix.

In addition to the above chemical analysis, we also submitted samples to the New Mexico State University (NMSU) Soil, Water, and Plant Testing Laboratory (SWAT). This laboratory performed a "standard soil test" of each sample collected from the pits. Appendix B provides a list of the chemical and physical soil characteristics evaluated by the "standard soil test". SWAT uses a saturated paste method (i.e. water mixed with sample) to extract constituents from the soil.

In addition to the depth discrete samples, we collected relatively undisturbed core samples from Pits 1-3. We collected the core samples by digging down 2.5 feet and driving a 1-foot section of 6-inch diameter PVC into the soil with the aid of a backhoe. We then removed the PVC with the core sample intact and wrapped it in plastic. We submitted the core samples to Dr. Jan Hendrickx's laboratory at the New Mexico Institute of Mining and Technology (NMIMT), where they evaluated the saturated conductivity of each sample.

4.2.3 DELINEATION OF THE SPILL BOUNDARY

On March 28, when we mapped the aerial extent of the spill, we observed no standing water. However, surface indications of areas impacted by the spill were evident. These indications included (1) stressed and dead vegetation, (2) stained vegetation and surface soil, (3) plant litter and other debris pushed to the perimeter of the spill by the flowing water, and (4) grass flattened by the spill. We used these surface indications and the grid to delineate the spill boundary.

4.3 VADOSE ZONE AND GROUNDWATER MODELING

4.3.1 OVERVIEW

We used HYDRUS-1D (Simunek et al., 1998) and a simple-mixing model to assist us in predicting potential impacts of the release and restoration alternatives to groundwater quality in the Ogallala aquifer. In addition, we used HYDRUS-1D to evaluate the efficacy of each restoration alternative (mechanical restoration, natural restoration, and in-place chemical amendment).

HYDRUS-1D is a modeling environment that can be used to assess the one-dimensional movement of water and solutes in unsaturated, partially saturated, or fully saturated porous media. Dr. J. Simunek and Dr. R. van Genuchten of the U.S. Salinity Laboratory developed the model (www.ussl.ars.usda.gov/MODELS/HYDR1D1.HTM). HYDRUS-1D is a finite element model that numerically solves the Richards' equation and Fickian-based advection dispersion equations. The Richards equation describes water flow, and the Fickian-base equations simulate heat and solute transport. Appendix C contains a more detailed description of HYDRUS-1D.

Because of the ability of HYDRUS-1D to describe unsaturated flow and solute transport, we used the model to simulate the movement of chloride from surface soil to the water table of the Ogallala aquifer. The flexibility of HYDRUS-1D allowed us to include major processes in the model that would influence the movement of chloride and water such as water uptake by plants, root growth, and soil heterogeneity.

To assess potential groundwater impairment of each restoration alternative, we applied HYDRUS-1D results to a simple mixing model we created using Microsoft Excel. The mixing model combined the volumetric fluxes of water and chloride of the Ogallala aquifer with the water and chloride fluxes predicted by HYDRUS for the vadose zone. In order to apply the HYDRUS results to the mixing model, we scaled the HYDRUS results to the aerial extent of impacted soil at the spill site. To provide a conservative estimate of potential groundwater quality impairment, we used only the upper 10-feet of the Ogallala aquifer in the mixing calculations. The Ogallala aquifer is about 110 feet thick in this area and dispersion throughout the saturated zone would significantly dilute any high chloride flux to groundwater. Nevertheless, we believe a 10-foot mixing zone provides a conservative estimate of the chloride concentration that would be expected in a monitoring well located immediately down-gradient from the spill site. Typical monitoring well screens are 15 feet in length with 10 feet of that length below the water table. Below is a brief description of how we simulated each restoration alternative using HYDRUS-1D:

1. Mechanical restoration: We assumed removal of the top 60 cm (2.0 feet) of soil and then modeled precipitation as a mechanism to leach chloride from underlying soil. We used precipitation data from Las Cruces. Because annual precipitation is 8 inches in Las Cruces and 15 inches in Hobbs, we multiplied the Las Cruces precipitation data by days (0.5 cm/day). We also assumed that amendment of gypsum to the soil minimized significant clay swelling. Swelling clay would reduce the hydrualic conductivity of the soil.

2. In-Place Chemical Amendment: We simulated application of 100 cm of water (3.3 acre-feet) to the surface over a period of 200 days (0.5 cm/day). We also assumed that amendment of gypsum to the soil minimized significant clay swelling. Swelling clay would reduce the hydrualic conductivity of the soil.

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3. Natural restoration: We relied only on precipitation to leach chloride from the surface soil. This simulation was also used to assess the immediate impact of the spill on soil. We used the same precipitation and PET data as number one above (mechanical removal).

For all simulations, we used a 4 meter-thick soil profile consisting of heavy clay and a 20-cm thick layer of caliche. We placed the caliche layer 1.35 to 1.55 meters below ground surface. We used a saturated hydrualic conductivity of 1.0 cm/day for the caliche and 0.5 cm/day for the heavy clay. We assumed a chloride concentration of 10,000 ppm for a brine spill of 20-cm (of standing water).

We ran two simulations for each alternative listed above. The first with a dispersivity of 200 cm, and the second with a dispersivity of 20 cm. We believe a dispersivity of 200 cm better reflects the uneven solute flux of real soil. Soil heterogeniety contributes to an uneven solute flux.

Parameters of the Ogallala aquifer used in mixing model calculations where obtained from investigations at the Linam Ranch Gasoline Plant (IT Corporation, 1993; Daniel B. Stephens, 1994). The hydraulic gradient was estimated at 0.003 feet per foot, and the hydraulic conductivity was estimated at 3.6 feet/day.

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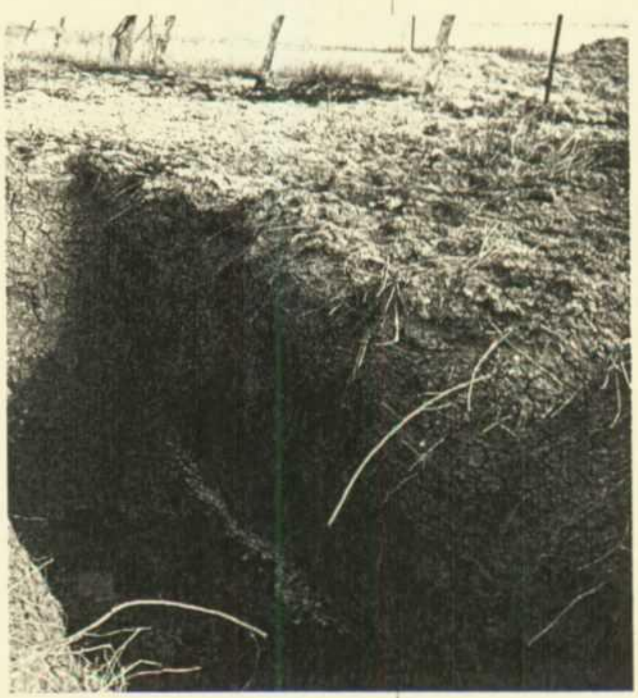
5.0 PRE-RELEASE SITE CHARACTERISTICS

5.1 SOILS AND VEGETATION

5.1.1 BACKGROUND SOILS

Figure 4 is a photograph of a soil pit trenched on State land approximately 20 feet north of the pipeline release. The photo shows the caliche layer that underlies the High Plains and dark clay of the Quaternary alluvium.

Figure 4: Photograph of a soil pit directly north of the release



To define pre-release soil characteristics, we trenched soil Pit 3 approximately 25 feet east of the release in an area unaffected by spill (see Plate 4). SWAT classified the soil texture of soils from this pit as clay and clay loam. Table 6 shows Assaigai's laboratory results for samples collected from Pit 3, and Plate 5 shows the distribution of chloride, sodium, and calcium with depth. Sodium concentration decreases with depth, and calcium concentration increases with depth. Chloride and the other metals analyzed show consistent concentrations with depth (Table 6). The average concentrations of chromium, iron, magnesium, and potassium are 14; 9,778; 2,758; and 3,048 mg/Kg soil, respectively. Chloride ranges from 182 to 502 mg/Kg soil with an average of 321 mg/Kg. Appendix D contains Assaigai's Laboratory reports.

In addition to the chloride concentrations of Pit 3, we also measured the chloride concentrations of surface soils located at grid points located outside the spill boundary (Plate 6). The average chloride concentration of these samples was 49 mg/Kg soil.

The higher chloride concentrations of Pit 3 relative to samples collected at grid points are the result of differences in laboratory and field protocols. Both laboratory and field protocols use water to extract chloride from soil samples. However, while the field methodology is clearly precise, the laboratory methodology is more accurate.

Table 7 shows results from the SWAT laboratory. The average pH, electrical conductance (EC), sodium absorption ratio (SAR), and cation exchange capacity (CEC) of samples collected between the land surface and a depth of 1.0 foot are 6.57 s.u., 4.04 mmhos/cm, 17.25, and 35.13 meq/100 g, respectively. The deepest sample (2.5-4.5 feet bgs) shows a higher pH due to the proximity of the caliche to the sample location and a much lower SAR (1.93) than the shallower samples. The concentration range of chloride in extraction water of all samples from Pit 3 is 692-1567 mg/L. Appendix E provides SWAT's complete analysis.

5.1.2 VEGETATION

Figure 5 is photograph showing the vegetation at the spill site. Gramma grasses and mesquite are dominate vegetation types at the spill site. Because the site is located in slight depression vegetation is abundant relative to surrounding areas.

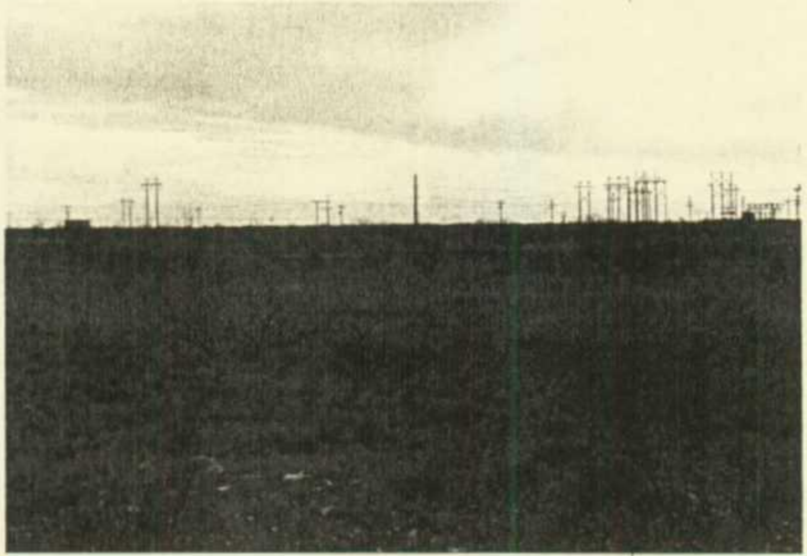


Figure 5: Photograph of the vegetation at the site

5.2 SITE HYDROGEOLOGY

Well logs from a groundwater investigation at the Linam Ranch Gasoline Plant (Daniel B. Stephens & Associate, Inc., 1994) show that the local hydrogeology is consistent with the regional hydrogeologic description of Section 3.3. The Ogallala Formation near the spill site consists of very fine-to-medium-grained sand. Well logs of the Linam Ranch show that the caliche layer above the Ogallala Formation varies in thickness from 0-24 feet with a median thickness of 13 feet. When installing four soil pits during the March 2001 field campaign, we encountered the caliche layer at depths of 3.5 to 4.5 feet bgs.

We estimate the groundwater elevation at the field site at 3,657 feet, and depth to water at approximately 60 feet. The hydraulic conductivity of the aquifer near the spill site has been estimated at 1.7-5.5 feet/day (IT Corporation, 1993).

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As described in earlier, Table 3 presents groundwater chemistry data of samples collected from nearby windmills in March 2001.

5.3 HUMAN AND ECOLOGICAL RECEPTORS

Human and ecological receptors in this area of Lea County are cattle and water supply wells. The closest reported down gradient water well is approximately 2.5 miles from the site according to the New Mexico Office of the State Engineer's records. We field-checked the position of the well and were unable to locate it.

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6.0 RELEASE CHARACTERISTICS AND POST-RELEASE CHARACTERISTICS

6.1 DURATION, FLOWRATE AND CHEMISTRY OF RELEASE

Before the December 29, 2000 pipeline inspection and consequent discovery of the release, ROC personnel had conducted a similar inspection on September 13, 2000 and found no evidence of a release. During the December 29 inspection, ROC discovered surface flow from the release point and about 1-inch of standing water in the lower elevation area adjacent to the pipeline right-of-way. Interviews with ROC staff regarding the characteristics of the release suggest that the observed surface flow began sometime before the December 29 inspection.

The clay-rich soil that lies beneath the pipeline and disturbed fill that covers the pipeline creates a preferential flow path to the ground surface for any pipeline release.

ROC staff did not measure the flowrate of the release. Instead, ROC responded immediately, using a vacuum truck to remove the standing water and repaired the leak. We were unable to estimate the flowrate at this time.

We know that the pipeline carries produced water from one tank battery and wastewater from the Linam Ranch Gasoline Plant. We know that fluid character is highly variable from day to day and week to week. Therefore, we elected to forego sampling of the pipeline liquids as a means of characterizing the chemistry of the release. Based on soil sample results from the January and March 2001 field programs, the pipeline rupture released water with a high concentration of sodium chloride and only trace amounts of volatile organic compounds (BTEX and naphthalene). Chromium, magnesium, iron, calcium, and potassium concentrations of background samples and samples collected within the spill boundary are similar, indicating that the spill did not contain significant quantities of these metals.

6.2 SURFACE EXTENT OF RELEASE

Table 4 presents results from the January 2001 field campaign. The average chloride concentration of impacted surface soil is 2,282 mg/kg soil, and the median concentration is 2,550 mg/kg. The range of chloride concentration in the surface soil was 210 to 3,600 mg/kg. The highest chloride concentration was observed at sample location number 3 approximately 225 feet south of the release (see Plate 5).

Plate 6 shows the aerial extent of land impacted by the release based primarily on the presence of stressed and stained vegetation observed during the March 2001 field program. The total area of impacted land is approximately 1.0 acre. Plate 6 also provides chloride concentrations measured during the March 2001 field campaign. The average soil chloride concentration of sample locations located within the spill boundary (the same area sampled in January) is 1,141 mg/Kg soil with a median of 1,000 mg/Kg. The average chloride concentration of samples located in areas that appeared unaffected by the release was 49 mg/Kg. Table 5 provides the observed chloride concentrations and surface characteristics of each sample location.

We sent samples from Pits 1, 2, and 3 to Assaigai and SWAT. Assaigai results for chloride concentrations are 1,990; 3,170; and 296 mg/kg, respectively. SWAT results, using a different analytical protocol showed a similar relationship (see table 6). Pit 3 is in an area unaffected by the release and represents background conditions.

6.3 VERTICAL EXTENT OF RELEASE

Tables 6 and 7 present chloride data from the four backhoe trenches (Pits 1-4), and Plate 5 shows chloride variability with depth at Pits 1-4. At Pit 3, chloride showed little variability with depth, ranging from 182 to 502 mg/kg. The average chloride concentration at Pit 3 was 321 mg/kg. Pits 1, 2, and 4 all show greater chloride concentration relative to Pit 3. In the areas of Pits 1, 2 and 4, the release has infiltrated to the top of the caliche, which is located 3.5 to 4.5 feet bgs. Chloride concentrations decrease with depth, samples from immediately above the caliche are about 50% less than samples collected closer to the land surface. Appendix D contains all analytical results from Assaigai.

The field data in table 4 also provide information regarding the vertical distribution of chloride in the soil. These data also show the same decline in concentration with depth. Using field techniques, samples above the caliche exhibit 50% less chloride than the shallow surface soil.

6.4 INFLUENCE ON SOIL AND VEGETATION

6.4.1 METALS AND CHLORIDE CONCENTRATIONS IN SOIL

The release has resulted in elevated levels of sodium chloride in soil. The lateral and vertical extent of the chloride impact is discussed above in sections 6.2 and 6.3.

Sodium concentrations of soil in Pits 1 and 2 were greater than the background concentrations observed in Pit 3 (see Plate 5 and Tables 6 and 7). The sodium concentration of Pit 4 measured above the caliche was also greater than background. All pits showed a decrease of sodium concentration with depth.

Pits 1, 2 and 4 contained chromium, iron, magnesium and potassium at concentrations similar to background (table 5). These pits showed elevated concentrations of calcium relative to background. In all pits, calcium was greatest near the caliche (see plate 5).

6.4.2 VOLATILE ORGANIC COMPOUNDS IN SOIL

BTEX was not detected in the soils samples of Pit 3 (table 6). The soil sample of Pit 4 contained 12.1 milligrams of BTEX plus naphthalene per Kilogram of soil. This concentration is much greater than the concentrations observed in samples from Pits 1 and 2 (Table 6). The highest concentrations observed at Pits 1 and 2 were 0.013 and 0.963 mg/Kg soil, respectively.

6.4.3 OTHER SOIL CHARACTERISTICS (SWAT ANALYSIS)

Table 7 presents results of the SWAT analysis. The SWAT laboratory classifies soil within the spill boundary as clay loam and clay. The spill has elevated the electric conductance (EC), sodium absorption ratio (SAR), and percent of exchangeable sodium (ESP) and extractable chloride of the soil. The cation exchange capacity (CEC) of impacted soil has decreased relative to background. Appendix E provides the SWAT analysis of each sample.

6.4.4 HYDRUALIC PROPERTIES

We are waiting for final results of the hydrologic analysis (i.e., saturated hydraulic conductivity). Prelimanary results suggested that the hydrualic conductivity of unaffected soil is 0.2 in/day (0.5 cm/day) and affected soils is 0.02 in/day (0.05 cm/day). The lower conductivity of the affected soil is most likely due to the swelling of clay caused by high concentration of sodium in the pipeline release.

6.4.5 VEGETATION

The high concentrations of salt (sodium chloride) have resulted in stressed and dead vegetation. For example, gramma grasses within the spill boundary appear gray and pale yellow. Whereas, gramma grasses in unaffected areas are green. We could not determine the impact of the spill on mesquite during the March 2001 field program because mesquite was still dormant.

6.5 INFLUENCE ON THE DEEP UNSATURATED ZONE AND THE OGALLALA AQUIFER

Currently, we have no chemical or physical analyses of the deep subsurface at the site. However, the soil samples show a significant decline in chloride concentration with depth. In the absence of significant precipitation, we expect the remaining 50 feet of the unsaturated zone to attenuate and/or absorb the released water. We do not believe that significant amounts of chloride have entered the Ogallala aquifer at the time of writing. Therefore, we did not simulate the movement of the release through the unsaturated zone. We discuss our simulations of water and chloride migration during and after soil restoration in the next section of this report.

7.0 EVALUATION OF SURFACE SOIL RESTORATION ALTERNATIVES

7.01 THE ALTERNATIVE OF NATURAL RESTORATION

Passive or natural restoration may be effective where chloride concentrations are low or limited to the uppermost soil zone. At this site, the land owned by the State of New Mexico may fit these criteria.

7.02 THE ALTERNATIVE OF IN-PLACE CHEMICAL AMENDMENT

In-Place Chemical Amendment uses the analytical parameters discussed earlier to determine the amount of chemicals and water needed for soil restoration. API Publication 4663 provides formulae and worksheets to calculate the amount of chemical and water needed to treat the soil then flush the salt to a depth where it will not impair plant growth. For the subject site, theparameters employed by the worksheets are presented in the table on the following page.

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Parameter	Criteria	Site Characteristic
Texture of Soil	Soil must drain well so as not to create ponding when water is added	High clay content may require engineered increased permeability
pH of Soil Saturation Paste	Must not be too acidic or too basic (between 5.5-8.5)	The soil has a neutral pH of 7
Erosion Potential	Errosion potential must be low enough that water will not wash away soil and create gullies	The site is flat and not subject to erosion of disturbed soil
Electroconductivity (EC) The percent decrease in EC (1-(target EC / current EC)*100) is used with the annual precipitation/ evaporation (precipitation – evaporation) index and soil texture to determine the amount of supplemental water needed to flush salts from soil	If the annual precipitation/evaporation index is very low (<-12 to-28), the EC is very high then large amounts of supplemental water is needed. If supplemental water is unavailable due to cost or location, then fine grained, highly impacted soils in an arid climate may not be acceptable for in-situ chemical amendment.	Due to a relatively high EC and low permeability, large amounts of water must be available for irrigation. Because of a probable monitoring well requirement, a supply well will be available for irrigation use at the spill site.
SAR-Soil Adsorption Ratio The SAR is used to calculate the Exchangeable Sodium Percentage (ESP) (see below)	ESP and the CEC (below) are used in a calculation to determine the amount of chemical amendment needed (ESP*CEC *.078=lbs gypsum/sq feet). Ten to thirty tons of gypsum per acre appears to be a normal range.	In an acceptable range. Using the ESP and CEC from the most highly impacted area of the spill, the amount of gypsum needed for 67% (2800C sq. feet) of an acre is approximately 20 tons.
CEC-Cation Exchange Capacity	The higher the number, the more chemical amendment needed	Acceptable-see above
ESP-Exchangeable Sodium Percentage	The higher the number, the more chemical amendment needed	Acceptable-see above
Precipitation Evaporation Index	Evaporation may necessitate the need for covering	PEI is very low (-38); need covering

Using the parameters listed above, we calculated that between 15-25 tons of gypsum are required to effectively return the sodium/calcium ratio to acceptable conditions, thereby restoring the soil permeability, at the 1-acre site. Although the worksheets suggest that approximately 2 acre-feet of water will dissolve the gypsum into the soil, we will monitor the application and use only sufficient water to restore soil permeability. Then, the API worksheets suggest that application of up to 2 acre-feet of supplemental water will effectively flush the chloride from the root zone into the subsoil. Again, we will carefully monitor the application rate. Finally, we will apply water periodically to move the chloride to at or below the caliche horizon, below the depth which osmotic forces during drought will cause upward migration of chloride to the root zone. These calculations of water application assume minimal evaporation.

For the subject site, in-place chemical amendment will follow the process outlined below.

1. We will till the uppermost two feet of soil to incorporate surface organic matter (grass, roots, etc.) into the soil and increase permeability. Then, we will add 10-30 tons of gypsum and re-till the soil.

2. Over the next several months, we will apply about two acre-feet of water to dissolve the gypsum into the soil and subsoil. We will construct a simple flood irrigation system using several distribution pipes. To minimize evaporation, black plastic will cover most of the site. We will "tent" the plastic to direct precipitation to the soil. Irrigation will occur in pulses of about ½ to 2 inches every week. The application rate will be determined in the field and will depend upon the permeability of the soil. To monitor the saturation of the soil, we will install tensiometers at 1-foot, 2.5 feet and 4 feet at two locations. We will use readings from the tensiometers to adjust the application rate. We also propose a 4-inch well located about 100-300 feet down gradient from the site. The well will serve as a supply well for irrigation water.

3. After restoration of soil permeability through the application of gypsum, we will use about two-acre feet of water to flush the chloride below the root zone. We will employ the same flood irrigation system described above, applying as much as 1-2 inches per week. The amount of water

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applied to flush the chloride is limited by the permeability of the clay-rich horizon underlying the root zone. Moni toring the system with the tensiometers will allow appro priate application of chemical amendment and water.

4. After chloride is below the root zone, we will remove the plastic evaporation barrier and seed the site with native grass.
5. After seeding, periodic application of supplemental water will continue to flush chloride to a depth at or below the caliche horizon. We anticipate application of 1-2 inches of water per month during the typically dry seasons of fall and winter.
6. The project ends when soil sampling confirms chloride flushing.

7.03 THE ALTERNATIVE OF MECHANICAL RESTORATION

As discussed earlier, mechanical restoration uses heavy equipment to remove the impacted soil or dilute the effect of the impact by mixing affected soil with underlying or nearby soil unaffected by the spill.

We concluded that restoration by dilution was not practical. Although the chloride content of the soil at the 4-foot depth is 50% less than near surface soil, this deeper impaired soil is 2-5 times greater than background. Mixing the 4-foot soil column at Pit 1, for example, would yield a chloride concentration of about 1,500 mg/Kg soil. This concentration is above the tolerance level for the native grasses. Incorporating unimpaired soil adjacent to the spill significantly expands the size of the disturbance. We concluded that mechanical restoration by removal and replacement is the better of the two mechanical restoration alternatives.

Mechanical restoration by removal and replacement involves:

1. excavation of sufficient impaired soil to permit successful natural restoration,
2. transportation to a facility that accepts salt impacted media,
3. restoration and/or long term monitoring of the soil at the centralized facility (e.g. landfarm).
4. placement of new soil of the same general type in the excavation, and

7.1 SOIL AND VADOSE ZONE MODELING

1. Natural Restoration: Preliminary results show that precipitation as the sole mechanism for chloride removal is not effective at reducing chloride concentration in the soil water of the root zone. The results also show that over 5000 days the chloride concentration shows high variability; for example, between 2000 and 3000 days chloride concentration fluctuates between 3500 and 6000 mg/L (ppm) (Appendix F).
2. In-place chemical amendment: Preliminary results show that soil leaching is the most effective mechanism for removing chloride from the root zone. The application of 39 inches (100 cm) of water for 200 days results in an immediate chloride concentration decrease. In addition, chloride concentration shows little variability past 1000 days.
3. Mechanical Restoration: Preliminary results show that mechanical removal of only the upper 2 feet (60 cm) of surface soil causes a slight decrease in chloride concen tration in the soil water of the subsoil. In addition, ap proximately 13 years of precipitation are needed before chloride concentration returns to background lev els. Background soil water concentration measured at Pit 3 is approximately 1100 mg/L (ppm). Like natural restoration, chloride concentration fluctuates significantly.

7.1.1 MIXING MODEL

Our preliminary modeling results have been used to assess the efficiency of each restoration alternative. A future draft will include results from the mixing model and assess potential groundwater quality impairment.

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8.0 DESCRIPTION AND JUSTIFICATION OF PROPOSED REMEDY

We propose in-place chemical amendment as the primary soil restoration strategy. The design of the remedy is generally outlined in the previous section of this report. We believe in-place chemical amendment offers several advantages over excavation and replacement. First, replacement of native soil with soil of different characteristics could conflict with the existing ecosystem. Second, excavation of impaired soil often simply transports a contamination from one site (the spill site) to another site, such as a landfill. Third, the environmental damage due to excavation equipment, transport trucks, etc. is significantly greater than the impact from chemical amendment. In addition to these advantages, preliminary modeling results show that in-place chemical amendment is the most effective remedy.

In-place chemical amendment is widely used to restore soils damaged by high water tables, poor agricultural practices, and oilfield releases. When implemented and monitored by professionals, this strategy can show dramatic results in a relatively short time.

We also propose to compare the effectiveness of in-place chemical amendment to natural restoration and to excavation and replacement. We propose that the impacted property north of the fence line, on state land, undergo natural restoration. South of the fence line, we propose excavation and soil replacement for the southernmost quarter of the site.

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9.0 IMPLEMENTATION SCHEDULE

May 1-4 2001

- Present draft plan to landowner.
- Present plan to NMOCD and obtain input.
- Obtain soil samples from state land
- Meet with potential contractors to perform work
- Obtain initial comments from landowner and NMOCD

May 14-18

- Submit final plan to landowner and NMOCD.

May 21-25

- Answer questions and address comments of landowner and/or NMOCD.
- Order materials and prepare for field program.

May 28-June 15

- Excavate and remove soil from southern quarter of site
- Import and place clean soil into excavation
- For the remainder of the site, till uppermost 1-2 feet of soil to incorporate vegetation
- Observe soil excavation/removal and tilling process to develop more detailed description of soil profile and char acteristics throughout the site, sample subsoil for chloride as necessary
- Add 15-25 tons of gypsum to tilled soil
- Drill water supply well and install submersible pump
- Install one 100-barrel tank and plumbing to well
- Test groundwater pumping system, fill storage tank, sample groundwater

- Install irrigation system
- Install rain gauge at storage tank and tensiometers in gypsum/soil area
- Install fence around site
- Complete any remaining installation tasks
- Brief test of irrigation system for leaks and operation characteristics
- Obtain initial tensiometer measurements, instruct Rice personnel
- Implement first supplemental water application (1/2 inch) to dissolve gypsum into soil
- Observe infiltration patterns (horizontal and vertical)
- Adjust irrigation system as required
- Re-test system after adjustments
- Finally, install black plastic

June 15-September

- Apply water at rate of 1-2 inches per week (including rainfall events)
- Sample soil in mid August to monitor effect of gypsum amendment, adjust water application rates, add gypsum to irrigation water as required
- Sample soil at various depths in late September to moni tor chloride migration

October-November

- Apply 2 inches of water per week to flush chloride from root zone
- Remove black plastic and seed with native grass in No vember
- Sample soil at various depths in late November to monitor chloride migration

December 2001-June 2002

- Continue supplemental irrigation as required to flush chloride from clay-rich subsoil
- Sample soil at various depths in late May to monitor chlo ride migration

July

- Submit final restoration report to landowner and NMOCD
- Remove restoration equipment as required
- Return site to grazing

TABLES

Table 1. Pearl Precipitation Data

	Average Maximum Temperature (F)	Average Minimum Temperature (F)	Precipitation (inches)	Snow Fall (inches)
January	56.2	26.0	0.40	1.2
February	60.9	29.5	0.42	1.1
March	68.1	35.3	0.40	0.4
April	77.0	44.3	0.61	0.1
May	83.8	53.2	1.66	0.0
June	91.0	61.3	1.84	0.0
July	92.3	65.1	1.82	0.0
August	90.7	63.8	2.10	0.0
September	84.4	56.9	2.30	0.0
October	76.4	46.8	1.27	0.1
November	65.0	34.4	0.46	0.8
December	57.8	27.8	0.51	1.2
Annual	75.3	45.4	13.79	5.0

Data provided by the Western Regional Climatic Center (www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?nmpear) and represent month averages from 1915 to 1996 recorded at the Pearl weather station in Section20 of Township-19-South, Range-36-East.

Table 2. Lea County Regional Airport Precipitation Data

	Precipitation (inches)
January	0.26
February	1.80
March	1.08

Table 3. Water Quality of the Ogallala Aquifer

Parameter	Units	Windmill	
		Weber	North
TDS	mg/L	378	572
Bicarbonate	mg/L	174	228
Carbonate	mg/L	nd	nd
Chloride	mg/L	39.8	63.6
Nitrate	mg/L	1.88	4.14
Sulfate	mg/L	48.1	88.9
Calcium	mg/L	69.8	101
Iron	mg/L	0.06	0.23
Magnesium	mg/L	11.4	17.5
Potassium	mg/L	2.7	2.8
Silicon	mg/L	20.6	22.0
Sodium	mg/L	33.0	56.2
Zinc	mg/L	0.03	0.06
Location Relative to Site	miles /direction	2.1 /NE	1.4 /NE

not detected (nd)

Table 4. January 2001 Surface Soil Chloride Concentrations (mg/kg soil)

Sample Locations	Sample Depths (feet bgs)						
	0.01	**1**	**2**	**3**	**5**	**7**	**8**
1	2500	1800	1700	1500	ns	ns	ns
2	210	ns	ns	ns	ns	ns	ns
3	3600	300	1900	1700	ns	ns	ns
4	2800	2200		1900	ns	ns	ns
5	2900	2600	2200	1900	ns	ns	ns
6	2700	2800	2200	1900	ns	ns	ns
7	3300	2900	2300	1900	ns	ns	ns
8	1800	1500	1300	1100	ns	ns	ns
9	3000	2700	2200	1800	ns	ns	ns
10	300	ns	ns	ns	ns	ns	ns
11	940	430	ns	ns	ns	ns	ns
15	ns	ns	ns	450	430	430	ns
16	ns	ns	ns	1200	960	960	800
17	ns	ns	ns	510	540	510	ns
18	ns	ns	ns	920	520	480	ns
19	ns	ns	ns	950	970	1200	ns
20	ns	ns	ns	900	510	850	ns
21	ns	ns	ns	200	ns	ns	ns
22	ns	ns	ns	1200	850	750	ns
23	ns	3600	1850	1300	875	ns	ns
24	ns	2500	1500	800	800	ns	ns
25	ns	1800	1800	1600	1600	ns	ns
26	ns	3000	2700	1800	1200	ns	ns
27	ns	1300	900	600	1700	720	ns
28	ns	1800	1500	800	1700	700	ns
Median	2550						
Average	2282						
Standard Deviation	910						

*not sampled (ns)

Table 5. Soil Chemistry of Backhoe Trenches

	Sample Depth (feet bgs)	Extracted BTEX + Naphthalene (ppm)	Extracted Chloride (ppm)	Digested Calcium (ppm)	Digested Chromium (ppm)	Digested Iron (ppm)	Digested Magnesium (ppm)	Digested Potassium (ppm)	Digested Sodium (ppm)	Sample Date
Pit 1	0.0-0.25	nd	1990	2450	15.9	10700	2620	3410	4240	3/28/01
Pit 1	0.5-1.0	nd	1870	2510	15.9	10900	2820	3300	3530	3/28/01
Pit 1	2.5-4.5	0.013	956	10500	16.9	11500	3960	3040	1060	3/28/01
Pit 2	0.0-0.25	0.006		3170	14	9920	2490	2990	3180	3/28/01
Pit 2	0.25-0.5	0.095	1860	3750	15.9	10700	3260	3250	3100	3/28/01
Pit 2	0.5-1.0	0.963	1080	13400	15.4	10400	3550	2550	890	3/28/01
Pit 2	2.5-4.5	0.135	486	15600	14.3	9680	3600	2310	686	3/28/01
Pit 3	0.0-0.25	nd	296	2970	11.7	8410	2080	2760	846	3/28/01
Pit 3	0.25-0.5	nd	304	3820	14.3	10000	2610	3120	506	3/28/01
Pit 3	0.5-1.0	nd	502	4570	14.8	10600	3050	3210	210	3/28/01
Pit3	2.5-4.5	nd	182	7730	14	10100	3290	3100	176	3/28/01
Pit 4	Above Caliche	12.085	1450	9270	15	10500	4150	2690	1700	3/28/01
average of Pit 3 samples	-	nd	321	4773	14	9778	2758	3048	435	
standard deviation	-	nd	133	2077	1	949	532	198	312	

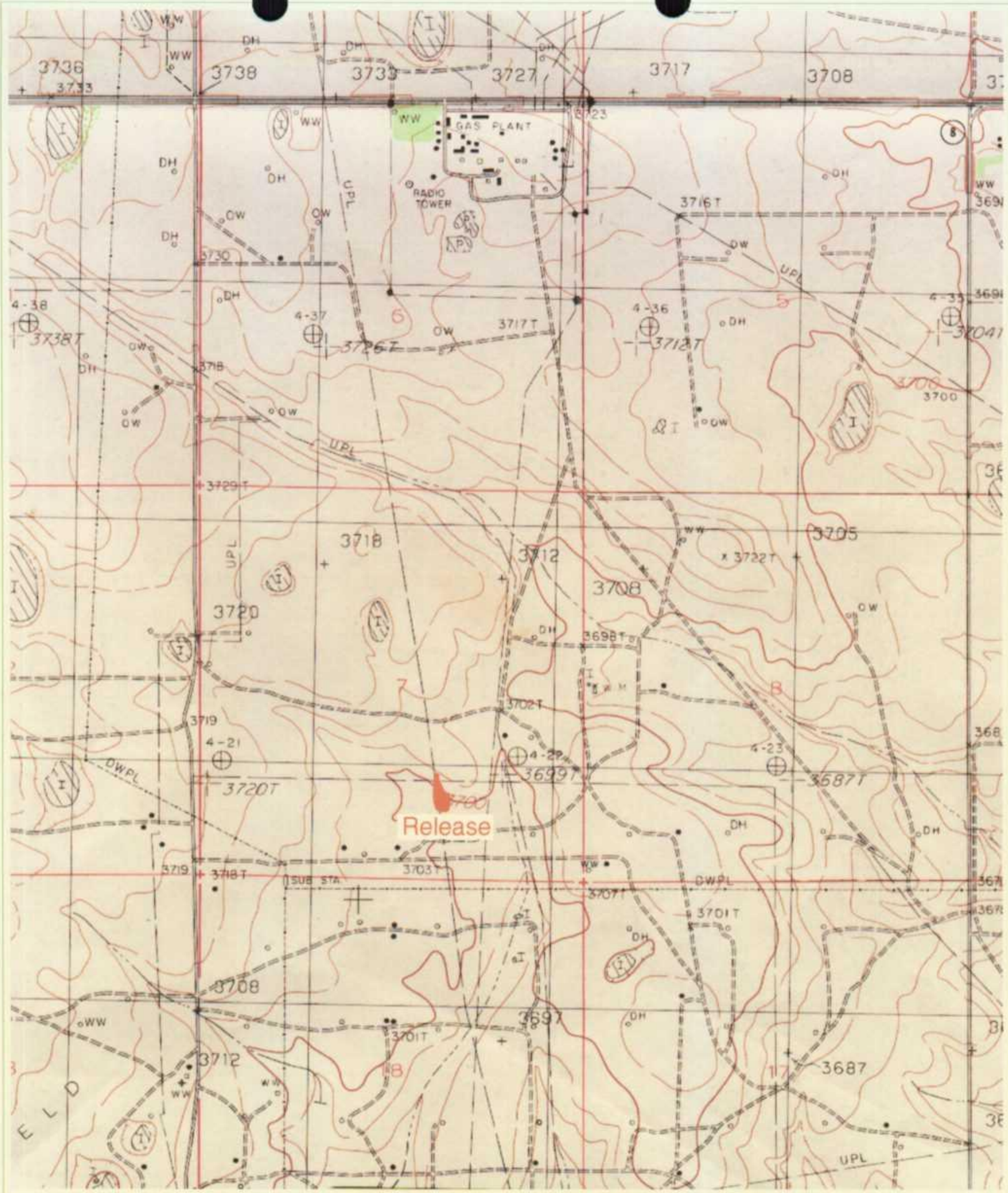
Table 6: SWAT Data

		SWAT Test Parameter							
Sample Location	**Depth (feet)**	**pH**	**EC (mmhos/cm)**	**SAR**	**Exchangeable Na (%)**	**Organic Matter (%)**	**Texture**	**Chloride (mg/L)**	**CEC (meq/100 gr)**
Pit 1	0.0-0.25	6.59	24.1	44.97	39.4	3.90	clay loam	8086	29.2
Pit 1	0.5-1.0	7.60	22.7	48.37	41.2	1.72	clay loam	8689	24.7
Pit 1	2.5-4.5	7.37	12.1	10.05	11.9	0.50	clay loam	4330	30.8
Pit 2	0.25-0.5	7.26	27.7	33.90	33.9	1.20	clay	11817	30.8
Pit 2	0.5-1.0	7.33	11.6	10.95	13.0	1.04	clay	4458	33.3
Pit 2	2.5-4.5	7.48	8.59	9.40	11.2	1.06	clay	3220	32.8
Pit 3	0.0-0.25	6.57	4.39	10.97	13.0	1.38	clay loam	1361	30.6
Pit 3	0.25-0.5	6.53	3.05	20.69	22.6	1.03	clay loam	816	36.2
Pit 3	0.5-1.0	6.62	4.69	20.10	5.1	1.72	clay	1567	38.6
Pit 3	2.5-4.5	7.40	3.68	1.93	1.6	1.48	clay loam	692	35.8

Table 7. March 2001 Field Data

Sample Location	Chloride (mg / Kg soil)	Vegetation and Soil Characteristics
A1	100	stiff brown clay, stressed vegetation to the east
A2	50	stiff brown clay, stressed vegetation to the east
composite: B1, B2 and C2	1475	brown clay, stressed vegetation
B3	600	silty brown clay, stressed vegetation
composite: B4 and B5	50	silty brown clay, vegetation not stressed
composite: B6 and B7	15	stiff dark brown clay, vegetation not stressed
B8	50	brown clayey silt, vegetation not stressed
C1	3050	stiff black clay, stressed vegetation
C3	1100	not assessed
composite: C4, C5, D4 and D5	1000	stiff black clay, stressed vegetation
composite: C6, C7, D6 and D7	600	stiff black clay, stressed vegetation
composite: C8 and D8	1400	stiff dark brown to black clay, stressed vegetation
D1	400	brown silty clay, transition between stressed and non-stressed vegetation
D2	850	dark brown clay, very moist soil, stressed vegetation
D3	1800	stiff dark brown clay, moist soil, stressed vegetation
E1	50	brown silty clay, vegetation thin but not stressed
composite: E2 and E3	1000	brown silty clay, stressed vegetation
composite: E4 and E5	50	slightly stiff brown clay with silt, vegetation not stressed
E5	ns	ns
composite: E6, E7 and E8	25	stiff black clay, stressed vegetation

PLATES



Map source: USGS 7.5 minute Monument North, New Mexico quadrangle map

1000 0 2000 feet

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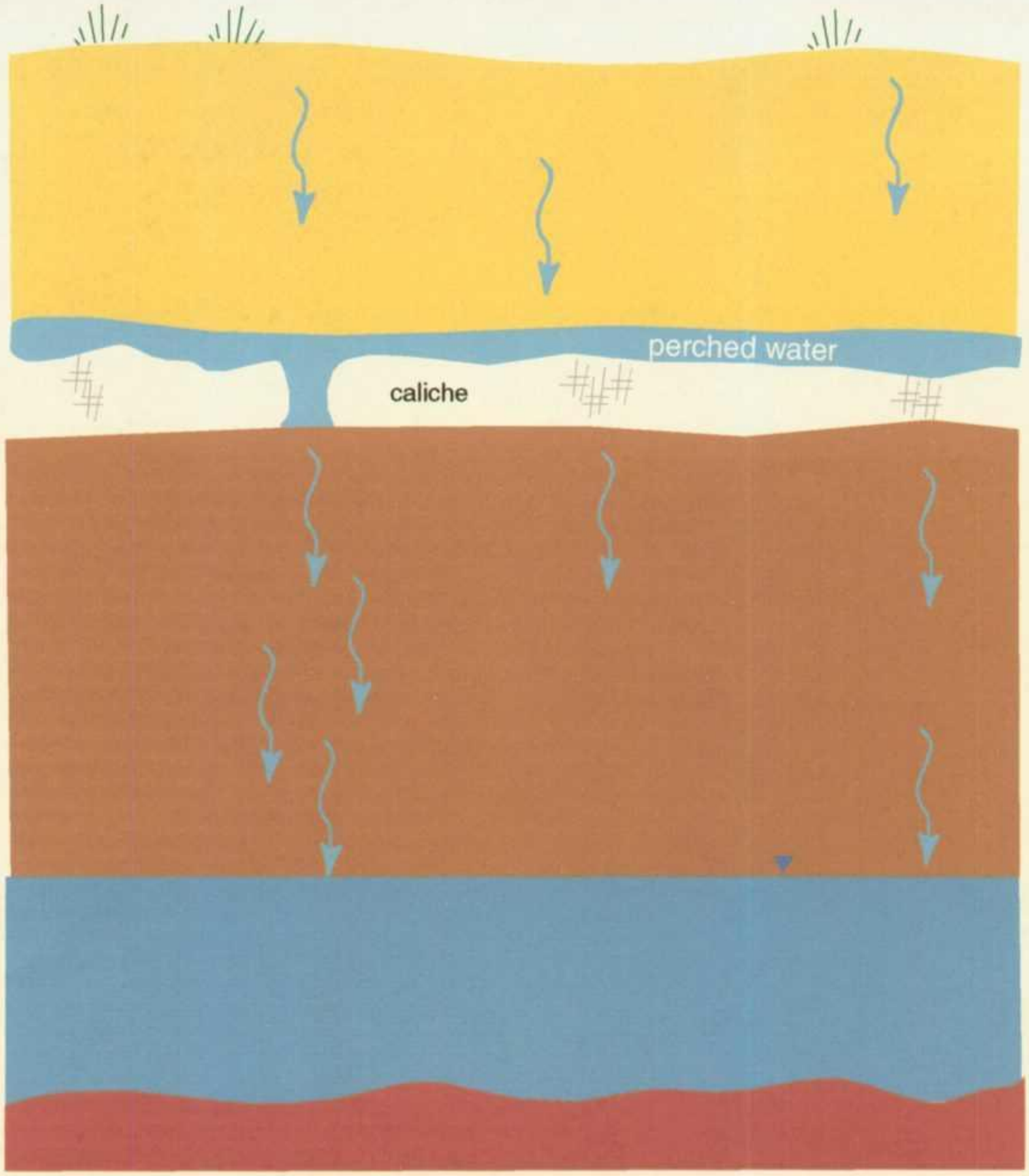
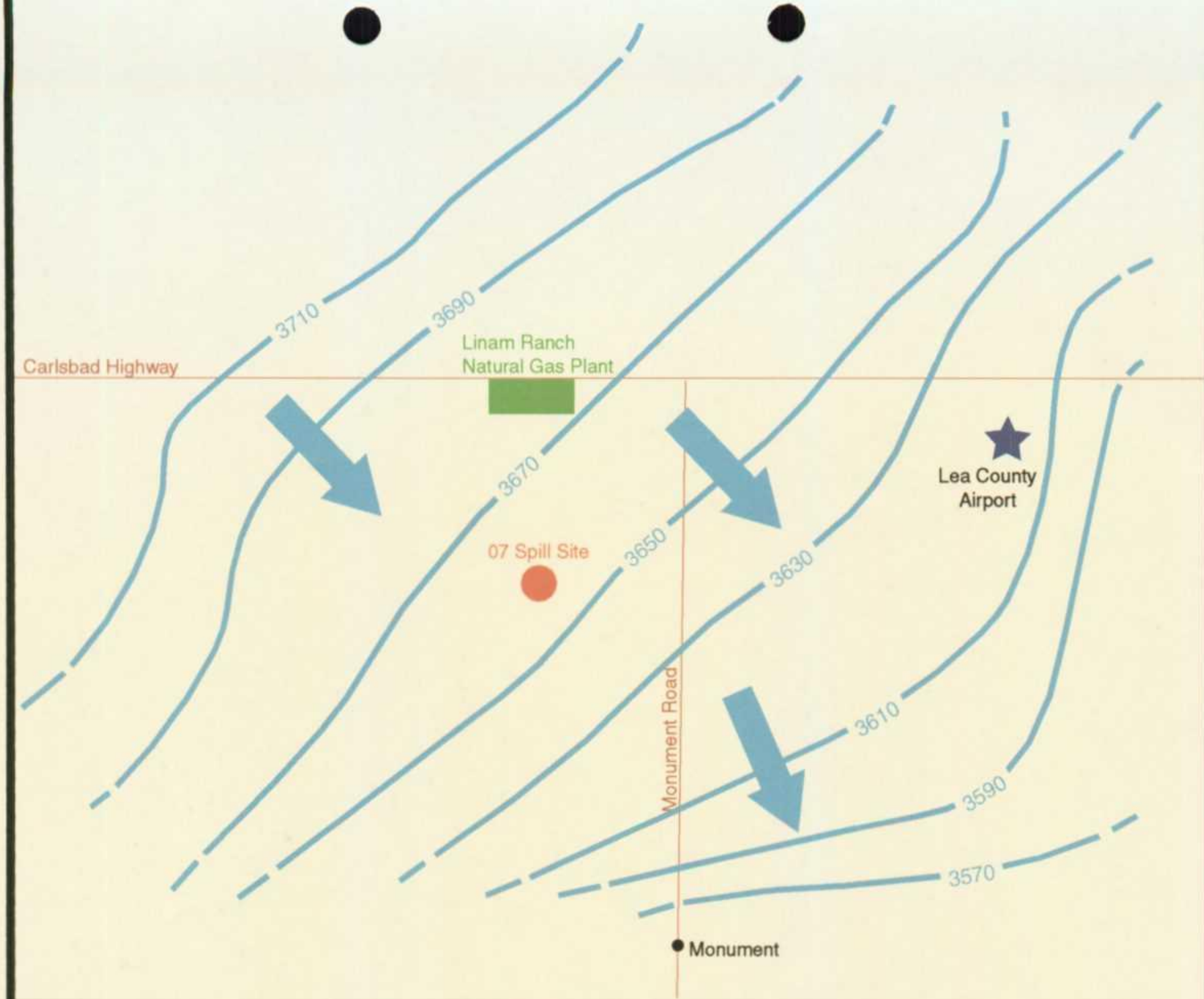
Rice Operating Company	Plate 1
Topographic Map	April 18, 2001



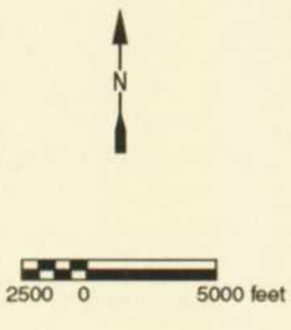
Legend

- Alluvial soils
- Ogallala Formation
- Ogallala Aquifer
- Dockum Group
- Unsaturated flow
- Water table

R.T. HICKS CONSULTANTS, LTD. 4665 Indian School Road NE Suite 106 Albuquerque, NM 87110 505.266.5004 Fax: 505.266.7738	Rice Operating Company	Plate 2
	Schematic of Typical Subsurface High Plains Hydrogeology	April 18, 2001



Map source: Map modified from Daniel B. Stephens & Associates, Inc. (1994)



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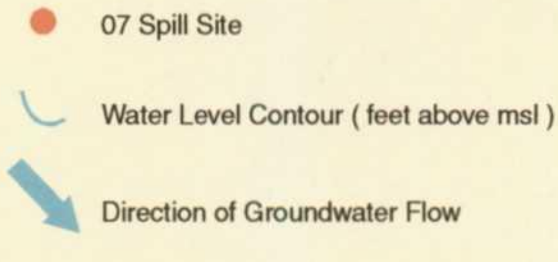

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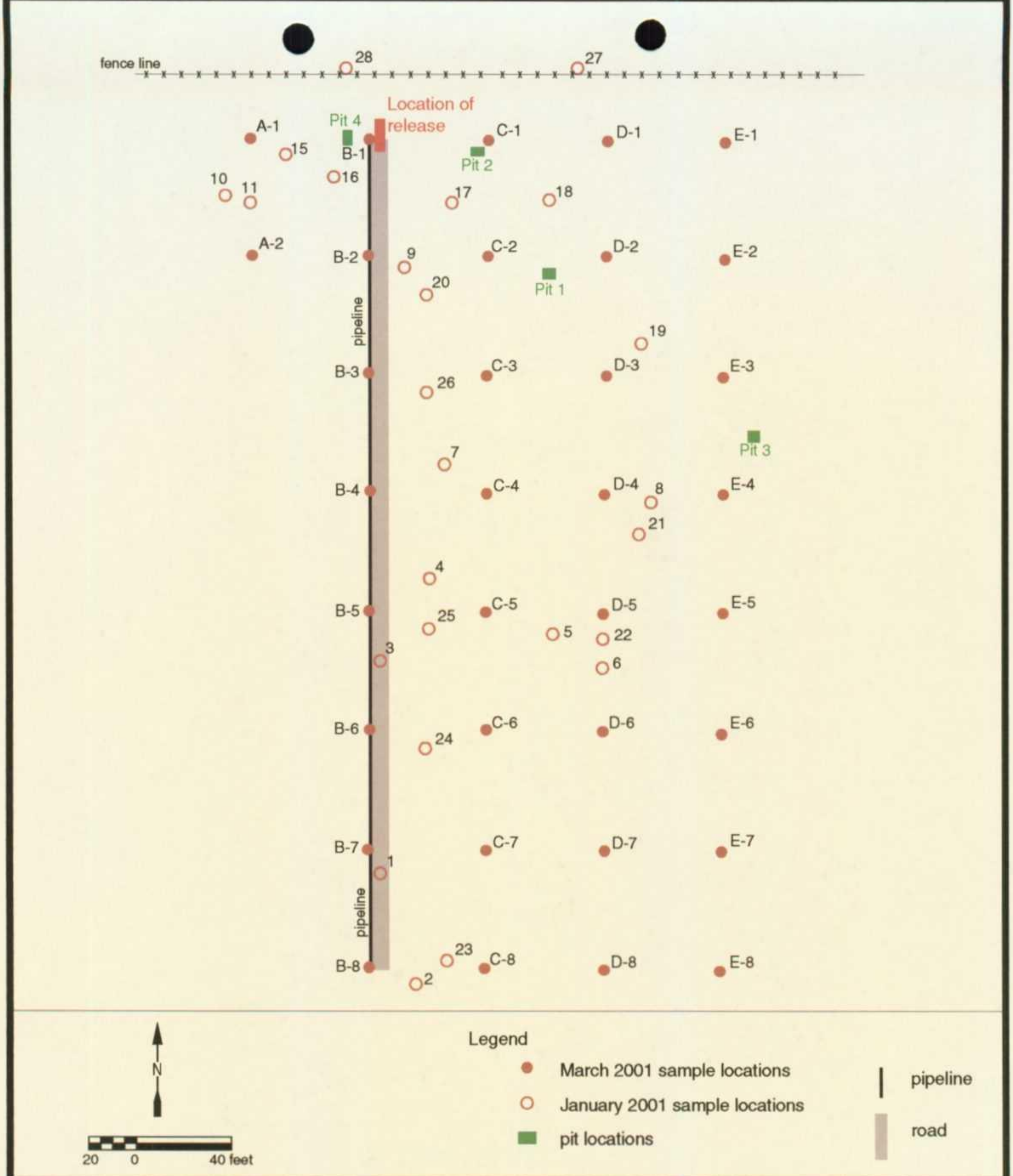
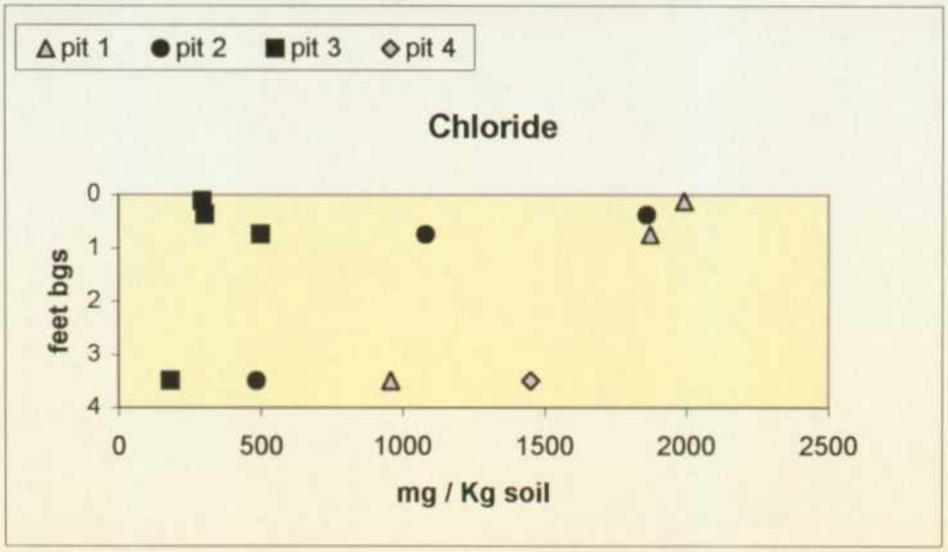
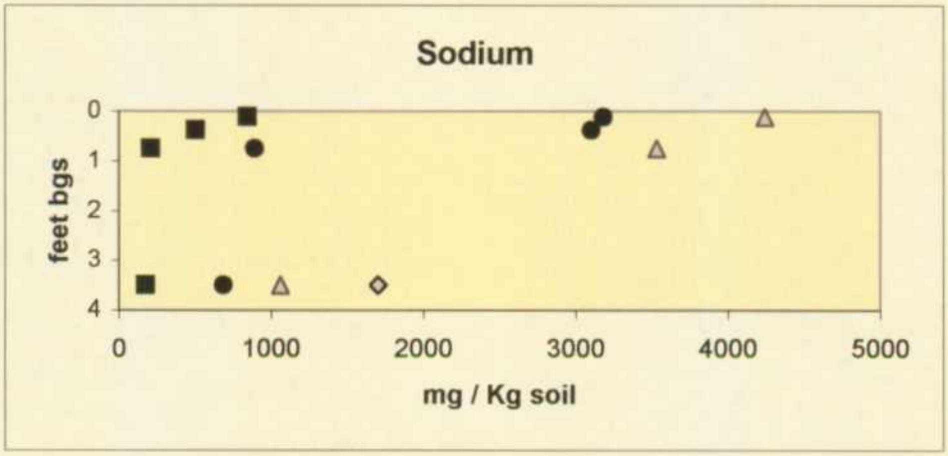
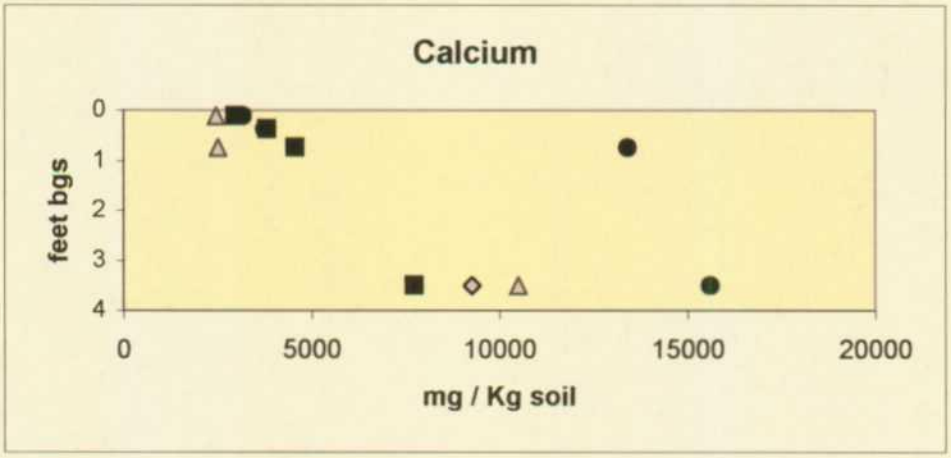
Rice Operating Company	Plate 3
Regional Water Table and Direction of Groundwater Flow	April 18, 2001



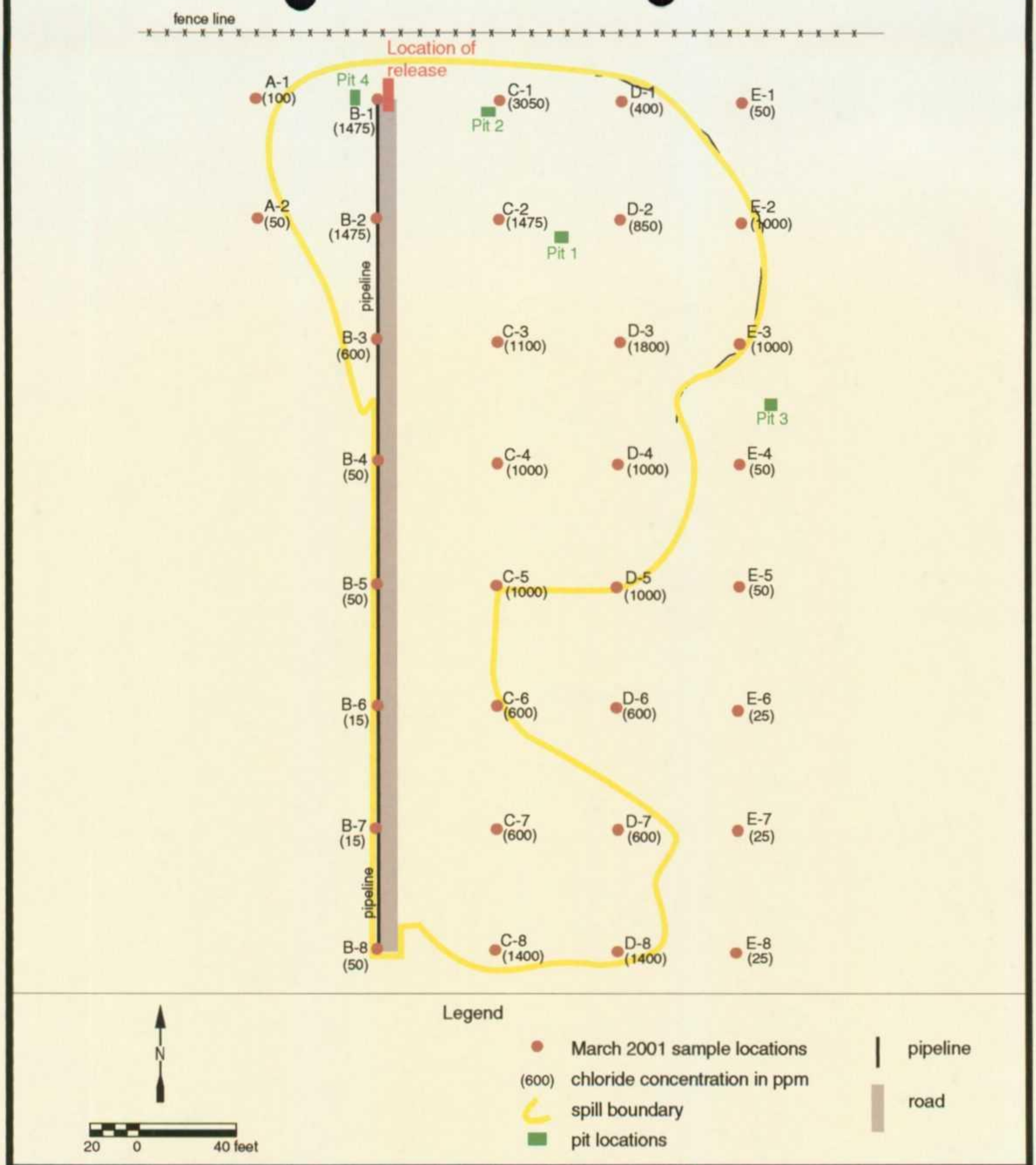
R.T. HICKS CONSULTANTS, LTD. 4665 Indian School Road NE Suite 106 Albuquerque, NM 87110 505.266.5004 Fax: 505.266.7738	Rice Operating Company	Plate 4
	January and March 2001 Surface Soil Sample Locations	April 18, 2001







Rice Operating Company	Plate 5
Analytes as a Function of Depth	April 2001



R.T. HICKS CONSULTANTS, LTD. 4665 Indian School Road NE Suite 106 Albuquerque, NM 87110 505.266.5004 Fax: 505.266.7738	Rice Operating Company	Plate 6
	March 2001 Surface Soil Sample Results	April 18, 2001

APPENDIX A

brown to brown loam subsoil (see Lea Series). Indurated caliche is at a depth of 20 to 40 inches.

The soils in this complex are used as range, wildlife habitat, and recreational areas. They are also a source of caliche for use in road construction. Kimbrough soil: Dryland capability unit VIIs-1; Shallow (HP) range site; wildlife habitat group K. Lea soil: Dryland capability unit VIIs-1; Loamy range site; wildlife habitat group K.

Kimbrough-Lea complex (0 to 3 percent slopes) (KU).—In some areas this complex is about 50 percent Kimbrough gravelly loam and 25 percent Lea loam, and in a few about 40 percent Kimbrough soils and 40 percent Lea soils. It is 20 to 25 percent inclusions of Stegall, Arvana, Slaughter, and Sharvana soils. The Kimbrough soil is gently sloping and is on the tops and sides of low ridges. The Lea soil is nearly level and is in swales between the ridges.

The soils in this complex are used as range, wildlife habitat, and recreational areas. They are also a source of caliche for use in construction. Kimbrough soil: Dryland capability unit VIIs-1; Shallow (HP) range site; wildlife habitat group K. Lea soil: Dryland capability unit VIIs-1; Loamy range site; wildlife habitat group K.

Kimbrough-Sharvana complex (0 to 3 percent slopes) (Ks).—This complex is on smooth broad prairies in association with the Kimbrough-Lea complex in the northern part of Lea County. It is about 60 percent Kimbrough gravelly loam, 25 percent Sharvana fine sandy loam, and 15 percent inclusions of Slaughter, Stegall, and Arvana soils.

The Kimbrough soil is underlain by indurated caliche at a depth of 6 to 16 inches. The Sharvana soil is similar to Sharvana loamy fine sand (see Sharvana Series), but its surface layer is fine sandy loam about 6 inches thick.

These soils are eroded in places. Soil blowing has removed most of the original surface layer in old abandoned fields and exposed caliche at the surface, or it has exposed fragments of caliche and the reddish-brown sandy clay loam subsoil of the Sharvana soil. The Kimbrough soil is on slightly elevated level areas and has a few small caliche pebbles on the mounds. The underlying caliche undulates irregularly near the surface. Runoff generally accumulates in small intermittent lakes and potholes.

These soils are used for range and wildlife and as a source of caliche. Kimbrough soil: Dryland capability unit VIIs-1; Shallow (HP) range site; wildlife habitat group K. Sharvana soil: Dryland capability unit VIIs-1; Sandy range site; wildlife habitat group K.

Kimbrough-Sharvana complex (0 to 3 percent slopes) (KX).—This complex is about 55 percent Kimbrough gravelly loam, 25 percent Sharvana fine sandy loam, and 20 percent inclusions of Slaughter, Stegall, and Arvana soils. The Kimbrough soil is gently sloping and is on the tops and sides of low ridges in the northern part of Lea County. The Sharvana soil is nearly level to gently sloping and is between the ridges. It is similar to Sharvana loamy fine sand, but its surface layer is fine sandy loam about 6 inches thick.

The soils in this complex are used for range and wildlife and as a source of caliche. Kimbrough soil: Dryland capability unit VIIs-1; Shallow (HP) range site; wildlife habitat group K. Sharvana soil: Dryland capability unit VIIs-1; Sandy range site; wildlife habitat group K.

Largo Series

The Largo series consists of well-drained, calcareous soils that have a light loam surface layer underlain by loam to clay loam. These gently sloping soils are on alluvial fans below outcrops of Triassic materials, in the southern part of Lea County. They formed in calcareous loamy alluvium. Slopes are 0 to 3 percent. The vegetation is short and mid grasses, forbs, and shrubs. The average annual precipitation is 10 to 12 inches, the average annual air temperature is 60° to 62° F., and the frost-free season is 190 to 200 days. Elevations range from 3,200 to 3,700 feet. These soils are associated with Pajarito and Palomas soils.

Typically, the surface layer is brown light loam about 6 inches thick. The next layer is reddish-brown to yellowish-red stratified loam, light silty clay loam, and clay loam about 24 inches thick. The substratum, to a depth of about 60 inches, is weak red silty and clayey shale. These soils are calcareous throughout.

Largo soils are used as range, wildlife habitat, and recreational areas. Indian artifacts can be found in this area.

Largo-Pajarito complex (0 to 3 percent slopes) (LP).—The soils in this complex formed on alluvial fans and plains and on foot slopes having outcrops of Triassic red-bed material. This complex is about 45 percent Largo loam, about 40 percent Pajarito loamy fine sand, and 15 percent inclusions of Palomas and Maljamar soils. It occurs only in the Southern Desertic Basins, Plains, and Mountains Resource Area in the southern part of Lea County.

The Largo soil is on alluvial plains and lower alluvial fans near deep gullied channels or in valley-filled channels where overflow and flooding are common after torrential rains.

Representative profile of Largo loam in an area of Largo-Pajarito complex, one-half mile south of State Highway No. 128, northwest of Jal, about 0.3 mile east of Jal Dump grounds, sec. 24, T. 25 S., R. 36 E.:

A11—0 to 1 inch, brown (7.5YR 5/4) fine sandy loam, dark brown (10YR 4/4) when moist; weak, thin, platy structure; slightly hard, very friable when moist, slightly sticky and slightly plastic when wet; many fine roots; many fine interstitial pores; few dark organic stains; mildly alkaline (pH 7.7), slightly calcareous; abrupt boundary. 0 to 1 inch thick.

A12—1 to 6 inches, brown (7.5YR 5/5) light loam, dark brown (10YR 4/4) when moist; moderate, thick, platy and weak, fine, granular structure; soft, very friable when moist, slightly sticky and slightly plastic when wet; few fine roots; few coarse tubular pores; few organic stains; few worm casts; few root channels; few mycelia; mildly alkaline (pH 7.7), slightly calcareous; abrupt boundary. 4 to 12 inches thick.

AC1—6 to 13 inches, reddish-brown (5YR 5/4) loam, reddish brown (5YR 4/4) when moist; weak, coarse, subangular blocky and moderate, medium, granular structure; hard, firm when moist, sticky and plastic when wet; few fine roots; few small shale fragments intermixed; many worm casts; moderately alkaline (pH 7.9), strongly calcareous; clear boundary. 6 to 10 inches thick.

plastic when wet; few fine roots; mildly alkaline (pH 7.7), slightly calcareous; abrupt boundary. 2 to 4 inches thick.

A12—2 to 4 inches, dark grayish-brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) when moist; moderate, fine, subangular blocky structure; slightly hard, friable when moist, slightly sticky and slightly plastic when wet; few fine roots; few worm casts; mildly alkaline (pH 7.8), slightly calcareous; abrupt boundary. 2 to 3 inches thick.

B21—4 to 12 inches, grayish-brown (10YR 5/2) clay loam, brown (10YR 5/3) when moist; moderate, medium, subangular blocky structure; hard, firm when moist, sticky and plastic when wet; few fine roots; many fine tubular pores; few worm casts; many fine calcium carbonate concretions; moderately alkaline (pH 8.2), strongly calcareous; clear boundary. 7 to 20 inches thick.

B22—12 to 22 inches, pale-brown (10YR 6/3) clay loam, brown (10YR 5/3) when moist; moderate, medium, subangular blocky structure; slightly hard, very friable when moist, sticky and plastic when wet; few fine roots; many, soft and hard, fine calcium carbonate concretions; moderately alkaline (pH 8.4), strongly calcareous; gradual boundary. 9 to 12 inches thick.

Cca—22 to 60 inches, light-gray (10YR 7/2), soft caliche consisting of clay loam, gray (10YR 6/1) when moist; moderate, fine, subangular blocky structure; hard, firm when moist, sticky and plastic when wet: about 35 percent chalky or silty soils mixed with soft calcium carbonate, decreasing in lime content below a depth of 48 inches; moderately alkaline (pH 8.4), strongly calcareous.

The A horizon ranges from dark grayish brown to brown light loam to heavy loam. The B horizon is 20 to 30 percent clay and ranges from loam to clay loam. Depth to chalky material or caliche is 20 to 39 inches.

This soil is moderately permeable. Runoff is slow. Water intake is moderate, and the available water holding capacity is 4 to 7 inches. Roots penetrate to a depth of 20 to 39 inches to the strong lime zone. Soil blowing is a moderate hazard.

This soil is used as range and wildlife habitat. Dryland capability unit VIIe-3; Loamy range site; wildlife habitat group G.

Midessa and Wink fine sandy loams (0 to 3 percent slopes) (MN).—This unit is about 45 percent Midessa fine sandy loam and 40 percent Wink fine sandy loam. Some areas are mostly Midessa soil or Wink soil, and other areas are made up of both soils. Included in mapping are areas of Maljamar, Palomas, and Kermit soils that make up the remaining 15 percent of this unit.

The Midessa soil is similar to Midessa loam, but its surface layer is fine sandy loam. The Wink soil is similar to Wink fine sand (see Wink Series), but its surface layer differs in texture and is about 6 inches thick. Surface runoff is slow. Water intake is moderate to rapid. There is a strong lime zone at a depth of 20 to 40 inches. Soil blowing is a moderate hazard.

These soils are used as range, wildlife habitat, and recreational areas. Dryland capability unit VIIe-3; Sandy range site; wildlife habitat group G.

Mixed Alluvial Land

Mixed alluvial land (MU) consists of unconsolidated, stratified alluvium of varying texture. It is mainly along Monument Draw and its tributaries in the southeastern part of Lea County. It occurs intermittently in drainageways. A small acreage is along swales in the northeastern part. Included in mapping are small areas of Amarillo and Portales soils.

The alluvium is generally no more than 24 to 36 inches thick over a buried soil or the parent material of adjacent soils. Evidence of the origin of this material is the stratification, the location in drainageways, and the debris from floods that has accumulated on the vegetation within the drainageway.

The alluvium consists of recently deposited soil material from adjacent slopes. In places where the adjacent soils are fine to medium textured, the alluvium is loamy. In places where the adjacent soils are moderately coarse textured and coarse textured, the alluvium is sandy. Where the adjacent soils are of varying textures, the alluvium is stratified, loamy, and sandy.

Loamy alluvium is most extensive. It is generally dark-gray, calcareous loam that is moderately deep over caliche. The sandy alluvium consists of deep sands that bury the original soils, or of deep windblown sands that were subsequently flooded.

Permeability is moderate to rapid. Runoff is slow. Water intake is moderate to rapid, and the available water holding capacity is 4 to 7 inches. Roots penetrate to a depth of about 40 to 60 inches, or more. The vegetation consists of mid grasses, forbs, and shrubs. Erosion is a moderate hazard.

Mixed alluvial land is used as range and wildlife habitat. Some tracts are cut for native hay. Dryland capability unit VIe-1; Bottomland range site; wildlife habitat group C.

Mobeetie Series

The Mobeetie series consists of well-drained soils that have a light fine sandy loam subsoil. These soils formed in calcareous sandy loam sediments derived from outcrops of the Ogallala Formation. They are mainly on foot slopes and on alluvial fans along the margins of the Southern High Plains. These soils are nearly level to rolling. Slopes are 1 to 10 percent. The vegetation consists of mid grasses and shrubs. The average annual precipitation is 10 to 13 inches, the average annual temperature is 60° to 62° F., and the frost-free season is 195 to 205 days. Elevations range from 3,700 to 4,000 feet. These soils are closely associated with Potter and Mansker soils.

Typically, the surface layer is brown fine sandy loam about 4 inches thick. The subsoil is brown light fine sandy loam about 20 inches thick. The substratum, to a depth of 60 inches, is brown fine sandy loam that contains lime. This soil is calcareous throughout the profile.

The Mobeetie soils in Lea County are mapped only with Potter soils. They are used as range and wildlife habitat.

Mobeetie-Potter association, 1 to 15 percent slopes (MW).—This association is about 70 percent Mobeetie fine sandy loam and about 25 percent Potter gravelly fine sandy loam. Slopes range from 1 to 10 percent in the Mobeetie soil and from 5 to 15 percent in the Potter soil, but are dominantly 4 to 6 percent. These soils are along the escarpment of the Southern High Plains and draws

TABLE 6.—*Estimated engineering properties of the soils*

[An asterisk in the first column indicates that at least one mapping unit in this series is made up of two or more kinds of soil. The soils in such mapping units may have different properties and limitations, and for this reason it is necessary to follow carefully the instructions for referring to other series that appear in the first column of table. Symbol > means more than]

Soil series and map symbols	Depth to bedrock or indurated caliche	Depth from surface	Classification: Dominant USDA texture	Classification: Unified	Classification: AASHO	Percentage passing sieve— No. 4	No. 10	No. 200	Permeability	Available water capacity	Reaction	Salinity	Shrink-swell potential	Corrosivity of uncoated steel [1]
	Ft.	*In.*							*In./hr.*	*In./in. of soil*	*pH*	*Mmhos./cm.*		
Active dune land: Aa	>5	0–60	Fine sand	SP	A–3	100	100	0–5	>20	0.04–0.06	6.6–7.8	0–1	Low	Low.
*Amarillo: Ad, Ae, Af, Ag, Ah, Ak, AB, AL, AS, AU. For Arvana part of AB, AL, and AS, see Arvana series; for Gomez part of Ak and AU, see Gomez series.	>5	0–36	Sandy clay loam	SM or SC	A–4 or A–6	100	100	40–50	0.63–2.0	0.14–0.16	6.6–7.3	0–1	Moderate	Moderate.
		36–60	Chalky loam	SC	A–4	95–100	90–100	40–50	0.63–2.0		7.9–8.4	0–1	Low	Low.
*Arch: Am, AV. For Drake part of AV, see Drake series.	>5	0–16	Loam	ML or CL	A–4 or A–6	100	100	78–80	0.63–2.0	0.16–0.18	7.9–8.4	0–2	Moderate	Moderate.
		16–60	Soft caliche (clay loam to silty clay loam).	CL	A–6	100	100	85–95	0.63–2.0		8.5–9.0	0–4	Moderate	High.
*Arvana: An, Ao, Ap, Ar, At, AW. For Lea part of AW, see Lea series.	1½–3	0–28	Sandy clay loam	SC	A–6	100	100	35–50	0.63–2.0	0.14–0.16	6.6–7.3	0–1	Moderate	Moderate.
		28	Indurated caliche.											
Badland: BD. Variable: no estimates of properties.														
*Berino: BE, BF, BH. For Cacique part of BE, BF, and BH, see Cacique series.	>5	0–48	Sandy clay loam	SC	A–6	100	100	35–45	0.63–2.0	0.14–0.16	6.6–7.8	0–2	Moderate	Moderate.
		48–60	Soft caliche (sandy clay loam)	SC	A–6	100	100	35–50	0.63–2.0		7.9–8.4	0–2	Moderate	Moderate.
*Brownfield: Bp, BN, Br, BO, BS. For Patricia part of Br, Bp, and BN, see Patricia series; for Springer part of BO and BS, see Springer series.	>5	0–22	Fine sand	SM	A–1 or A–2	100	100	20–30	6.3–20.0	0.06–0.08	6.6–7.3	0–1	Low	Low.
		22–63	Sandy clay loam	SM or SC	A–4 or A–6	100	100	40–50	0.63–2.0	0.14–0.16	6.6–7.8	0–1	Moderate	Moderate.
Cacique. Mapped only with Berino soils.	1½–3	0–12	Loamy fine sand	SM	A–2 or A–4	100	100	25–50	2.0–6.3	0.09–0.15	6.6–7.3	0–1	Low	Low.
		12–28	Sandy clay loam	SC	A–6	100	100	35–50	0.63–2.0	0.14–0.16	6.6–7.3	0–1	Moderate	Moderate.
		28	Indurated caliche.											
Cottonwood. Mapped only with Reeves soils.	([2])	0–8	Loam	ML	A–4	100	100	60–80	0.63–2.0	0.16–0.18	8.5–9.0	8–15	Low	High.
		8	Gypsum.											
Drake: Dr	>5	0–30	Fine sandy loam	ML	A–4	100	100	50–60	0.63–2.0	0.13–0.15	7.4–7.8	0–4	Low	Moderate.
		30–60	Sandy clay loam	SC	A–6	100	100	35–45	0.63–2.0	0.14–0.16	7.9–8.4	0–4	Moderate	Moderate.
Drake, low rainfall variant. Mapped only with Jal soils.	>5	0–12	Loamy fine sand	SM	A–2	100	100	20–35	6.3–20.0	0.08–0.10	7.4–7.8	0–4	Low	Moderate.
		12–60	Sandy clay loam	SC	A–6	100	100	35–45	0.63–2.0	0.14–0.16	7.9–8.4	0–4	Moderate	Moderate.
Gomez: GF, Go, GM, Gs	>5	0–15	Loamy fine sand	SM	A–2	100	100	15–30	6.3–20.0	0.05–0.09	6.6–7.8	0–1	Low	Low.
		15–22	Fine sandy loam	SM	A–4	100	100	35–50	2.0–6.3	0.13–0.15	7.4–7.8	0–1	Low	Low.
		22–60	Soft caliche (fine sandy loam)	SM	A–4	100	100	35–50	2.0–6.3		7.9–8.4	0–2	Low	Moderate.
*Jal: JA. For Drake part of JA, see Drake, low rainfall variant.	>5	0–12	Sandy loam	SM	A–2 or A–4	100	100	30–40	2.0–6.3	0.11–0.13	7.9–8.4	0–2	Low	Moderate.
		12–60	Soft caliche (loam texture)	ML	A–4	100	100	50–65	0.63–2.0		8.5–9.0	0–4	Low	Moderate.
*Kermit: KD, KE, KM. For Palomas part of KD, see Palomas series; for Dune land part of KM, see Active dune land; for Wink part of KE, see Wink series.	>5	0–60	Fine sand	SP-SM or SM	A–2 or A–3	100	100	5–15	>20.0	0.04–0.06	6.6–7.3	0–1	Low	Low.
*Kimbrough: Kb, KN, Kc, Kg, KO, Kh, KU, Ks, KX. For Sharvana part of Ks and KX, see Sharvana series; for Lea part of Kh and KU, see Lea series.	½–1½	0–6	Gravelly loam	SM, SC, or ML	A–4	85–95	75–90	40–60	0.63–2.0	0.12–0.18	7.4–7.8	0–2	Low	Low to moderate.
		6	Indurated caliche.											
*Largo: LP. For Pajarito part of LP, see Parjarito series.	2 to 5	0–30	Loam, silty clay loam, and clay loam.	ML or CL	A–4 or A–6	100	100	65–85	0.2–0.63	0.17–0.19	7.4–8.4	0–1	Moderate	Moderate.
		30	Shale.											

See footnotes at end of table.

TABLE 6.—*Estimated engineering properties of the soils*

[An asterisk in the first column indicates that at least one mapping unit in this series is made up of two or more kinds of soil. The soils in such mapping units may have different properties and limitations, and for this reason it is necessary to follow carefully the instructions for referring to other series that appear in the first column of table. Symbol > means more than]

Soil series and map symbols	Depth to bedrock or indurated caliche	Depth from surface	Classification: Dominant USDA texture	Classification: Unified	Classification: AASHO	Percentage passing sieve—No. 4	Percentage passing sieve—No. 10	Percentage passing sieve—No. 200	Permeability	Available water capacity	Reaction	Salinity	Shrink-swell potential	Corrosivity of uncoated steel [1]
	Ft.	*In.*							*In./hr.*	*In./in. of soil*	*pH*	*Mmhos./cm.*		
Active dune land: Aa	>5	0-60	Fine sand	SP	A-3	100	100	0-5	>20	0.04-0.06	6.6-7.8	0-1	Low	Low.
*Amarillo: Ad, Ae, Af, Ag, Ah, Ak, AB, AL, AS, AU. For Arvana part of AB, AL, and AS, see Arvana series; for Gomez part of Ak and AU, see Gomez series.	>5	0-36	Sandy clay loam	SM or SC	A-4 or A-6	100	100	40-50	0.63-2.0	0.14-0.16	6.6-7.3	0-1	Moderate	Moderate.
		36-60	Chalky loam	SC	A-4	95-100	90-100	40-50	0.63-2.0	----	7.9-8.4	0-1	Low	Low.
*Arch: Am, AV. For Drake part of AV, see Drake series.	>5	0-16	Loam	ML or CL	A-4 or A-6	100	100	78-80	0.63-2.0	0.16-0.18	7.9-8.4	0-2	Moderate	Moderate.
		16-60	Soft caliche (clay loam to silty clay loam).	CL	A-6	100	100	85-95	0.63-2.0	----	8.5-9.0	0-4	Moderate	High.
*Arvana: An, Ao, Ap, Ar, At, AW. For Lea part of AW, see Lea series.	1½-3	0-28	Sandy clay loam	SC	A-6	100	100	35-50	0.63-2.0	0.14-0.16	6.6-7.3	0-1	Moderate	Moderate.
		28	Indurated caliche.											
Badland: BD. Variable: no estimates of properties.														
*Berino: BE, BF, BH. For Cacique part of BE, BF, and BH, see Cacique series.	>5	0-48	Sandy clay loam	SC	A-6	100	100	35-45	0.63-2.0	0.14-0.16	6.6-7.8	0-2	Moderate	Moderate.
		48-60	Soft caliche (sandy clay loam)	SC	A-6	100	100	35-50	0.63-2.0	----	7.9-8.4	0-2	Moderate	Moderate.
*Brownfield: Bp, BN, Br, BO, BS. For Patricia part of Br, Bp, and BN, see Patricia series; for Springer part of BO and BS, see Springer series.	>5	0-22	Fine sand	SM	A-1 or A-2	100	100	20-30	6.3-20.0	0.06-0.08	6.6-7.3	0-1	Low	Low.
		22-63	Sandy clay loam	SM or SC	A-4 or A-6	100	100	40-50	0.63-2.0	0.14-0.16	6.6-7.8	0-1	Moderate	Moderate.
Cacique. Mapped only with Berino soils.	1½-3	0-12	Loamy fine sand	SM	A-2 or A-4	100	100	25-50	2.0-6.3	0.09-0.15	6.6-7.3	0-1	Low	Low.
		12-28	Sandy clay loam	SC	A-6	100	100	35-50	0.63-2.0	0.14-0.16	6.6-7.3	0-1	Moderate	Moderate.
		28	Indurated caliche.											
Cottonwood. Mapped only with Reeves soils.	(2)	0-8	Loam	ML	A-4	100	100	60-80	0.63-2.0	0.16-0.18	8.5-9.0	8-15	Low	High.
		8	Gypsum.											
Drake: Dr	>5	0-30	Fine sandy loam	ML	A-4	100	100	50-60	0.63-2.0	0.13-0.15	7.4-7.8	0-4	Low	Moderate.
		30-60	Sandy clay loam	SC	A-6	100	100	35-45	0.63-2.0	0.14-0.16	7.9-8.4	0-4	Moderate	Moderate.
Drake, low rainfall variant. Mapped only with Jal soils.	>5	0-12	Loamy fine sand	SM	A-2	100	100	20-35	6.3-20.0	0.08-0.10	7.4-7.8	0-4	Low	Moderate.
		12-60	Sandy clay loam	SC	A-6	100	100	35-45	0.63-2.0	0.14-0.16	7.9-8.4	0-4	Moderate	Moderate.
Gomez: GF, Go, GM, Gs	>5	0-15	Loamy fine sand	SM	A-2	100	100	15-30	6.3-20.0	0.05-0.09	6.6-7.8	0-1	Low	Low.
		15-22	Fine sandy loam	SM	A-4	100	100	35-50	2.0-6.3	0.13-0.15	7.4-7.8	0-1	Low	Low.
		22-60	Soft caliche (fine sandy loam)	SM	A-4	100	100	35-50	2.0-6.3	----	7.9-8.4	0-2	Low	Moderate.
*Jal: JA. For Drake part of JA, see Drake, low rainfall variant.	>5	0-12	Sandy loam	SM	A-2 or A-4	100	100	30-40	2.0-6.3	0.11-0.13	7.9-8.4	0-2	Low	Moderate.
		12-60	Soft caliche (loam texture)	ML	A-4	100	100	50-65	0.63-2.0	----	8.5-9.0	0-4	Low	Moderate.
*Kermit: KD, KE, KM. For Palomas part of KD, see Palomas series; for Dune land part of KM, see Active dune land; for Wink part of KE, see Wink series.	>5	0-60	Fine sand	SP-SM or SM	A-2 or A-3	100	100	5-15	>20.0	0.04-0.06	6.6-7.3	0-1	Low	Low.
*Kimbrough: Kb, KN, Kc, Kg, KO, Kh, KU, Ks, KX. For Sharvana part of Ks and KX, see Sharvana series; for Lea part of Kh and KU, see Lea series.	½-1½	0-6	Gravelly loam	SM, SC, or ML	A-4	85-95	75-90	40-60	0.63-2.0	0.12-0.18	7.4-7.8	0-2	Low	Low to moderate.
		6	Indurated caliche.											
*Largo: LP. For Pajarito part of LP, see Parjarito series.	2 to 5	0-30	Loam, silty clay loam, and clay loam.	ML or CL	A-4 or A-6	100	100	65-85	0.2-0.63	0.17-0.19	7.4-8.4	0-1	Moderate	Moderate.
		30	Shale.											

See footnotes at end of table.

461-652—73——6

TABLE 6.—*Estimated engineering properties of the soil*—Continued

Soil series and map symbols	Depth to bedrock or indurated caliche	Depth from surface	Classification: Dominant USDA texture	Classification: Unified	Classification: AASHO	Percentage passing sieve—: No. 4	Percentage passing sieve—: No. 10	Percentage passing sieve—: No. 200	Permeability	Available water capacity	Reaction	Salinity	Shrink-swell potential	Corrosivity of uncoated steel [1]
	Ft.	*In.*							*In./hr.*	*In./in. of soil*	*pH*	*Mmhos./cm.*		
Lea: La, Le	1¼–3½	0–26	Loam	ML or CL	A-4	100	100	60–75	0. 63–2. 0	0. 16–0. 18	6. 6–8. 4	0–2	Moderate	Moderate.
		26	Indurated caliche.											
*Maljamar: MF	3½–>5	0–24	Fine sand	SM	A-2	100	100	15–25	6. 3–20. 0	0. 05–0. 07	6. 6–7. 3	0–1	Low	Low.
For Palomas part of MF, see Palomas series.		24–50	Sandy clay loam	SC	A-6	100	100	35–45	0. 63–2. 0	0. 14–0. 16	6. 6–7. 3	0–1	Moderate	Moderate.
		50	Indurated caliche.											
Mansker: Ma, MK, Me	>5	0–10	Loam	ML	A-4	100	100	60–75	0. 63–2. 0	0. 16–0. 18	7. 9–8. 4	0–2	Moderate	Moderate.
		10–19	Clay loam	CL	A-6	100	100	70–80	0. 63–2. 0	0. 19–0. 21	7. 9–8. 4	0–2	Moderate	Moderate.
		19–60	Soft caliche (light clay loam texture).	CL	A-6	100	100	70–80	0. 63–2. 0	----------	7. 9–8. 4	0–2	Moderate	Moderate.
*Midessa: MM, MN	>5	0–22	Clay loam	CL	A-6	100	100	70–80	0. 63–2. 0	0. 19–0. 21	7. 4–8. 4	0–2	Moderate	Moderate.
For Wink part of MN, see Wink series.		22–60	Soft caliche (clay loam texture)	CL	A-6	100	100	70–80	0. 63–2. 0	----------	7. 9–8. 4	0–2	Moderate	Moderate.
Mixed alluvial land: MU														
Variable; no estimates of properties.														
*Mobeetie: MW	>5	0–60	Fine sandy loam	SM	A-4	100	100	40–50	2. 0–6. 3	0. 13–0. 15	7. 9–8. 4	0–1	Low	Low.
For Potter part of MW, see Potter series.														
Pajarito	>5	0–16	Loamy fine sand	SM	A-2	100	100	20–30	6. 3–20. 0	0. 09–0. 11	7. 4–7. 8	0–1	Low	Low.
Mapped only with Largo soils.		16–60	Fine sandy loam	SM	A-4	100	100	35–50	2. 0–6. 3	0. 13–0. 15	8. 5–9. 0	0–1	Low	Low.
Palomas	>5	0–16	Fine sand	SM	A-2	100	100	20–30	6. 3–20. 0	0. 05–0. 07	6. 6–7. 3	0–1	Low	Low.
Mapped only with Kermit and Maljamar soils.		16–60	Fine sandy loam and sandy clay loam.	SM or SC	A-4	100	100	35–50	0. 63–2. 0	0. 14–0. 16	6. 6–7. 8	0–1	Moderate	Moderate.
		60–66	Soft caliche (sandy loam)	SM	A-2 or A-4	100	100	30–40	0. 63–2. 0	----------	7. 4–7. 8	0–2	Low	Moderate.
Patricia	>5	0–16	Fine sand	SM	A-1 or A-2	100	100	20–30	6. 3–20. 0	0. 06–0. 08	6. 6–7. 3	0–1	Low	Low.
Mapped only with Brownfield soils.		16–70	Sandy clay loam	SM or SC	A-4 or A-6	100	100	40–50	0. 63–2. 0	0. 14–0. 16	5. 6–8. 4	0–1	Moderate	Moderate.
Playas: Pb														
Variable; no estimates of properties.														
*Portales: Pe, Pf, Ph, PC, Po, PG, PS	>5	0–26	Loam and clay loam	CL	A-6	100	100	65–75	0. 63–2. 0	0. 17–0. 19	7. 4–8. 4	0–2	Moderate	Moderate.
For Stegall part of PS, see Stegall series; for Gomez part of PG, see Gomez series.		26–60	Soft caliche (loam texture)	CL	A-6	100	100	65–75	0. 63–2. 0	----------	7. 9–8. 4	0–2	Moderate	Moderate.
Potter	½–1	0–4	Gravelly fine sandy loam	SM	A-2	85–95	70–85	20–30	0. 63–2. 0	0. 10–0. 12	7. 4–7. 8	0–2	Low	Moderate.
Mapped only with Mobeetie soils.		4	Fragmental platy caliche.											
*Pyote: PT, PU, PY	>5	0–30	Fine sand or loamy fine sand	SP-SM or SM	A-2 or A-3	100	100	5–30	6. 3–20. 0	0. 06–0. 08	6. 6–7. 3	0–1	Low	Low.
For Maljamar part of PU, see Maljamar series; for Dune land part of PY, see Active dune land.		30–60	Fine sandy loam	SM	A-4	100	100	40–50	2. 0–6. 3	0. 13–0. 15	6. 6–7. 3	0–1	Low	Low.
*Reeves: RE, RT	[3]	0–12	Loam	ML	A-4	100	100	60–75	0. 63–2. 0	0. 19–0. 21	7. 4–7. 8	4–8	Moderate	High.
For Cottonwood part of RT, see Cottonwood series.		12–16	Light clay loam	CL	A-6	100	100	70–80	0. 63–2. 0	0. 13–0. 15	7. 9–8. 4	8–15	Moderate	High.
		16–60	Gypsum and chalky loam.											
Sharvana: Sf, SA, Sh, SD	1–2	0–16	Sandy clay loam	SC	A-6	100	100	35–50	0. 63–2. 0	0. 14–0. 16	6. 6–7. 3	0–1	Moderate	Moderate.
		16	Indurated caliche.											
*Simona: Sm, SE, Sn, SR	1–1½	0–16	Fine sandy loam	SM	A-2 or A-4	80–100	75–100	20–50	2. 0–6. 3	0. 09–0. 15	7. 9–8. 4	0–1	Low	Low.
For Upton part of SR, see Upton series.		16	Indurated caliche.											
Slaughter: So	1–2	0–15	Heavy clay loam and clay	CL	A-6	100	100	75–95	0. 06–0. 2	0. 16–0. 18	6. 6–7. 3	0–1	High	High.
		15	Indurated caliche.											
Springer	>5	0–14	Loamy fine sand	SM	A-2	100	100	20–30	6. 3–20. 0	0. 05–0. 09	6. 6–7. 8	0–1	Low	Low.
Mapped only with Brownfield soils.		14–60	Fine sandy loam	SM	A-4	100	100	40–50	2. 0–6. 3	0. 13–0. 15	6. 6–7. 8	0–1	Low	Low.
		60	Soft caliche.											
*Stegall: St, Su, SS	1¼–3	0–28	Clay loam	CL	A-6	100	100	70–80	0. 06–0. 2	0. 17–0. 19	6. 6–7. 8	0–4	High	High.
For Slaughter part of SS, see Slaughter series.		28	Indurated caliche.											

See footnotes at end of table.

TABLE 7.—*Engineering interpretations*—Continued

Soil series and map symbols	Suitability as a source of—			Degree of limitation for—	
	Topsoil	Sand	Road fill	Filter fields	Sewage lagoons
Caclque. Mapped only with Berino soils.	Fair to poor: texture.	Unsuitable: mainly fine-grained material.	Good to poor (A-2 and A-6): moderate shrink-swell potential.	Severe: indurated caliche at a depth of 1½ to 3 feet.	Severe: depth to indurated caliche is 1½ to 3 feet.
Cottonwood. Mapped only with Reeves soils.	Poor: low fertility; reaction.	Unsuitable: fine-grained material.	Fair (A-4): low shear strength; very shallow.	Severe: gypsum within a depth of 1 foot; danger of pollution.	Severe: gypsum within a depth of 1 foot.
Drake: Dr	Poor: low fertility; texture.	Poor: sandy clay loam below a depth of 30 inches.	Fair to poor (A-4 and A-6).	Slight to moderate: moderate permeability.	Moderate: moderate permeability; slopes mainly 2 to 5 percent.
Drake, low rainfall variant. Mapped only with Jal soils.	Poor: low fertility; texture.	Unsuitable: mainly fine-grained material.	Fair to poor (A-2 and A-6).	Slight to moderate: moderate permeability.	Moderate: moderate permeability.
Gomez: GF, Go, GM, Gs	Poor: low fertility; texture.	Poor: fine sandy loam below a depth of 15 inches.	Good to fair (A-2 and A-4) if soil binder is added.	Slight	Severe: moderately rapid permeability.
*Jal: JA. For Drake part of JA, see Drake, low rainfall variant.	Poor: low fertility; high lime content.	Unsuitable: mainly fine-grained material.	Fair (mainly A-4)	Slight to moderate: moderate permeability.	Moderate: moderate permeability.
*Kermit: KD, KE, KM. For Palomas part of KD, see Palomas series. For Dune land part of KM, see Active dune land. For Wink part of KE, see Wink series.	Poor: low fertility; texture.	Good	Good (A-2 and A-3) if soil binder is added.	Slight to moderate: in places slopes exceed 5 percent; pollution of ground water possible.	Severe: very rapid permeability; slopes mainly 0 to 12 percent.
*Kimbrough: Kb, KN, Kc, Kg, KO, Kh, KU, Ks, KX. For Sharvana part of units Ks and KX, see Sharvana series. For Lea part of Kh and KU, see Lea series.	Poor: gravelly; indurated caliche at a depth of ½ foot to 1½ feet.	Unsuitable: indurated caliche at a depth of ½ foot to 1½ feet.	Fair (A-4): depth to indurated caliche is ½ foot to 1½ feet.	Severe: indurated caliche at a depth of ½ foot to 1½ feet.	Severe: indurated caliche at a depth of ½ foot to 1½ feet.
*Largo: LP. For Pajarito part of LP, see Pajarito series.	Fair: low fertility	Unsuitable: fine-grained material.	Fair to poor (A-4 and A-6): moderate shrink-swell potential.	Severe: moderately slow permeability.	Moderate: subject to flooding.
Lea: La, Le	Good: moderate fertility.	Unsuitable: mainly fine-grained material.	Fair (A-4): moderate shrink-swell potential.	Severe: indurated caliche at a depth of 1½ to 3½ feet.	Severe: indurated caliche at a depth of 1½ to 3½ feet.
*Maljamar: MF. For Palomas part of MF, see Palomas series.	Poor: low fertility; texture.	Poor: sandy clay loam below a depth of 2 feet.	Good to poor (A-2 and A-6).	Slight to moderate: moderate permeability.	Moderate: moderate permeability.
Mansker: Ma, MK, Me	Fair: moderate fertility.	Unsuitable: fine-grained material.	Fair to poor (A-4 and A-6).	Slight to moderate: moderate permeability.	Moderate: moderate permeability.
*Midessa: MM, MN. For Wink part of MN, see Wink series.	Fair: moderate fertility.	Unsuitable: mainly fine-grained material.	Poor (A-6)	Slight to moderate: moderate permeability.	Moderate: moderate permeability.

Soil series and map symbols	Soil features affecting—							
	Highway location	Dikes and levees	Farm ponds		Irrigation	Leveling and benching	Foundations for low buildings	Pipelines
			Reservoir area	Embankment				
Caclque	Indurated caliche at a depth of 1½ to 3 feet.	Moderate shrink-swell potential.	Indurated caliche at a depth of 1½ to 3 feet; moderate seepage.	Limited fill material.	Moderate to severe erosion hazard; indurated caliche at a depth of 1½ to 3 feet.	Indurated caliche at a depth of 1½ to 3 feet.	Moderate shrink-swell potential.	Indurated caliche at a depth of 1½ to 3 feet.
Cottonwood	Gypsiferous material within a depth of 1 foot.	Gypsiferous material.	Soluble gypsum	Soluble gypsum	Low water holding capacity.	Gypsum within a depth of 1 foot.	Soluble gypsum	Gypsum; highly corrosive.
Drake: Dr	Severe erosion hazard.	Poor stability; piping hazard.	Moderate seepage; piping hazard.	Severe erosion hazard; piping hazard.	Severe erosion hazard; low productivity; 0 to 5 percent slopes.	Severe erosion hazard; cuts limited by high lime content.	Low shear strength; moderate shrink-swell potential below a depth of 30 inches.	Moderately corrosive.
Drake, low rainfall variant	Severe erosion hazard.	Poor stability; piping hazard.	Moderate seepage; piping hazard.	Severe erosion hazard; piping hazard.	Severe erosion hazard; low productivity.	Severe erosion hazard.	Low shear strength; moderate shrink-swell potential below a depth of 12 inches.	Moderately corrosive.
Gomez: GF, Go, GM, Gs	Soft caliche at a depth of 1½ to 3½ feet; severe erosion hazard.	Soft caliche at a depth of 1½ to 3½ feet; severe erosion hazard.	Soft caliche at a depth of 1½ to 3½ feet; high seepage.	High seepage; piping hazard; severe erosion hazard.	Rapid water intake; severe erosion hazard.	Unstable; cuts limited by soft caliche at a depth of 1½ to 3½ feet.	Low shear strength; low shrink-swell potential.	Moderate ditchbank sloughing.
*Jal: JA	Soft caliche at a depth of 12 inches; severe erosion hazard.	Piping hazard; severe erosion hazard.	Moderate permeability; high seepage; high lime content.	Piping hazard; poor compaction.	Severe erosion hazard; rooting depth 20 to 30 inches.	Severe erosion hazard.	Low shrink-swell potential.	Moderately corrosive; soft caliche at a depth of 12 inches.
*Kermit: KD, KE, KM	Loose sand hinders hauling; very severe erosion hazard.	Very severe erosion hazard.	Very rapid permeability.	Very severe erosion hazard.	Very severe erosion hazard.	Very severe erosion hazard.	Low shrink-swell potential.	Ditchbank sloughing.
*Kimbrough: Kb, KN, Kc, Kg, KO, Kh, KU, Ks, KX	Indurated caliche at a depth of ½ foot to 1½ feet.	Indurated caliche at a depth of ½ foot to 1½ feet.	Indurated caliche at a depth of ½ foot to 1½ feet.	Indurated caliche at a depth of ½ foot to 1½ feet.	Indurated caliche at a depth of ½ foot to 1½ feet.	Indurated caliche at a depth of ½ foot to 1½ feet.	Indurated caliche at a depth of ½ foot to 1½ feet.	Indurated caliche at a depth of ½ foot to 1½ feet.
*Largo: LP	Periodic flooding; erosion hazard.	Unstable: subject to cracking.	Moderate shrink-swell potential; moderately slow permeability.	Fair stability; piping hazard.	Low water intake; erosion hazard.	Subject to flooding	Subject to flooding; moderate shrink-swell potential.	Subject to flooding.
Lea: La, Le	Indurated caliche at a depth of 1½ to 3½ feet.	Indurated caliche at a depth of 1½ to 3½ feet.	Indurated caliche at a depth of 1½ to 3½ feet.	Indurated caliche at a depth of 1½ to 3½ feet.	Indurated caliche at a depth of 1½ to 3½ feet.	Cuts limited by indurated caliche at a depth of 1½ to 3½ feet.	Moderate shrink-swell potential.	Indurated caliche at a depth of 1½ to 3½ feet.
*Maljamar: MF	Sand hinders hauling; severe erosion hazard.	Thick fine sand surface layer.	Moderately permeable below a depth of 2 feet; moderate seepage.	Slight cracking; severe erosion hazard.	Severe erosion hazard.	Severe erosion hazard.	Moderate shrink-swell potential below a depth of 2 feet.	Surface sands; slough or cave-in hazard.
Mansker: Ma, MK, Me	Soft caliche at a depth of 10 to 20 inches.	Moderate shrink-swell potential.	Seepage; soft caliche at a depth of 10 to 20 inches.	High seepage potential; erosion hazard.	Shallow over caliche; low water-holding capacity.	Cuts limited by soft caliche at a depth of 10 to 20 inches.	Moderate shrink-swell potential.	High lime content; corrosive.
*Midessa: MM, MN	Moderate shrink-swell potential.	Moderate shrink-swell potential.	Soft caliche at a depth of 2 to 3 feet; requires compaction.	Poor stability; piping hazard.	Soft caliche at a depth of 2 to 3 feet.	Cuts limited by soft caliche at a depth of 2 to 3 feet.	Moderate shrink-swell potential.	High lime content; corrosive.

TABLE 7.—*Engineering interpretations*—Continued

Soil series and map symbols	Suitability as a source of—			Degree of limitation for—	
	Topsoil	Sand	Road fill	Filter fields	Sewage lagoons
Mixed alluvial land: MU. Variable; no interpretations.					
*Mobeetie: MW. For Potter part of MW, see Potter series.	Fair: moderate fertility.	Poor: fine sandy loam material.	Fair (A-4).	Slight to moderate: slopes are 1 to 10 percent.	Severe: moderately rapid permeability; slopes are 1 to 10 percent.
Pajarito. Mapped only with Largo soils.	Poor: low fertility; texture.	Fair to poor: loamy fine sand and fine sandy loam material.	Good to fair (A-2 and A-4).	Slight.	Severe: moderately rapid permeability.
Palomas. Mapped only with Kermit and Maljamar soils.	Poor: low fertility; texture.	Poor: sandy clay loam below a depth of 16 inches.	Good to fair (A-2 and A-4).	Slight to moderate: moderate permeability.	Moderate: moderate permeability.
Patricia. Mapped only with Brownfield soils.	Poor: low fertility; texture.	Poor: sandy clay loam below a depth of 16 inches.	Good (A-2) in upper 16 inches; fair to poor (A-4 or A-6) below a depth of 16 inches; moderate shrink-swell potential.	Slight to moderate: moderate permeability.	Moderate: moderate permeability.
Playas: Pb. Variable; no interpretations.					
*Portales: Pe, Pf, Ph, PC, PS, PG, Po. For Stegall part of PS, see Stegall series. For Gomez part of PG, see Gomez series.	Fair: high lime content.	Unsuitable: mainly fine-grained material.	Poor (A-6): moderate shrink-swell potential.	Slight to moderate: moderate permeability.	Moderate: moderate permeability.
Potter. Mapped only with Mobeetie soils.	Poor: low fertility; gravelly.	Unsuitable: limited material.	Good.	Severe: fragmented platy caliche at a depth of 6 to 12 inches.	Severe: platy caliche at a depth of 6 to 12 inches.
*Pyote: PT, PU, PY. For Maljamar part of PU, see Maljamar series. For Dune land part of PY, see Active dune land.	Poor: low fertility; texture.	Fair to poor: fine sand and fine sandy loam.	Good (A-2) if soil binder is added; fair (A-4) below a depth of 30 inches.	Slight.	Severe: moderately rapid permeability.
*Reeves: RE, RT. For Cottonwood part of RT, see Cottonwood series.	Poor: low fertility; saline.	Unsuitable: fine-grained material.	Fair to poor (A-4 and A-6): unstable.	Severe: gypsum at a depth of 1½ to 2½ feet; danger of pollution.	Severe: moderate permeability; gypsum at a depth of 1½ to 2½ feet.
Sharvana: Sf, SA, Sh, SD.	Poor: 1 to 2 feet to indurated caliche.	Unsuitable: limited material; some fine-grained material.	Fair to poor (A-4 and A-6): moderate shrink-swell potential in subsoil; shallow.	Severe: indurated caliche at a depth of 1 to 2 feet.	Severe: indurated caliche at a depth of 1 to 2 feet.
*Simona: Sm, SE, SR, Sn. For Upton part of SR, see Upton series.	Poor: fertility is low; shallow over indurated caliche.	Poor: limited fine sandy loam material.	Good to fair (A-2 or A-4) to a depth of 20 inches.	Severe: indurated caliche at a depth of 1 to 1½ feet.	Severe: shallow over indurated caliche.

Soil series and map symbols	Soil features affecting—							
	Highway location	Dikes and levees	Farm ponds		Irrigation	Leveling and benching	Foundations for low buildings	Pipelines
			Reservoir area	Embankment				
Mixed alluvial land: MU.								
*Mobeetie: MW.	Unstable material; slopes are 1 to 10 percent.	Piping hazard; slopes are 1 to 10 percent.	Moderately rapid permeability.	Moderate erosion hazard; permeability.	Moderately rapid permeability; slopes are 1 to 10 percent.	Moderate erosion hazard; slopes are 1 to 10 percent.	Unstable; low shrink-swell potential.	Slopes are 1 to 10 percent.
Pajarito.	Loose, drifting sands; erosion hazard.	Unstable; requires soil binders.	Moderately rapid permeability.	Fair stability; moderate permeability when compacted.	Severe hazard of soil blowing.	Severe hazard of soil blowing.	Low shrink-swell potential.	Ditchbank sloughing.
Palomas.	Drifting sand; sand hinders hauling; erosion hazard.	Moderate shrink-swell potential in subsoil.	Moderate seepage.	Slight cracking; erosion hazard.	Severe hazard of soil blowing.	Severe hazard of soil blowing.	Moderate shrink-swell potential below a depth of 16 inches.	Ditchbank sloughing.
Patricia.	Drifting sand; sand hinders hauling; severe erosion hazard.	Moderate shrink-swell potential in subsoil.	Moderate seepage.	Slight cracking; severe erosion hazard.	Severe erosion hazard; rapid water intake.	Severe erosion hazard.	Moderate shrink-swell potential below a depth of 16 inches.	Severe erosion hazard; sloughing.
Playas: Pb.								
*Portales: Pe, Pf, Ph, PC, PS, PG, Po.	Moderate (A-6) shrink-swell potential.	Moderate shrink-swell potential.	Chalky loam at a depth of 20 to 36 inches; moderate seepage.	Unstable; difficult to compact.	High water-holding capacity; high lime content.	Cuts limited by moderate depth to chalky loam subsoil.	Moderate shrink-swell potential.	High lime content; moderately corrosive.
Potter.	Platy caliche at a depth of 6 to 12 inches.	Platy caliche at a depth of 6 to 12 inches.	Platy caliche at a depth of 6 to 12 inches; slopes are 5 to 15 percent.	Platy caliche at a depth of 6 to 12 inches.	Platy caliche at a depth of 6 to 12 inches; slopes are 5 to 15 percent.	Platy caliche at a depth of 6 to 12 inches; slopes are 5 to 15 percent	Platy caliche at a depth of 6 to 12 inches; low shrink-swell potential	Platy caliche at a depth of 6 to 12 inches.
*Pyote: PT, PU, PY.	Severe erosion hazard; loose, drifting sands.	Unstable; soil binders needed.	Moderately rapid permeability.	Fair stability; moderate permeability when compacted.	Severe hazard of soil blowing; moderately rapid permeability.	Severe hazard of soil blowing.	Low shrink-swell potential.	Severe erosion hazard; ditchbank sloughing.
*Reeves: RE, RT.	Gypsiferous materials at a depth of 1½ to 2½ feet; moderate shrink-swell potential.	Gypsum at a depth of 1½ to 2½ feet; unstable.	Gypsum at a depth of 1½ to 2½ feet.	Gypsum at a depth of 1½ to 2½ feet.	Low productivity; gypsum at a depth of 1½ to 2½ feet.	Cuts limited by gypsum at a depth of 1½ to 2½ feet.	Moderate shrink-swell potential; gypsum at a depth of 1½ to 2½ feet.	Corrosive; gypsum at a depth of 1½ to 2½ feet.
Sharvana: Sf, SA, Sh, SD.	Indurated caliche at a depth of 1 to 2 feet; drifting sand.	Indurated caliche at a depth of 1 to 2 feet.	Indurated caliche at a depth of 1 to 2 feet.	Indurated caliche at a depth of 1 to 2 feet.	Indurated caliche at a depth of 1 to 2 feet; low productivity; erosion hazard.	Cuts limited by indurated caliche at a depth of 1 to 2 feet.	Moderate shrink-swell potential; erosion hazard.	Indurated caliche at a depth of 1 to 2 feet.
*Simona: Sm, SE, SR, Sn.	Indurated caliche at a depth of 1 to 1½ feet; erosion hazard.	Indurated caliche at a depth of 1 to 1½ feet.	Indurated caliche at a depth of 1 to 1½ feet.	Indurated caliche at a depth of 1 to 1½ feet.	Shallow; low water-holding capacity; erosion hazard.	Cuts limited by indurated caliche.	Indurated caliche at a depth of 1 to 1½ feet; erosion hazard.	Shallow over indurated caliche.

APPENDIX B

REFERENCES FOR SOIL ANALYSIS

Test	Procedure	Reference
Standard Soil Test		
Organic Matter	Walkley - Black	6
pH	Saturated Paste	2
Salts	Solution conductivity	2
Phosphorus	Olsen	3 & 7
ESP	SAR Estimation	2
Texture	By Feel	10
Potassium (K)	ICP, 1:5 H20 Extract	1
Nitrate - Nitrogen (NO3)	Cadmium Reduction Column	3 & 4
Fertitility Tests		
Phosphorus	Olsen	3 & 7
Nitrate	Cd reduction, 1:5 H2O Extract	4
Potassium	1:5 NH4OAc Extract	3
Nitrogen	Kjeldahl	5
Fe, Zn, Cu, and Mn	DPTA Extract	3
Organic Matter	Walkley - Black	5
Boron	Hot Water Soluble	5
Soil Characterization Tests		
pH	Choice of Procedure	8
E.C. of saturated extract	Solution conductivity	2
% H2O at saturation	Drying at 110 +/- 5 degrees C	12
CaCO3 (equivalent)	Rapid titration	5
Gypsum	Acetone Precipitation	8
Mechanical Analysis	Hydrometer	8
Mechanical Analysis	Pipet	8
Extractable Cations	NH4OAc at pH 7 or 9	8
Exchangeable Cations	NH4OAc extractable minus soluble	8
Cation Exchange Capacity	Na saturated then NH4OAc extracted	5
Extractable Hydrogen	BaCl2 - TEA Extraction	8
Extractable NH4	2N KCl (colorimetric)	5
Soluble ions from saturated paste extract		
Saturated Paste	Deionized H2O	2
Soluble cations	ICP-ES	4
Chloride	Colorimetric	4

CO3 + HCO3	Titration	4
Soluble Sulfate	Turbidimetric	4
Soluble Ammonium	Colorimetric	4
Soluble Boron	ICP	4
Metals	ICP	4
Miscellaneous		
Grinding Soils	Stainless Steel Grinders	
Extractable Arsenic	NaHCO3 extract	11
Extractable Selenium	Hot Water reflux	5
Microwave digest	EPA method 3015	9

References:

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5. **Methods of Soil Analysis Part 2 Chemical and Micobiological Properties.** 1965. Ed., C.A. Black, ASA Monograph 9, Madison Wis.

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APPENDIX C

(HOME-TOP) (MODELS-TOP) CFITM CFITIM CHAIN CHAIN 2D CXTFIT 3DADE DISC ESAP-95 GEOPACK HYDRUS HYDRUS-1D HYDRUS-2D N3DADE RETC ROSETTA SALT SOILC02 SWMS-2D SWMS-3D TETRANS UNSATCHEM-2D UNSATCHEM UNSODA WATSUIT

HYDRUS-1D for Windows
October 1998
Version: 2.0

" Tutorial for HYDRUS-1D "

The **Demo** Version of the Program;
and Examples and Manual,
can be Downloaded from our FTP site,
using our GEBJSL FTP Access
Click Here!

A MS Windows Program for Simulating Water Flow and Solute Transport in One-Dimensional Variably Saturated Media with full-color, high-resolution Graphics User Interface

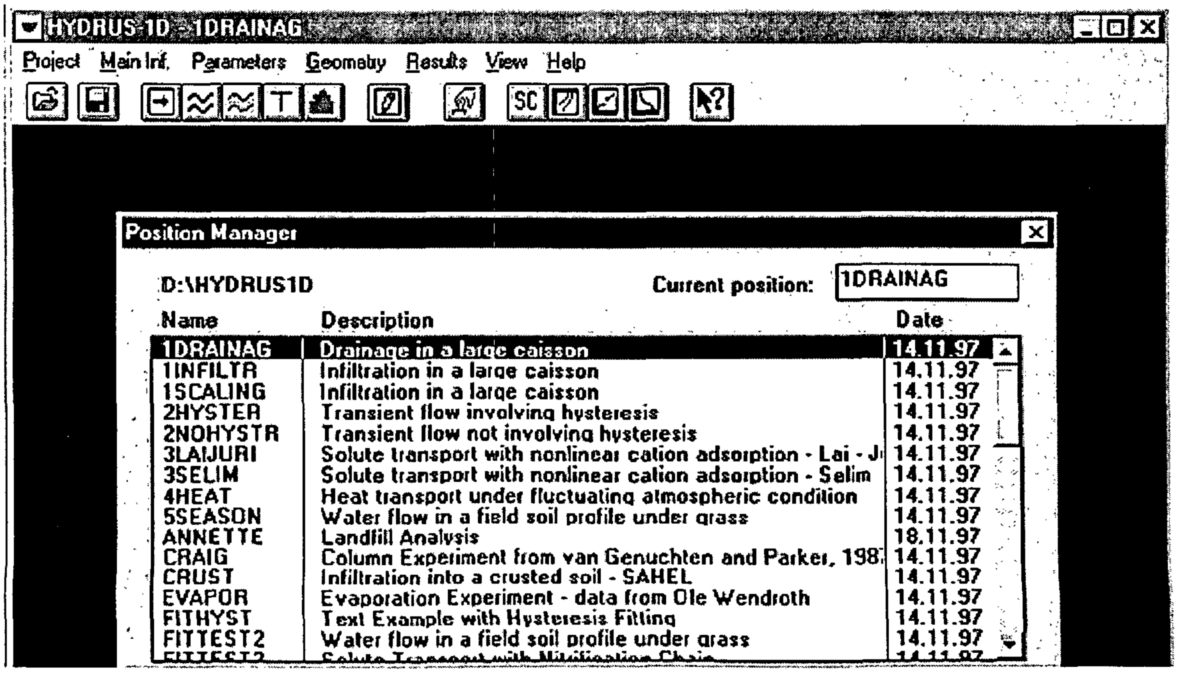
Authors:

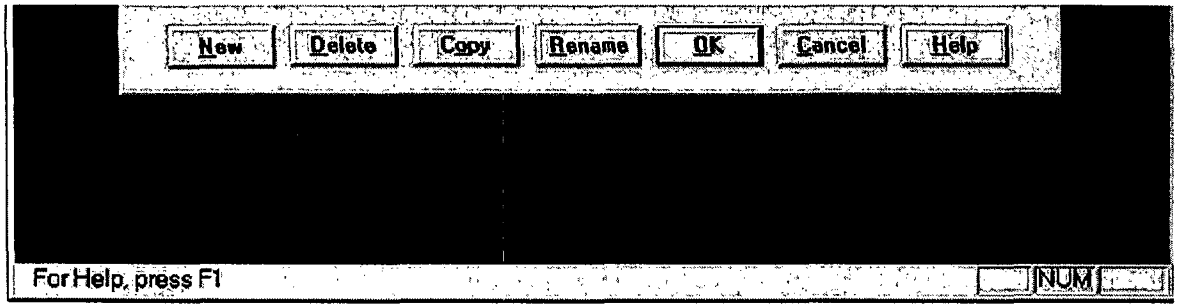
J. Simunek , K. Huang, M. Sejna, and M.Th. van Genuchten
U.S. Salinity Laboratory, USDA/ARS, Riverside, California

HYDRUS-1D is a Microsoft Windows based modeling environment for analysis of water flow and solute transport in variably saturated porous media.

The software package includes the one-dimensional finite element model HYDRUS (version 7.0) for simulating the movement of water, heat, and multiple solutes in variably saturated media.

The model is supported by an interactive graphics-based interface for data-preprocessing, discretization of the soil profile, and graphic presentation of the results.





HYDRUS Model (version 7.0)

The 'HYDRUS' program is a finite element model for simulating the **one-dimensional** movement of water, heat, and multiple solutes in variably saturated media. The program numerically solves the Richards' equation for saturated-unsaturated water flow and Fickian-based advection dispersion equations for heat and solute transport.

The **Flow** equation incorporates a sink term to account for water uptake by plant roots.

The **Heat** transport equation considers conduction as well as convection with flowing water.

The **Solute** transport equations consider advective-dispersive transport in the liquid phase, and diffusion in the gaseous phase.

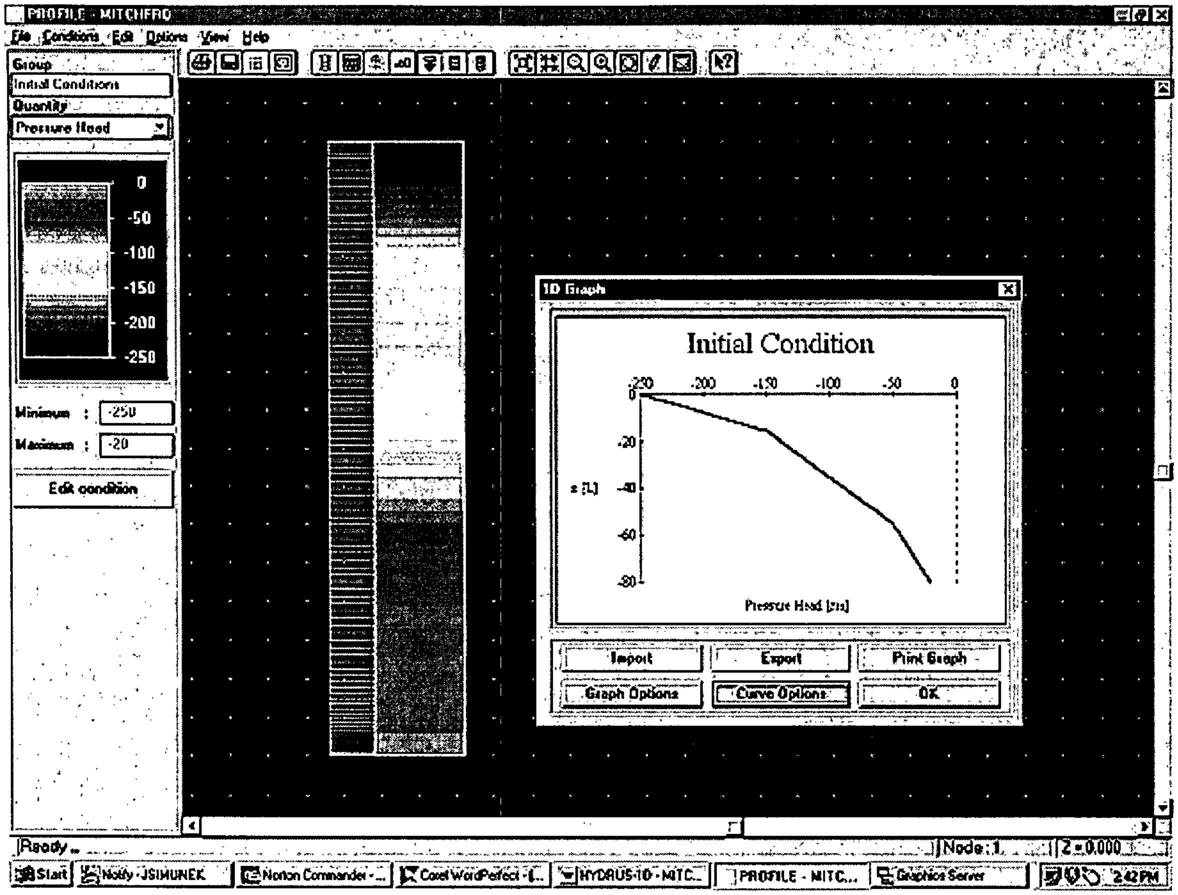
The transport equations also include provisions for:

- **Nonlinear** *and/or* **Nonequilibrium** reactions between the solid and liquid phases,
- **Linear** equilibrium reactions between the liquid and gaseous phases,
- **Zero order** production, and
- Two **First order** degradation reactions:
  - One which is independent of other solutes, and
  - One which provides the coupling between solutes involved in sequential first-order decay reactions.

The program may be used to analyze water and solute movement in unsaturated, partially saturated, or fully saturated porous media.

The flow region itself may be composed of nonuniform soils. Flow and transport can occur in the vertical, horizontal, or a generally inclined direction. The water flow part of the model can deal with (constant or time-varying) prescribed head and flux boundaries, boundaries controlled by atmospheric conditions, as well as free drainage boundary conditions. Soil surface boundary conditions may change during the simulation from prescribed flux to prescribed head type conditions (and viceversa).

For solute transport the code supports both (constant and varying) prescribed concentration (Dirichlet or first-type) and concentration flux (Cauchy or third-type) boundary conditions. The dispersion coefficient includes terms reflecting the effects of molecular diffusion and tortuosity.



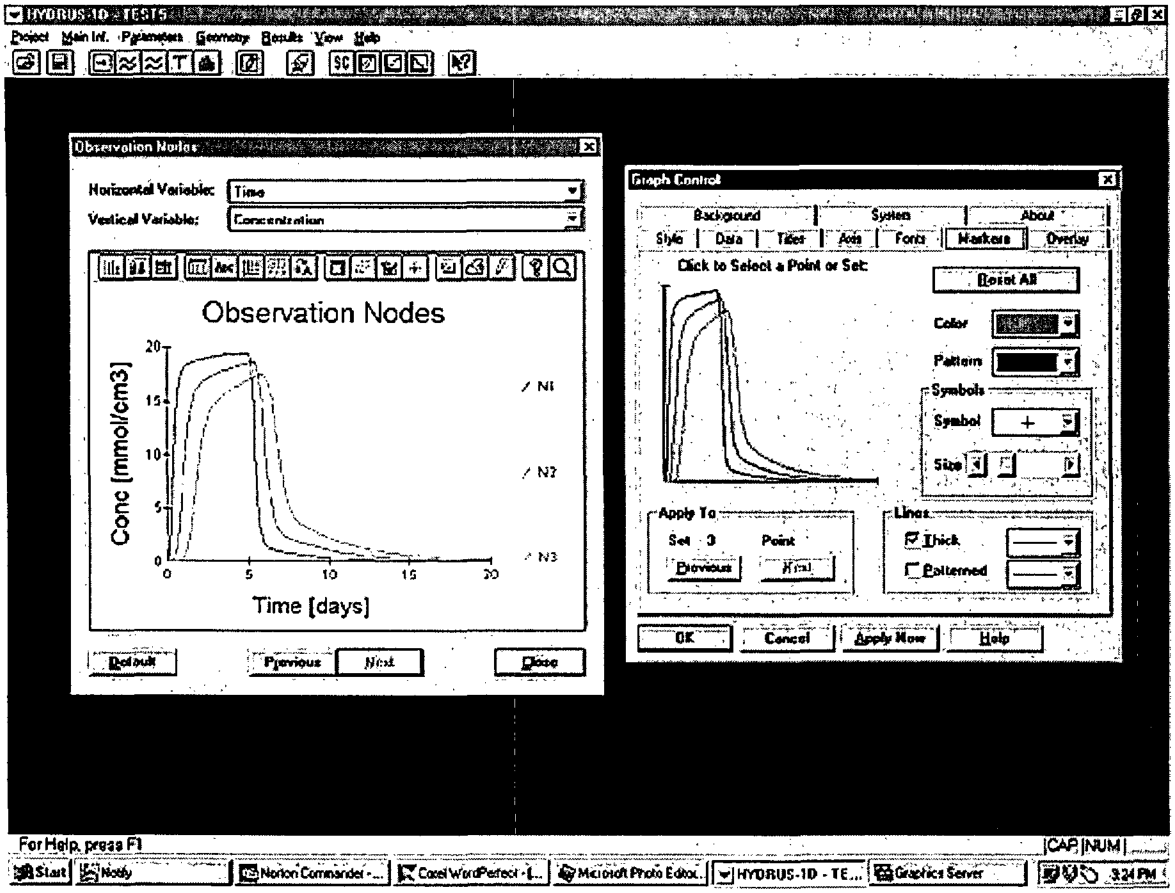
The **Unsaturated Soil Hydraulic Properties** are described using van Genuchten [1980], Brooks and Correy [1964] and modified van Genuchten type analytical functions. Modifications were made to improve the description of hydraulic properties near saturation. The HYDRUS code incorporates **hysteresis** by using the empirical model introduced by Scott et al. [1983] and Kool and Parker [1987]. This model assumes that drying scanning curves are scaled from the main drying curve, and wetting scanning curves from the main wetting curve.

HYDRUS also implements a **scaling** procedure to approximate hydraulic variability in a given soil profile by means of a set of linear scaling transformations which relate the individual soil hydraulic characteristics to those of a reference soil.

Root growth is simulated by means of a logistic growth function. Water and salinity stress response functions can be defined according to functions proposed by Feddes et al. [1978] or van Genuchten [1987].

The governing flow and transport equations are solved **numerically** using Galerkin type linear finite element schemes. Integration in time is achieved using an implicit (backwards) finite difference scheme for both saturated and unsaturated conditions. Additional measures are taken to improve solution efficiency for transient problems, including automatic time step adjustment and adherence to preset ranges of the Courant and Peclet numbers. The water content term is evaluated using the mass conservative method proposed by Celia et al. [1990]. Possible options for minimizing numerical oscillations in the transport solutions include upstream weighing, artificial dispersion, and/or performance indexing.

HYDRUS implements a Marquardt-Levenberg type parameter estimation technique for inverse estimation of selected soil hydraulic and/or solute transport and reaction parameters from measured transient or steady-state flow and/or transport data. The procedure permits several unknown parameters to be estimated from observed water contents, pressure heads, concentrations, and/or instantaneous or cumulative boundary fluxes (e.g., infiltration or outflow data). Additional retention or hydraulic conductivity data, as well as a penalty function for constraining the optimized parameters to remain in some feasible region (Bayesian estimation), can be optionally included in the parameter estimation procedure.



User Interface

A Microsoft Windows based Graphics User Interface (GUI) manages the input data required to run HYDRUS, as well as for nodal discretization and editing, parameter allocation, problem execution, and visualization of results.

All spatially distributed parameters, such as soil type/layer, root water uptake distribution, and the initial conditions for water, heat and solute movement, are specified in a graphical environment.

The location of discretization nodes can be graphically edited by a user to optimize the thickness of different elements.

The program includes controls to allow a user to build an application specific flow and transport model, and to perform graphical analyses on the fly.

Both input and output can be examined using graphical tools.

The HYDRUS-1D shell program translates all geometric and parameter data into the HYDRUS input format.

File management is handled by a sophisticated project manager.

Post-Processing

Post-processing is also carried out in the shell.

HYDRUS-1D offers graphs of the distribution of the pressure head, water content, water and solute fluxes, root water uptake, temperature and the concentration in the soil profile at preselected times.

Output also includes variable-versus-time plots, such as actual, potential and cumulative fluxes across boundaries or leaving the root zone.

Observation points can be added anywhere in the profile to obtain graphical output for the water content, pressure head, temperature, and/or the concentration.

Peripheral devices supported include most popular types of printers and plotters.

A small catalog of soil hydraulic properties is included in the program.

Extensive context-sensitive, online Help is part of the interface.

Test Examples distributed with the model:

Direct:

1. Water Flow and Solute Transport in a field soil profile under grass
   Seasonal simulation
2. Infiltration and Drainage in a large caisson
3. Transient Flow involving hysteresis
4. Skaggs' Column Infiltration Test
5. Solute Transport with nonlinear cation adsorption - Data from Lai and Jurinak
6. Solute Transport with nonlinear cation adsorption - Data from Selim
7. Solute Transport with nitrification chain
8. Solute Transport with non-equilibrium cation adsorption
9. Heat Transport under fluctuating atmospheric condition

Inverse:

1. One-step outflow experiment - Data from Kool et al. (1987)
2. Multistep Outflow Experiment - Data from Jan Hopmans
3. Evaporation Experiment - Data from Ole Wendroth
4. Upward Infiltration
5. Transient Flow involving hysteresis
6. Solute Transport with nonlinear cation adsorption - Data from Lai and Jurinak
7. Solute Transport with nonlinear cation adsorption - Data from Selim
8. Solute Transport with nitrification chain
9. Horizontal infiltration - Data from George Vachaud
10. Horizontal infiltration and redistribution - Data from George Vachaud
11. Drainage in a sand column - Data from George Vachaud
12. Water Flow in a field soil profile under grass - Seasonal simulation

SYSTEM REQUIREMENTS

Intel 80386 with math coprocessor, Intel 80486DX, or higher processor, 4 Mb RAM, DOS 5.0 or higher, hard disk with at least 10 Mb free disk space, VGA graphics (SVGA with 256 colors recommended), MS Windows 95, 98, or Windows NT.

Ordering Information

The **HYDRUS-1D** software package is distributed by the International Groundwater Modeling Center. **IGWMC** also prints the manual and provides help with its installation and use. *Below* is the reference of the manual and the IGWMC contact address where you can get more information, and where you can order the software.

Dr. Eileen Poeter
Professor of Groundwater Engineering
Department of Groundwater Engineering
Co-director of International Ground Water Modeling Center
Colorado School of Mines
Golden, Colorado, 80401-1887
Phone: (303) 273-3103
Fax.: (303) 384-2037
Email: IGWMC@mines.edu
http://magma.Mines.EDU/igwmc/software/igwmcsoft/

Return to *GEBJSL (USSL)* Models Menu
Return to *GEBJSL* (USSL) Programs
Return to *GEBJSL* (USSL) HomePage

f4mdl_set2000 nod hydrus-2d1 000531a mcliath iclia

f4mdl_set2k_001206 nod ipowerof1 iclia mcliath

APPENDIX D

PRELIMINARY REPORT

ASSAIGAI ANALYTICAL LABORATORIES, INC.
7300 Jefferson, NE • Albuquerque, New Mexico 87109 • (505) 345-8964 • FAX (505) 345-7259
3332 Wedgewood Dr., Suite N • El Paso, Texas 79925 • (915) 593-6000 • FAX (915) 593-7820
127 Eastgate Drive, 212-C • Los Alamos, New Mexico 87544 • (505) 662-2558

Explanation of codes	
B	analyte detected in Method Blank
E	result is estimated
H	analyzed out of hold time
N	tentatively identified compound
S	subcontracted
1-9	see footnote

RT HICKS CONSULTING, LTD
attn: MICHELLE HUNTER / RANDY HICKS
4665 INDIAN SCH. NE 106
ALBUQUERQUE, NM 87110

Assaigai Analytical Laboratories, Inc.

Certificate of Analysis

Client: RT HICKS CONSULTING, LTD
Project: 0104013 RICE

PRELIMINARY REPORT

William P. Biava: President of Assaigai Analytical Laboratories, Inc.

Client Sample ID: *PIT#1 0-0.25'* Sample Matrix: *SOIL* Sample Collected: 03/28/01 15:00:00

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-01A		**EPA 300.0**							
W01115	MW.2001.533-3	16887-00-6	Chloride	1990	mg / Kg	100	0.05		04/12/01
0104013-01A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-20	7440-70-2	Calcium	2450	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-20	7440-47-3	Chromium	15.9	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-20	7439-89-6	Iron	10700	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-20	7439-95-4	Magnesium	2620	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-20	7440-09-7	Potassium	3410	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-20	7440-23-5	Sodium	4240	mg / Kg	1	15		04/12/01
0104013-01A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01105	XG.2001.384-6	71-43-2	Benzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-6	100-41-4	Ethylbenzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-6	91-20-3	Naphthalene	ND	mg / Kg	1	0.025	1	04/03/01
X01105	XG.2001.384-6	95-47-6	o-Xylene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-6	108-38-3/106-42	p/m Xylenes	ND	mg / Kg	1	0.01	1	04/03/01
X01105	XG.2001.384-6	108-88-3	Toluene	ND	mg / Kg	1	0.005	1	04/03/01

Assaigai Analytical Laboratories, Inc.

Certificate of Analysis

Client: **RT HICKS CONSULTING, LTD**
Project: **0104013 RICE**

Client Sample ID: ***PIT#1 0.5-1.0'*** Sample Matrix: ***SOIL*** Sample Collected: *03/28/01 15:00:00*

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-02A		**EPA 300.0**							
W01115	MW.2001.533-4	16887-00-6	Chloride	1870	mg / Kg	100	0.05		04/12/01
0104013-02A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-21	7440-70-2	Calcium	2510	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-21	7440-47-3	Chromium	15.9	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-21	7439-89-6	Iron	10900	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-21	7439-95-4	Magnesium	2820	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-21	7440-09-7	Potassium	3300	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-21	7440-23-5	Sodium	3530	mg / Kg	1	15		04/12/01
0104013-02A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01105	XG.2001.384-7	71-43-2	Benzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-7	100-41-4	Ethylbenzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-7	91-20-3	Naphthalene	ND	mg / Kg	1	0.025	1	04/03/01
X01105	XG.2001.384-7	95-47-6	o-Xylene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-7	108-38-3/106-42	p/m Xylenes	ND	mg / Kg	1	0.01	1	04/03/01
X01105	XG.2001.384-7	108-88-3	Toluene	ND	mg / Kg	1	0.005	1	04/03/01

Client Sample ID: ***PIT#1 3.5-4.5'*** Sample Matrix: ***SOIL*** Sample Collected: *03/28/01 13:00:00*

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-03A		**EPA 300.0**							
W01115	MW.2001.533-5	16887-00-6	Chloride	956	mg / Kg	100	0.05		04/12/01
0104013-03A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-22	7440-70-2	Calcium	10500	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-22	7440-47-3	Chromium	16.9	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-22	7439-89-6	Iron	11500	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-22	7439-95-4	Magnesium	3960	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-22	7440-09-7	Potassium	3040	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-22	7440-23-5	Sodium	1060	mg / Kg	1	15		04/12/01
0104013-03A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01105	XG.2001.384-8	71-43-2	Benzene	0.013	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-8	100-41-4	Ethylbenzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-8	91-20-3	Naphthalene	ND	mg / Kg	1	0.025	1	04/03/01
X01105	XG.2001.384-8	95-47-6	o-Xylene	ND	mg / Kg	1	0.005	1	04/03/01

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Certificate of Analysis

Client: **RT HICKS CONSULTING, LTD**
Project: **0104013 RICE**

X01105	XG.2001.384-8	108-38-3/106-42	p/m Xylenes	ND	mg / Kg	1	0.01	1	04/03/01
X01105	XG.2001.384-8	108-88-3	Toluene	ND	mg / Kg	1	0.005	1	04/03/01

Client Sample ID **PIT#2 0-0.25'** Sample Matrix **SOIL** Sample Collected 03/28/01 15:00:00

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-04A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-23	7440-70-2	Calcium	3170	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-23	7440-47-3	Chromium	14.0	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-23	7439-89-6	Iron	9920	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-23	7439-95-4	Magnesium	2490	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-23	7440-09-7	Potassium	2990	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-23	7440-23-5	Sodium	3180	mg / Kg	1	15		04/12/01
0104013-04A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01105	XG.2001.384-9	71-43-2	Benzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-9	100-41-4	Ethylbenzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.366-2	91-20-3	Naphthalene	ND	mg / Kg	10	0.025	12	04/04/01
X01105	XG.2001.384-9	95-47-6	o-Xylene	0.006	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-9	108-38-3/106-42	p/m Xylenes	ND	mg / Kg	1	0.01	1	04/03/01
X01105	XG.2001.384-9	108-88-3	Toluene	ND	mg / Kg	1	0.005	1	04/03/01

Client Sample ID **PIT#2 0.25-0.5'** Sample Matrix **SOIL** Sample Collected 03/28/01 15:00:00

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-05A		**EPA 300.0**							
W01115	MW.2001.533-6	16887-00-6	Chloride	1860	mg / Kg	100	0.05		04/12/01
0104013-05A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-26	7440-70-2	Calcium	3750	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-26	7440-47-3	Chromium	15.9	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-26	7439-89-6	Iron	10700	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-26	7439-95-4	Magnesium	3260	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-26	7440-09-7	Potassium	3250	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-26	7440-23-5	Sodium	3100	mg / Kg	1	15		04/12/01
0104013-05A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01105	XG.2001.384-10	71-43-2	Benzene	0.033	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-10	100-41-4	Ethylbenzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-10	91-20-3	Naphthalene	ND	mg / Kg	1	0.025	1	04/03/01
X01105	XG.2001.384-10	95-47-6	o-Xylene	0.019	mg / Kg	1	0.005	1	04/03/01

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Client: **RT HICKS CONSULTING, LTD**
Project: **0104013 RICE**

X01105	XG.2001.384-10	108-38-3/106-42	p/m Xylenes	0.020	mg / Kg	1	0.01	1	04/03/01
X01105	XG.2001.384-10	108-88-3	Toluene	0.023	mg / Kg	1	0.005	1	04/03/01

Client Sample ID **PIT#2 0.5-1.0'** Sample Matrix **SOIL** Sample Collected 03/28/01 15:00:00

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-06A		**EPA 300.0**							
W01115	MW.2001.533-7	16887-00-6	Chloride	1080	mg / Kg	100	0.05		04/12/01
0104013-06A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-27	7440-70-2	Calcium	13400	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-27	7440-47-3	Chromium	15.4	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-27	7439-89-6	Iron	10400	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-27	7439-95-4	Magnesium	3550	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-27	7440-09-7	Potassium	2550	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-27	7440-23-5	Sodium	890	mg / Kg	1	15		04/12/01
0104013-06A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01105	XG.2001.384-11	71-43-2	Benzene	0.25	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-11	100-41-4	Ethylbenzene	0.074	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-11	91-20-3	Naphthalene	ND	mg / Kg	1	0.025	1	04/03/01
X01105	XG.2001.384-11	95-47-6	o-Xylene	0.059	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-11	108-38-3/106-42	p/m Xylenes	0.21	mg / Kg	1	0.01	1	04/03/01
X01105	XG.2001.384-11	108-88-3	Toluene	0.37	mg / Kg	1	0.005	1	04/03/01

Client Sample ID **PIT#2 2.5-4.5'** Sample Matrix **SOIL** Sample Collected 03/28/01 15:00:00

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-07A		**EPA 300.0**							
W01115	MW.2001.533-8	16887-00-6	Chloride	486	mg / Kg	100	0.05		04/12/01
0104013-07A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-28	7440-70-2	Calcium	15600	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-28	7440-47-3	Chromium	14.3	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-28	7439-89-6	Iron	9680	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-28	7439-95-4	Magnesium	3600	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-28	7440-09-7	Potassium	2310	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-28	7440-23-5	Sodium	698	mg / Kg	1	15		04/12/01
0104013-07A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01105	XG.2001.384-12	71-43-2	Benzene	0.081	mg / Kg	1	0.005	1	04/03/01

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X01105	XG.2001.384-12	100-41-4	Ethylbenzene	0.005	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-12	91-20-3	Naphthalene	ND	mg / Kg	1	0.025	1	04/03/01
X01105	XG.2001.384-12	95-47-6	o-Xylene	0.009	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-12	108-38-3/106-42	p/m Xylenes	0.020	mg / Kg	1	0.01	1	04/03/01
X01105	XG.2001.384-12	108-88-3	Toluene	0.020	mg / Kg	1	0.005	1	04/03/01

Client Sample ID **PIT#3 0-0.25** Sample Matrix **SOIL** Sample Collected 03/28/01 15:00:00

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-08A		**EPA 300.0**							
W01115	MW.2001.533-9	16887-00-6	Chloride	296	mg / Kg	100	0.05		04/12/01
0104013-08A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-29	7440-70-2	Calcium	2970	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-29	7440-47-3	Chromium	11.7	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-29	7439-89-6	Iron	8410	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-29	7439-95-4	Magnesium	2080	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-29	7440-09-7	Potassium	2760	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-29	7440-23-5	Sodium	846	mg / Kg	1	15		04/12/01
0104013-08A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01105	XG.2001.384-13	71-43-2	Benzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-13	100-41-4	Ethylbenzene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.388-3	91-20-3	Naphthalene	ND	mg / Kg	10	0.025	12	04/04/01
X01105	XG.2001.384-13	95-47-6	o-Xylene	ND	mg / Kg	1	0.005	1	04/03/01
X01105	XG.2001.384-13	108-38-3/106-42	p/m Xylenes	ND	mg / Kg	1	0.01	1	04/03/01
X01105	XG.2001.384-13	108-88-3	Toluene	ND	mg / Kg	1	0.005	1	04/03/01

Client Sample ID **PIT#3 0.25-0.5** Sample Matrix **SOIL** Sample Collected 03/28/01 15:00:00

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-09A		**EPA 300.0**							
W01115	MW.2001.533-10	16887-00-6	Chloride	304	mg / Kg	100	0.05		04/12/01
0104013-09A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-30	7440-70-2	Calcium	3820	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-30	7440-47-3	Chromium	14.3	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-30	7439-89-6	Iron	10000	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-30	7439-95-4	Magnesium	2610	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-30	7440-09-7	Potassium	3120	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-30	7440-23-5	Sodium	506	mg / Kg	1	15		04/12/01

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Project: **0104013 RICE**

0104013-09A SW846 8260A Purgeable VOCs by GC/MS

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
X01105	XG.2001.384-14	71-43-2	Benzene	ND	mg / Kg	1	0.005		04/03/01
X01105	XG.2001.384-14	100-41-4	Ethylbenzene	ND	mg / Kg	1	0.005		04/03/01
X01105	XG.2001.388-4	91-20-3	Naphthalene	ND	mg / Kg	10	0.025	2	04/04/01
X01105	XG.2001.384-14	95-47-6	o-Xylene	ND	mg / Kg	1	0.005		04/03/01
X01105	XG.2001.384-14	108-38-3/106-42	p/m Xylenes	ND	mg / Kg	1	0.01		04/03/01
X01105	XG.2001.384-14	108-88-3	Toluene	ND	mg / Kg	1	0.005		04/03/01

Client Sample ID ***PIT#3 0.5-1.0*** Sample Matrix ***SOIL*** Sample Collected *03/28/01 15:00:00*

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-10A		**EPA 300.0**							
W01115	MW.2001.533-12	16887-00-6	Chloride	502	mg / Kg	100	0.05		04/12/01
0104013-10A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-31	7440-70-2	Calcium	4570	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-31	7440-47-3	Chromium	14.8	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-31	7439-89-6	Iron	10600	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-31	7439-95-4	Magnesium	3050	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-31	7440-09-7	Potassium	3210	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-31	7440-23-5	Sodium	210	mg / Kg	1	15		04/12/01
0104013-10A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01105	XG.2001.384-15	71-43-2	Benzene	ND	mg / Kg	1	0.005		04/03/01
X01105	XG.2001.384-15	100-41-4	Ethylbenzene	ND	mg / Kg	1	0.005		04/03/01
X01105	XG.2001.388-5	91-20-3	Naphthalene	ND	mg / Kg	10	0.025	2	04/04/01
X01105	XG.2001.384-15	95-47-6	o-Xylene	ND	mg / Kg	1	0.005		04/03/01
X01105	XG.2001.384-15	108-38-3/106-42	p/m Xylenes	ND	mg / Kg	1	0.01		04/03/01
X01105	XG.2001.384-15	108-88-3	Toluene	ND	mg / Kg	1	0.005		04/03/01

Client Sample ID ***PIT#3 2.5-4.5*** Sample Matrix ***SOIL*** Sample Collected *03/28/01 15:00:00*

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-11A		**EPA 300.0**							
W01115	MW.2001.533-13	16887-00-6	Chloride	182	mg / Kg	100	0.05		04/12/01
0104013-11A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-32	7440-70-2	Calcium	7730	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-32	7440-47-3	Chromium	14.0	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-32	7439-89-6	Iron	10100	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-32	7439-95-4	Magnesium	3290	mg / Kg	1	10		04/12/01

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QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
M01370	MW.2001.512-32	7440-09-7	Potassium	3100	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-32	7440-23-5	Sodium	176	mg / Kg	1	15		04/12/01
0104013-11A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01118	XG.2001.405-2	71-43-2	Benzene	ND	mg / Kg	1	0.005		04/04/01
X01118	XG.2001.405-2	100-41-4	Ethylbenzene	ND	mg / Kg	1	0.005		04/04/01
X01118	XG.2001.405-2	91-20-3	Naphthalene	ND	mg / Kg	1	0.025		04/04/01
X01118	XG.2001.405-2	95-47-6	o-Xylene	ND	mg / Kg	1	0.005		04/04/01
X01118	XG.2001.405-2	108-38-3/106-42	p/m Xylenes	ND	mg / Kg	1	0.01		04/04/01
X01118	XG.2001.405-2	108-88-3	Toluene	ND	mg / Kg	1	0.005		04/04/01

Client Sample ID **PIT#4 ABOVE CALICHE** Sample Matrix **SOIL** Sample Collected *03/28/01 15:00:00*

QC Group	Run Sequence	CAS #	Analyte	Result	Units	Dilution Factor	Detection Limit	Code	Run Date
0104013-12A		**EPA 300.0**							
W01115	MW.2001.533-14	16887-00-6	Chloride	1450	mg / Kg	100	0.05		04/12/01
0104013-12A		**SW846 3050A/6010A ICP**							
M01370	MW.2001.512-33	7440-70-2	Calcium	9270	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-33	7440-47-3	Chromium	15.0	mg / Kg	1	1		04/12/01
M01370	MW.2001.512-33	7439-89-6	Iron	10500	mg / Kg	1	15		04/12/01
M01370	MW.2001.512-33	7439-95-4	Magnesium	4150	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-33	7440-09-7	Potassium	2890	mg / Kg	1	10		04/12/01
M01370	MW.2001.512-33	7440-23-5	Sodium	1700	mg / Kg	1	15		04/12/01
0104013-12A		**SW846 8260A Purgeable VOCs by GC/MS**							
X01118	XG.2001.405-4	71-43-2	Benzene	2.2	mg / Kg	10	0.005		04/04/01
X01118	XG.2001.405-4	100-41-4	Ethylbenzene	0.87	mg / Kg	10	0.005		04/04/01
X01118	XG.2001.405-3	91-20-3	Naphthalene	0.045	mg / Kg	1	0.025		04/04/01
X01118	XG.2001.405-4	95-47-6	o-Xylene	0.67	mg / Kg	10	0.005		04/04/01
X01118	XG.2001.405-4	108-38-3/106-42	p/m Xylenes	2.7	mg / Kg	10	0.01		04/04/01
X01118	XG.2001.405-4	108-88-3	Toluene	5.6	mg / Kg	10	0.005		04/04/01

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Project: **0104013 RICE**

**** Sample specific Detection Limit is determined by multiplying the sample Dilution Factor by the listed Reporting Detection Limit. ****

**** ND = Not detected: less than the sample specific Detection Limit. Results relate only to the items tested. ****

footnote

1 Sample was received in improper container.

2 Sample was re-analyzed with headspace.

APPENDIX E

SWAT Laboratory
New Mexico State University
Agronomy & Horticulture Department
Box 30003, Department 3Q
Las Cruces, NM 88003-8003

April 19, 2001

Randall Hicks
4665 Indian School Rd. NE #106
Albuqerque, NM 87110
266-5004

Dear Randall Hicks:

Below are the results of analysis of 10 samples received for examination on April 4, 2001:

Sample I.D. AB23460 Client Code: SOILNONE
Sample Description: Pit 1 0.5 - 1.0
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	*DETECTION LIMIT*
pH of Soil Saturation Paste		7.16	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	22.7 1870	0.01
Magnesium (for SAR)-	meq/L	11.4	0.1
Calcium (for SAR)-	meq/L	35.0	0.1
Sodium (for SAR)-	meq/L	233.0	0.1
Sodium Adsorption Ratio (SAR)		48.37	0.01
Calculated Exchangeable Na %-ESP		41.2	0.1
Organic Matter	percent	1.72	0.01
NO3-N 1:5 (soil:water) extract	ppm	3.3	0.1
Phosphorus (NaHCO3 extracted)	ppm	17.6	0.1
K 1:5 (soil:water) extract	ppm	116	1
Texture of soil by feel		clay loam	
Chloride in soil water extract	mg/Kg	8689	250
Cation exchange capacity	meq/100gr	24.7	0.01
Extractable Sodium	meq/100gr	26.1	0.01
Extractable Potassium	meq/100gr	2.73	0.01
Extractable Calcium	meq/100gr	14.7	0.01
Extractable Magnesium	meq/100gr	4.83	0.01
Saturated paste percent water	percent	72.70	0.01
Potassium in sat. paste extract	meq/L	3.49	2.01
CaCO3 equivalents in soil-	percent	0.60	0.01
Soil gypsum by acetone precip	percent	Not detected	0.1

Sample comments:

Exchangeable Cations
meq/100 gr

Mg	Ca	Na	K
4.0	12.2	9.2	2.5

Sample I.D. AB23461 Client Code: SOILNONE
Sample Description: Pit 1 3.5 - 4.5
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of Soil Saturation Paste		7.37	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	12.1 900	0.01
Magnesium (for SAR)-	meq/L	25.70	0.05
Calcium (for SAR)-	meq/L	70.70	0.05
Sodium (for SAR)-	meq/L	69.80	0.05
Sodium Adsorption Ratio (SAR)		10.05	0.01
Calculated Exchangeable Na %-ESP		11.9	0.1
Organic Matter	percent	0.50	0.01
NO3-N 1:5 (soil:water) extract	ppm	2.5	0.1
Phosphorus (NaHCO3 extracted)	ppm	3.3	0.1
K 1:5 (soil:water) extract	ppm	74	1
Texture of soil by feel		clay loam	
Chloride in soil water extract	mg/Kg	4330	100
Cation exchange capacity	meq/100gr	30.8	0.01
Extractable Sodium	meq/100gr	7.37	0.01
Extractable Potassium	meq/100gr	1.68	0.01
Extractable Calcium	meq/100gr	37.6	0.01
Extractable Magnesium	meq/100gr	9.25	0.01
Saturated paste percent water	percent	58.68	0.01
Potassium in sat. paste extract	meq/L	1.12	2.01
CaCO3 equivalents in soil-	percent	2.19	0.01
Soil gypsum by acetone precip	percent	0.23	0.1

Sample comments:

Exchangeable Cations
meq/100 gr

Mg	Ca	Na	K
7.7	33.5	3.3	1.6

Sample I.D. AB23462 Client Code: SOILNONE
Sample Description: Pit 2 0 - 0.25
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of Soil Saturation Paste		6.59	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	24.1	0.01
Magnesium (for SAR)-	meq/L	15.5	0.1
Calcium (for SAR)-	meq/L	48.8	0.1

April 19, 2001
Randall Hicks Sample I.D. AB23462 (continued)

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
Sodium (for SAR)-	meq/L	255.0	0.1
Sodium Adsorption Ratio (SAR)		44.97	0.01
Calculated Exchangeable Na %-ESP		39.4	0.1
Organic Matter	percent	3.90	0.01
NO3-N 1:5 (soil:water) extract	ppm	2.2	0.1
Phosphorus (NaHCO3 extracted)	ppm	68.6	0.1
K 1:5 (soil:water) extract	ppm	222	1
Texture of soil by feel		clay loam	
Chloride in soil water extract	mg/Kg	8086	250
Cation exchange capacity	meq/100gr	29.2	0.01
Extractable Sodium	meq/100gr	22.9	0.01
Extractable Potassium	meq/100gr	3.23	0.01
Extractable Calcium	meq/100gr	14.2	0.01
Extractable Magnesium	meq/100gr	4.30	0.01
Saturated paste percent water	percent	59.10	0.01
Potassium in sat. paste extract	meq/L	6.40	2.01
CaCO3 equivalents in soil-	percent	0.36	0.01
Soil gypsum by acetone precip	percent	Not detected	0.1

Sample comments:

Exchangeable Cations

meq/100 gr

Mg	Ca	Na	K
3.4	11.3	7.8	2.9

Sample I.D. AB23463 Client Code: SOILNONE
Sample Description: Pit 2 0.25 - 0.5
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of Soil Saturation Paste		7.26	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	27.7	0.01
Magnesium (for SAR)-	meq/L	24.5	0.1
Calcium (for SAR)-	meq/L	84.6	0.1
Sodium (for SAR)-	meq/L	263.0	0.1
Sodium Adsorption Ratio (SAR)		35.61	0.01
Calculated Exchangeable Na %-ESP		33.9	0.1
Organic Matter	percent	1.20	0.01
NO3-N 1:5 (soil:water) extract	ppm	3.0	0.1
Phosphorus (NaHCO3 extracted)	ppm	3.9	0.1
K 1:5 (soil:water) extract	ppm	116	1

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
Texture of soil by feel		clay	
Chloride in soil water extract	mg/Kg	11817	250
Cation exchange capacity	meq/100gr	30.8	0.01
Extractable Sodium	meq/100gr	24.8	0.01
Extractable Potassium	meq/100gr	2.28	0.01
Extractable Calcium	meq/100gr	23.2	0.01
Extractable Magnesium	meq/100gr	6.54	0.01
Saturated paste percent water	percent	67.53	0.01
Potassium in sat. paste extract	meq/L	3.59	2.01
CaCO3 equivalents in soil-	percent	1.60	0.01
Soil gypsum by acetone precip	percent	Not detected	0.1

Sample comments:

Exchangeable Cations

Mg	Ca	Na	K
meq/100 gr			
4.9	17.5	7.0	2.0

Sample I.D. AB23464 Client Code: SOILNONE
Sample Description: Pit 2 0.5 - 1.0
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of Soil Saturation Paste		7.33	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	11.6	0.01
Magnesium (for SAR)-	meq/L	19.00	0.05
Calcium (for SAR)-	meq/L	53.60	0.05
Sodium (for SAR)-	meq/L	66.00	0.05
Sodium Adsorption Ratio (SAR)		10.95	0.01
Calculated Exchangeable Na %-ESP		13.0	0.1
Organic Matter	percent	1.04	0.01
NO3-N 1:5 (soil:water) extract	ppm	3.3	0.1
Phosphorus (NaHCO3 extracted)	ppm	3.2	0.1
K 1:5 (soil:water) extract	ppm	58	1
Texture of soil by feel		clay	
Chloride in soil water extract	mg/Kg	4458	100
Cation exchange capacity	meq/100gr	33.3	0.01
Extractable Sodium	meq/100gr	6.91	0.01
Extractable Potassium	meq/100gr	1.53	0.01
Extractable Calcium	meq/100gr	25.8	0.01
Extractable Magnesium	meq/100gr	8.20	0.01

Page: 5
April 19, 2001
Randall Hicks Sample I.D. AB23464 (continued)

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
Saturated paste percent water	percent	62.17	0.01
Potassium in sat. paste extract	meq/L	1.24	2.01
CaCO3 equivalents in soil-	percent	3.45	0.01
Soil gypsum by acetone precip	percent	Not detected	0.1

Sample comments:

Exchangeable Cations

Mg	Ca	Na	K
meq/100 gr			
7.0	22.5	2.8	1.5

Sample I.D. AB23465 Client Code: SOILNONE
Sample Description: Pit 2 2.5 - caliche
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of Soil Saturation Paste		7.48	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	8.59	0.01
Magnesium (for SAR)-	meq/L	15.70	0.05
Calcium (for SAR)-	meq/L	38.70	0.05
Sodium (for SAR)-	meq/L	49.00	0.05
Sodium Adsorption Ratio (SAR)		9.40	0.01
Calculated Exchangeable Na %-ESP		11.2	0.1
Organic Matter	percent	1.06	0.01
NO3-N 1:5 (soil:water) extract	ppm	3.4	0.1
Phosphorus (NaHCO3 extracted)	ppm	7.4	0.1
K 1:5 (soil:water) extract	ppm	37	1
Texture of soil by feel		clay	
Chloride in soil water extract	mg/Kg	3220	100
Cation exchange capacity	meq/100gr	32.8	0.01
Extractable Sodium	meq/100gr	5.48	0.01
Extractable Potassium	meq/100gr	1.27	0.01
Extractable Calcium	meq/100gr	23.4	0.01
Extractable Magnesium	meq/100gr	8.63	0.01
Saturated paste percent water	percent	64.81	0.01
Potassium in sat. paste extract	meq/L	0.79	2.01
CaCO3 equivalents in soil-	percent	3.55	0.01
Soil gypsum by acetone precip	percent	Not detected	0.1

Sample comments:

Exchangeable Cations
meq/100 gr

Mg	Ca	Na	K
7.6	20.9	2.3	1.2

Sample I.D. AB23466 Client Code: SOILNONE
Sample Description: Pit 3 0 - 0.25
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of Soil Saturation Paste		6.57	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	4.39	0.01
Magnesium (for SAR)-	meq/L	3.73	0.05
Calcium (for SAR)-	meq/L	13.30	0.05
Sodium (for SAR)-	meq/L	32.00	0.05
Sodium Adsorption Ratio (SAR)		10.97	0.01
Calculated Exchangeable Na %-ESP		13.0	0.1
Organic Matter	percent	1.38	0.01
NO3-N 1:5 (soil:water) extract	ppm	3.8	0.1
Phosphorus (NaHCO3 extracted)	ppm	38.0	0.1
K 1:5 (soil:water) extract	ppm	63	1
Texture of soil by feel		clay loam	
Chloride in soil water extract	mg/Kg	1361	50
Cation exchange capacity	meq/100gr	30.6	0.01
Extractable Sodium	meq/100gr	5.28	0.01
Extractable Potassium	meq/100gr	2.47	0.01
Extractable Calcium	meq/100gr	23.6	0.01
Extractable Magnesium	meq/100gr	5.11	0.01
Saturated paste percent water	percent	65.59	0.01
Potassium in sat. paste extract	meq/L	1.17	2.01
CaCO3 equivalents in soil-	percent	0.55	0.01
Soil gypsum by acetone precip	percent	Not detected	0.1

Sample comments:

Exchangeable Cations
meq/100 gr

Mg	Ca	Na	K
4.9	22.7	3.2	2.4

Sample I.D. AB23467 Client Code: SOILNONE
Sample Description: Pit 3 0.25 - 0.5
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of Soil Saturation Paste		6.53	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	3.05	0.01
Magnesium (for SAR)-	meq/L	0.81	0.01
Calcium (for SAR)-	meq/L	3.01	0.01
Sodium (for SAR)-	meq/L	28.60	0.01
Sodium Adsorption Ratio (SAR)		20.69	0.01
Calculated Exchangeable Na %-ESP		22.6	0.1
Organic Matter	percent	1.03	0.01
NO3-N 1:5 (soil:water) extract	ppm	13.7	0.1
Phosphorus (NaHCO3 extracted)	ppm	56.2	0.1
K 1:5 (soil:water) extract	ppm	114	1
Texture of soil by feel		clay loam	
Chloride in soil water extract	mg/Kg	816	50
Cation exchange capacity	meq/100gr	36.2	0.01
Extractable Sodium	meq/100gr	6.22	0.01
Extractable Potassium	meq/100gr	2.67	0.01
Extractable Calcium	meq/100gr	15.9	0.01
Extractable Magnesium	meq/100gr	3.76	0.01
Saturated paste percent water	percent	57.84	0.01
Potassium in sat. paste extract	meq/L	1.10	2.01
CaCO3 equivalents in soil-	percent	0.38	0.01
Soil gypsum by acetone precip	percent	Not detected	0.1

Sample comments:

Exchangeable Cations
meq/100 gr

Mg	Ca	Na	K
3.7	15.7	4.6	2.6

Sample I.D. AB23468 Client Code: SOILNONE
Sample Description: Pit 3 0.5 - 1.0
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of Soil Saturation Paste		6.62	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	4.69	0.01
Magnesium (for SAR)-	meq/L	6.49	0.05
Calcium (for SAR)-	meq/L	24.80	0.05

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
Sodium (for SAR)-	meq/L	20.10	0.05
Sodium Adsorption Ratio (SAR)		5.08	0.01
Calculated Exchangeable Na %-ESP		5.9	0.1
Organic Matter	percent	1.72	0.01
NO3-N 1:5 (soil:water) extract	ppm	6.8	0.1
Phosphorus (NaHCO3 extracted)	ppm	14.7	0.1
K 1:5 (soil:water) extract	ppm	81	1
Texture of soil by feel		clay	
Chloride in soil water extract	mg/Kg	1567	50
Cation exchange capacity	meq/100gr	38.6	0.01
Extractable Sodium	meq/100gr	3.03	0.01
Extractable Potassium	meq/100gr	2.54	0.01
Extractable Calcium	meq/100gr	28.2	0.01
Extractable Magnesium	meq/100gr	6.48	0.01
Saturated paste percent water	percent	69.93	0.01
Potassium in sat. paste extract	meq/L	1.36	2.01
CaCO3 equivalents in soil-	percent	0.65	0.01
Soil gypsum by acetone precip	percent	Not detected	0.1

Sample comments:

Exchangeable Cations
meq/100 gr

Mg	Ca	Na	K
6.0	26.5	1.6	2.4

Sample I.D. AB23469 Client Code: SOILNONE
Sample Description: Pit 3 2.5 - caliche
Sample collector: R HICKS Sample collection date: 04/02/01
Lab submittal date: 04/04/01 Time: 11:35

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of Soil Saturation Paste		7.40	
Elect. Cond. of Soil Paste Extr.	mmhos/cm	3.68	0.01
Magnesium (for SAR)-	meq/L	9.87	0.05
Calcium (for SAR)-	meq/L	34.00	0.05
Sodium (for SAR)-	meq/L	9.04	0.05
Sodium Adsorption Ratio (SAR)		1.93	0.01
Calculated Exchangeable Na %-ESP		1.6	0.1
Organic Matter	percent	1.48	0.01
NO3-N 1:5 (soil:water) extract	ppm	4.8	0.1
Phosphorus (NaHCO3 extracted)	ppm	2.1	0.1
K 1:5 (soil:water) extract	ppm	76	1
Texture of soil by feel		clay loam	

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
Chloride in soil water extract	mg/Kg	692	10
Cation exchange capacity	meq/100gr	35.8	0.01
Extractable Sodium	meq/100gr	1.27	0.01
Extractable Potassium	meq/100gr	2.20	0.01
Extractable Calcium	meq/100gr	29.0	0.01
Extractable Magnesium	meq/100gr	7.89	0.01
Saturated paste percent water	percent	58.37	0.01
Potassium in sat. paste extract	meq/L	1.07	2.01
CaCO3 equivalents in soil-	percent	1.62	0.01
Soil gypsum by acetone precip	percent	Not detected	0.1

Sample comments:

Exchangeable Cations
meq/100 gr

Mg	Ca	Na	K
7.3	27.0	0.7	2.1

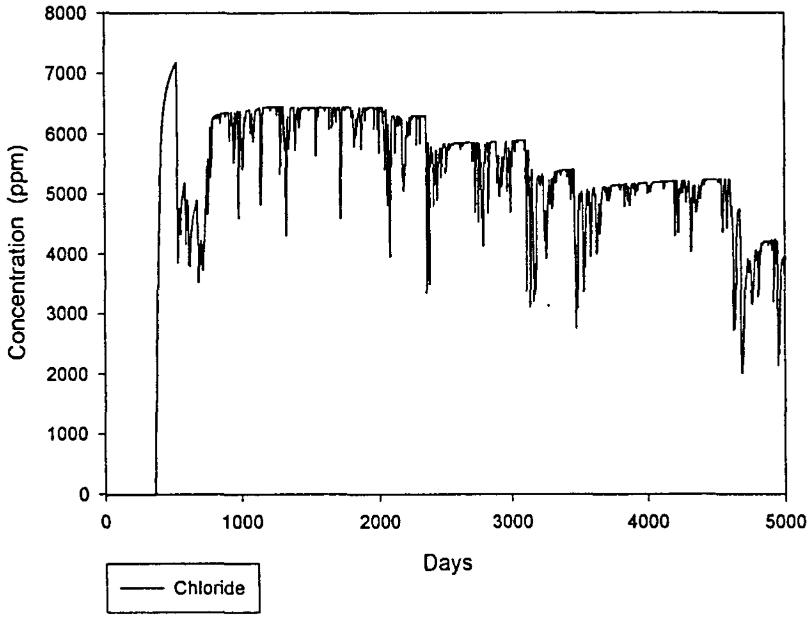
Please advise should you have questions concerning these data.

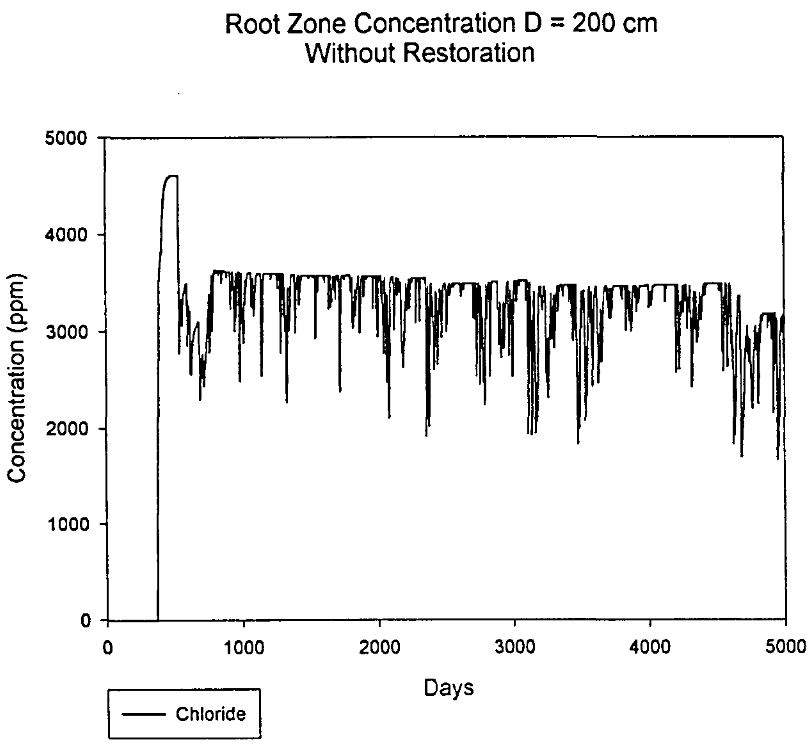
Respectfully submitted,

Andrew Lee Bristol
Laboratory Manager
(505) 646-4422

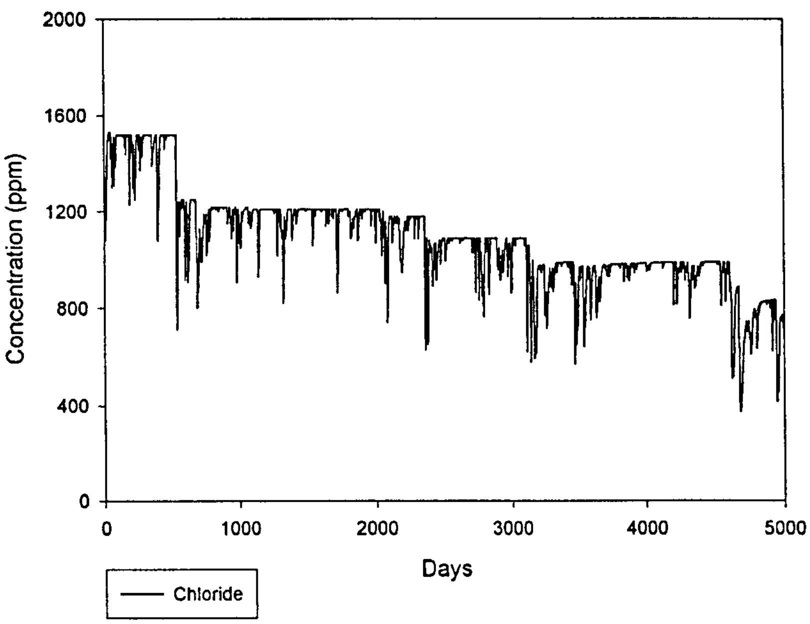
APPENDIX F

Root Zone Concentration D = 20 cm
Without Restoration

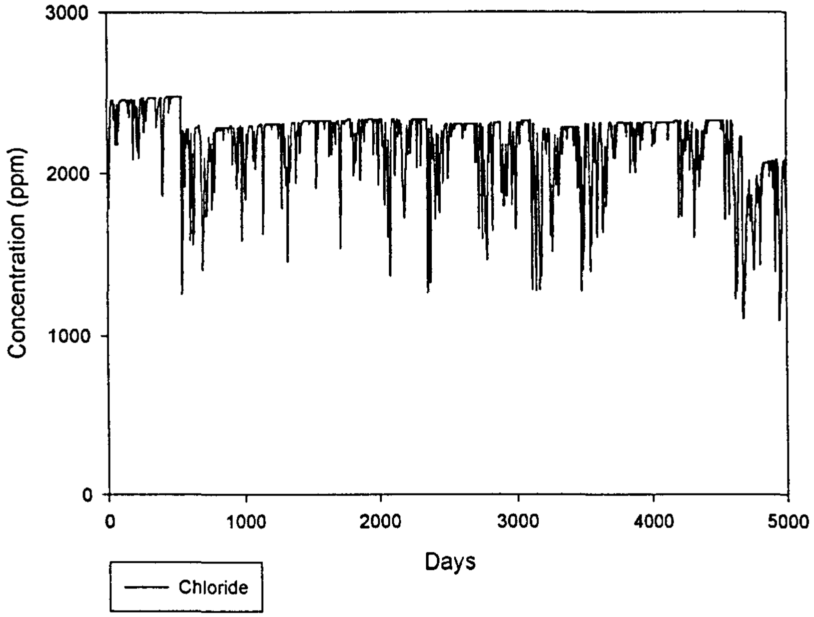



Root Zone Concentration D = 200 cm
Without Restoration
5000
4000
3000
2000
1000
0
Concentration (ppm)
0
1000
2000
3000
4000
5000
Days
Chloride

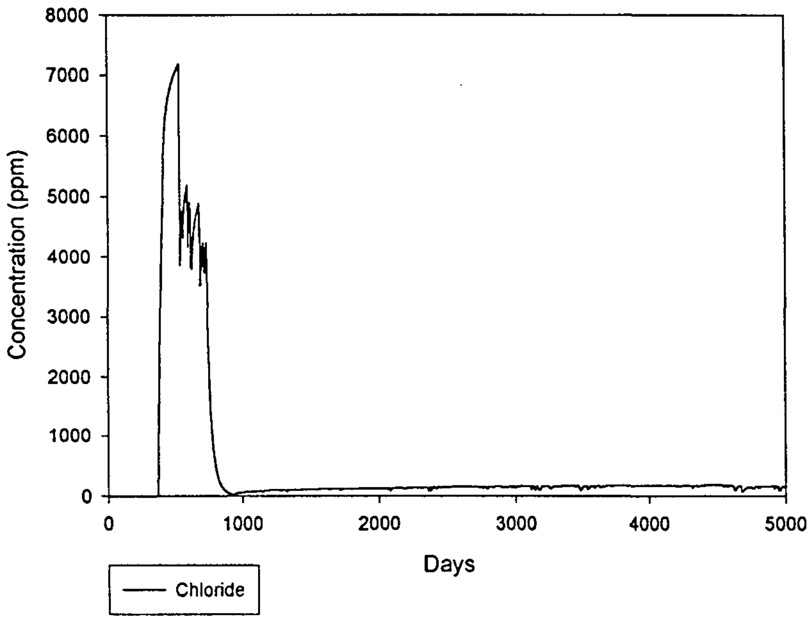
Root Zone oncentration D = 20 cm
With Restoration - Mechanical Removal (60 cm soil)



Root Zone Concentration D = 200 cm
With Restoration - Mechanical Removal (60 cm soil)



Root Zone Concentration D = 20 cm
With Restoration - Soil Leaching (100 cm water)



Root Zone Concentration D = 200 cm
With Restoration - Soil Leaching (100 cm water)