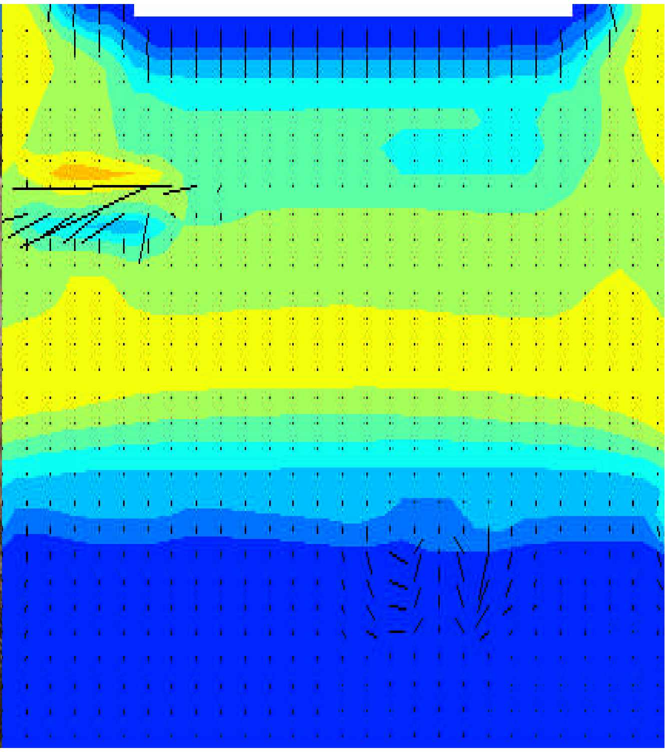
APPENDIX P

SEEPAGE STUDY FOR PROPOSED STORAGE RESERVOIRS PREPARED BY CASCADE EARTH SCIENCES



Seepage Study for Proposed Storage Reservoirs

Lancaster Water Reclamation Plant 2020 Facilities Plan EIR

March 2004

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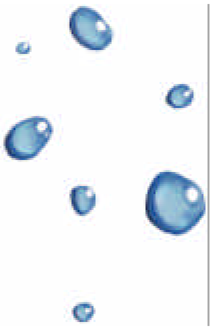

Seepage Study for Proposed Storage Reservoirs Lancaster Water Reclamation Plant 2020 Facilities Plan EIR

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EXECUTIVE SUMMARY

The County Sanitation Districts of Los Angeles County (CSDLAC) are considering expansion of their reclaimed water land application system to grow agricultural crops using reclaimed water from the Lancaster Water Reclamation Plant (WRP). The CSDLAC prepared a draft Environmental Impact Report (Draft EIR), which considers alternatives for the land application system. Several alternatives include construction of reservoirs to store reclaimed water during low crop demand periods for use during peak agricultural demand. One concern is how the stored effluent will migrate through the unsaturated zone and reach the groundwater table approximately 100 feet below ground surface. In light of this, the CSDLAC asked Cascade Earth Sciences (CES) to evaluate the following questions:

- What is the estimated travel time for water and solute to migrate from the proposed storage reservoirs through the unsaturated zone to the groundwater approximately 100 feet below ground surface (BGS)?
- What changes in concentration in total dissolved solids (TDS), chloride, and nitrate would be expected by the time reservoir percolate reaches the groundwater table?
- How will changing effluent concentrations, as treatment improvements are installed in the future, affect solute transport?

The CSDLAC needed a fast, but scientifically defensible, analysis to answer these questions. CES suggested numerically modeling the unsaturated zone (vadose zone) to assist. The modeling approach and assumptions had to be created using published reports and limited existing field data in order to complete the task within the short time frame. The model simulations included several reservoir depths, changes in hydraulic conductivity, and placement of a clay liner. Conclusions are summarized below:

- Using several saturated hydraulic conductivities in the sandy silt, water seepage and solute reached the groundwater table, 100 feet below ground surface, in 70 to 220 days.
- Simulations indicate that increasing or decreasing the reservoir depth by 5 feet does not alter the migration rate appreciably (17 to 35 days longer).
- Simulations were designed to identify the expected range of travel times by simulating travel times from scenarios using an unlined reservoir (where saturated hydraulic conductivities of the various natural lithologies range from 0.29 centimeters per second [cm/sec] to 5.5×10^{-6} cm/sec) and scenarios using a well-lined reservoir (two-foot compacted layer with saturated hydraulic conductivity of 10^{-7} cm/sec). A well-constructed clay liner could retard seepage to the groundwater by more than 20 years compared to the seepage rate from an unlined reservoir. If the caliche layer beneath the Site were left intact, the travel time would fall somewhere within the estimated range.
- The simulated travel times are consistent with extensive field investigations conducted elsewhere in the Mohave Desert under similar conditions.
- Model simulations predict that the TDS, chloride, and nitrate concentrations arrive at the groundwater table at approximately the same initial concentration in the storage reservoir. Therefore, changes to the water quality of the effluent introduced into the storage reservoirs

would result in similar changes in the seepage water reaching the groundwater table. These changes should be easy to observe through a well-designed and operated groundwater-monitoring program.

- TDS, chloride, and nitrate were modeled as conservative compounds, meaning they migrate similar to the flow of water with no adsorption or biogeochemical degradation. Though this is a valid assumption for this preliminary study, recent United States Department of Interior Geological Survey (USGS) studies suggest that nitrate concentrations can decline due to microbial denitrification as water moves through the unsaturated zone. Other variables, such as existing pore water, other nearby water sources, and soil geochemistry could also affect the water quality of migrating seepage. Collection of local field data to assess water quality at various depths and moisture contents in the unsaturated zone would be critical in determining the extent of degradation and potential effects to groundwater.

- Due to time constraints, a rigorous sensitivity analysis was not performed. However travel time is clearly sensitive to hydraulic conductivity of the unsaturated zone. Additional investigation and hydraulic conductivity data from the unsaturated zone beneath the proposed storage reservoir site would help to validate the model.

- The intent of this study was to provide a preliminary estimate of travel time and solute migration through the unsaturated zone under limited time constraints. It was beyond the scope of this study to interpret mixing or hydraulic interaction with the groundwater. The flow regime and degree of mixing is a function of the geometry, hydraulics, and water quality of the aquifer. CES recommends the collection of additional site-specific data about the aquifer in order to determine potential effects from reservoir seepage.

- The results of this modeling effort are based on assumptions from limited site-specific data. Simplifications, generalizations, and professional judgment estimates had to be made from published data about flow hydraulics, lithologic bedding, soil chemistry, liner permeability and thickness, and operating depths. Therefore the results and interpretations contained in this report are indications of what might be expected under the model conditions and should be used with those limitations in mind. If a more precise assessment of solute migration is desired, CES highly recommends the collection of additional site-specific data to address the generalizations listed above prior to designing or constructing the storage reservoirs.

1.0 INTRODUCTION

The County Sanitation Districts of Los Angeles County (CSDLAC) are considering expansion of a land application system for reclaimed municipal effluent from the Lancaster Water Reclamation Plant (Lancaster WRP). Land application is a viable method to recycle the effluent by supplying water to crops in the Antelope Basin. The CSDLAC has prepared a draft Environmental Impact Report (Draft EIR), which considers several alternatives for expanding the existing limited land application program. Some of the alternatives being considered include the construction of storage reservoirs to store treated effluent in the low irrigation demand winter season for use when it is needed during peak agricultural demand in the summer.

Cascade Earth Sciences (CES) has provided the CSDLAC with evaluation of specific land requirement, water balance, and storage issues in the Draft EIR. One issue that needs additional evaluation is how the stored effluent would seep as percolate from the storage reservoirs, migrate through the unsaturated zone in this arid environment, and reach the groundwater table approximately 100 feet below ground surface. In light of this, the CSDLAC asked CES to assist in addressing the following questions:

- What is the estimated travel time for water and solute to migrate from the proposed storage reservoirs through the unsaturated zone to the groundwater approximately 100 feet below ground surface (BGS)?
- What changes in concentration in total dissolved solids (TDS), chloride, and nitrate would be expected by the time reservoir percolate reaches the groundwater table?
- How will changing effluent concentrations in the future affect solute transport?

The CSDLAC needed a fast but scientifically defensible analysis to answer these questions. CES suggested numerically modeling the unsaturated zone (vadose zone) to assist. The modeling approach and assumptions had to be created using published reports and limited existing field data in order to complete the task within the short time frame.

The rationale for performing a numerical simulation of the unsaturated zone, including defining the conceptual model, is presented in Section 2. Once the conceptual model is defined, assumptions of how the model should, and should not, be used are discussed in Section 3. Model selection and development is also presented in Section 3. Results are presented in Section 4, and conclusions are summarized in Section 5.

2.0 CONCEPTUAL MODEL

The foundation of any numerical model is a sound understanding of the natural system to be modeled. The following section presents features and processes that are important in developing a conceptual understanding of the hydrogeologic system at the Site.

2.1 Site Location and Description

The proposed area for the storage reservoirs (Site) is approximately one square mile just north of the Lancaster WRP between the Antelope Valley Highway to the west and Sierra Highway to the East. The Site is shown in Figure 1. Other relevant features shown in Figure 1 include the existing WRP oxidation ponds and storage ponds, Paiute Ponds and the Rosamond Dry Lake

Bed to the east, and one of the potential land application areas under consideration to the west. The locations of nearby monitoring wells and boreholes providing hydrogeologic information are also shown.

The Site is located in the Antelope Valley in northern Los Angeles County with an arid climate that receives an average of 7.4 inches of rainfall annually. Sagebrush, Joshua trees, various desert range grasses, and other desert flora characterize the native vegetation.

Agriculture in the area must use irrigation for crop production. Irrigation water is provided from groundwater, and by the Antelope Valley-East Kern Water Agency. The cities of Lancaster and Palmdale, to the south, are the major population centers along with several smaller municipalities and Edwards Air Force Base to the north. Water for domestic use is supplied to the cities of Lancaster and Palmdale from groundwater and the Antelope Valley-East Kern Water Agency.

2.2 Topography

The Site resides in a flat, closed basin. Land slopes gently towards the Rosamond Dry Lakebed from all directions in the valley. The elevation along the southern edge of the Site is approximately 2,315 feet above mean sea level (amsl) dropping about 10 feet to 2,305 amsl to the northeast.

2.3 Soils

One of the assumptions made in this study is that the proposed storage reservoirs will be constructed to a depth of at least 10 feet BGS. Therefore, a thorough discussion of the surface soil profile is not included. Some of the soil aspects important to this investigation are: the well-drained nature of the soils throughout the area, the low soil organic matter content, and the calcareous evaporite and precipitate minerals in the subsurface horizons, all of which were observed by CES during a Site visit on July 10, 2003.

2.4 Geology

2.4.1 Regional

The lithology of the Lancaster sub-basin is comprised of a complex interfingering of moderately permeable alluvial deposits derived from erosion of the mountains along the southern and western edges of the sub-basin, and slightly permeable lacustrine deposits in the north and center of the sub-basin. The moderately permeable alluvial deposits consist of sands, silty sands, and gravels with modern geomorphic expression in the many alluvial fans at the mountainous edges of the basin. The less permeable lacustrine deposits consist of silts and clays that include the material beneath the modern playa lake known as the Rosamond Dry Lake. The extent and location of the more permeable alluvium from alluvial fans with respect to the less permeable beds of the closed playa system in the Lancaster sub-basin is highly variable through geologic time. This variability is well illustrated in the lithologic logs from borings and previous investigations performed throughout the region. However, in general, the interfingering of clays and silts increases, and becomes more pervasive, towards Rosamond Lake in the center of the basin (east of the Site). What this means from a hydrologic perspective is, even though the exact location and edges of the lower permeability lake beds have extended in different areas in the basin over geologic time, they become more significant closer to Rosamond Dry Lake.

2.4.2 Local

Site-specific geologic information was reviewed in order to develop a reasonable conceptual model of the lithology of the unsaturated zone. CES reviewed well logs from three monitoring wells installed at the Lancaster WRP in 1987 (MW-5, MW-6, and MW-7). The monitoring wells provided lithologic information through the unsaturated zone into the upper portion of the aquifer. Furthermore, the CSDLAC provided CES with the lithologic logs from four boreholes advanced in the vicinity of the proposed storage reservoir site in 2001. The boreholes were completed to a total depth of 51 feet BGS, about half the total depth of this study. The boring log for the Lancaster WRP water supply well, constructed in 1958, was also reviewed. The water supply well log provided lithologic information down to a total depth of 500 feet BGS. Only one borehole (B4) is actually located on the proposed Site. The locations of the wells and boreholes are shown in Figure 1. Copies of the logs are included in Appendix A.

The well and borehole logs were used to create a geologic cross section of the unsaturated zone through the Site. The line of the cross section is shown on Figure 1 and the cross section is presented in Figure 2. Information from MW-7 and borehole B8 logs were used to add to our understanding of the local subsurface lithology, though they do not fall on the cross section line. Each type of well and borehole was constructed for different reasons. Each employed different drilling techniques, and each was logged at a different scale and technical accuracy. Therefore, some interpretation was necessary to produce the conceptual cross section (Figure 2). Nonetheless, the following observations can be made:

- The general lithology of the unsaturated zone beneath the Site consists of fine-grained sediments, which are often classified as silty sands or sandy silts.
- The fine-grained sediments are interbedded (or interfingered) with lenses of higher permeability sands and gravels, as well as lower permeability silty clays and sandy clays.
- None of the interfingering lenses appear to be pervasive across the entire Site.
- The lenses randomly alternate through the vertical extent of the unsaturated zone.
- Sometimes the contacts between the different materials are obvious, but in most cases the contacts are gradational (change gradually from one lithology type to another) as would be expected in an environment that slowly altered between wet and dry over time.
- Though the conceptual geologic cross section runs south to north through the Site, it is reasonable to assume that similar spatial and vertical variability occurs within the Site area from east to west as well.

2.5 Hydrogeology

The principal source of natural recharge to the aquifer is precipitation that occurs in mountains to the south and west and subsequently percolates into the subsurface via flood flows and streams (Amjad 1995). However the natural groundwater flow regime has been significantly altered by anthropogenic (human-caused) activity in the recent past. Some of the most significant effects are cones of depression caused by pumping of production wells for municipalities and agriculture, and groundwater mounding from flood irrigation and man-made storage ponds and lakes (USGS 2003, USGS 1998, and TRC 2003). Not only do these mounds and cones alter the groundwater flow direction, they can significantly alter the flow gradient as well. For example, one of the cones of depression caused by relatively high rates of groundwater pumping south of the nearby Palmdale Water Reclamation Plant generates a 200-foot change in groundwater elevation in less than 2 miles (TRC 2003).

2.6 Unsaturated Zone Properties

Though conditions are typically unsaturated, knowledge of the saturated hydraulic conductivity (K_{sat}) of the different lithologic media, along with moisture content, is a cornerstone in understanding and predicting flow through the unsaturated zone. If there are no site-specific data, saturated hydraulic conductivity can be estimated from published sources. Saturated hydraulic conductivity data are available for many alluvial and lacustrine deposits, and many published values of K_{sat} for sands, gravels, silts, and clays are readily available. However, the values can range across several orders of magnitude for the same type of lithologic unit depending on the grain-size mixture (e.g., different sand units may have varying amounts of clay). Furthermore, as mentioned above, the lithology at the Site is an interfingering of alluvial deposits with gradational contacts, making it difficult to identify the exact location and extent of discrete lithologic units.

Fortunately, the site-specific geotechnical testing reported by MTC in 2001 included determination of moisture content and field and laboratory assessment of saturated hydraulic conductivity (K_{sat}) in different boreholes and at varying depths in one borehole (B5). K_{sat} was measured for each of the recent boreholes (B4, B5, B6, and B8) in the vicinity of the Site. These measurements included *in situ* field tests using the US Bureau of Reclamation shallow well permeameter method (Method 7305-89), and laboratory tests on samples collected at various depths in some of the boreholes using ASTM method D5084 (Appendix B). The K_{sat} at borehole B5 decreased one-thousand fold from a maximum of 4.1×10^{-4} centimeters per second (0.35 meters per day) at 3 feet BGS to 9.5×10^{-7} centimeters per second (8.2×10^{-4} meters per day) at 7 feet BGS as a result of caliche cementation. A copy of the summary of hydraulic conductivity test results is included in Appendix B. For the evaluation in this report, more emphasis was placed on the field tests, because the test is designed to take into account the effects of soil layering throughout the length of the borehole being tested. The field tests were performed in boreholes approximately 5 feet deep. The tests are influenced to some extent by the soil below the 5-foot bottom. This information was used in conjunction with the geologic assessment discussed above and the published values to identify K_{sat} values, porosity and other hydraulic properties necessary for modeling simulations. It was especially helpful in determining reasonable values for the sandy silts encountered throughout the unsaturated zone at the Site

The moisture content in the shallow portion of the unsaturated zone has been measured in several of the boreholes, and ranges from 1.2% (sand at 16 feet BGS in B4) to 13.8% (sand at 31 feet BGS in B5). Most values range from 8% to 12 %. This was helpful in setting initial moisture contents for simulations. The initial moisture content was set within this range near the surface, and was increased with depth beyond the evapotranspiration zone.

Natural deposits of caliche[1] in the subsoil are common in arid environments. Review of lithologic logs shows caliche is pervasive in the soils at or near the Site, occurring from approximately 4 to 8 ft BGS. The presence of caliche in the shallow soil is important when considering reservoir construction, as well as water and solute migration from land application methods. Geotechnical testing performed in the boreholes at the Site in 2001 confirms that the most extensive cementation typically occurs at 7 ft BGS (MTC 2001). Caliche is also found as discrete lenses at other depths in some of the alluvial deposits as noted on Figure 2 (Bookman, 2002). The horizontal and vertical location and extent of the caliche lenses that formed

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[1] Gravel and sand cemented by calcium carbonate.

historically throughout the area is highly variable, providing another heterogeneity in the bedding and permeability of the geologic profile.

2.7 Storage Reservoirs

Several treatment and storage ponds already exist at the Lancaster WRP immediately south of the Site. There are 8 treatment (oxidation) ponds that are not lined (Figure 1). Four larger storage ponds were constructed east of the oxidation ponds across the Sierra Highway. These ponds may have been lined by compacting local soil material, however the nature and degree of compaction are not known.

The proposed storage reservoirs will be larger than the existing ponds, unlined, and are planned to be constructed to a depth of approximately 10 feet. However variations, such as lining the reservoirs, altering the proposed 10-foot design water depth (head), and berming the area to allow minimum excavation to manage seepage from the reservoirs have been discussed by the CSDLAC.

2.8 Solute Concentrations

Three parameters, total dissolved solids (TDS), chloride, and nitrate, were selected for solute transport simulations. Monthly effluent concentrations for 2002 provided by CSDLAC were used to calculate an average concentration for each parameter expected in the reservoirs. However, additional effluent treatment, including chlorination, is planned after the first two years of storage reservoir use. Though the additional treatment would decrease concentrations of many compounds, including nitrate, the chlorination process would increase TDS, including chloride. In light of this, CES estimated the change in concentrations from the proposed treatment process.

Table 1 shows the average concentrations using the 2002 data and a ‘worst case’ concentration based on the highest values reported in 2002, along with the estimated concentrations expected from the chlorination process. The recent (2002) average values for TDS, chloride and nitrate were used as starting concentrations in the simulations. Due to the conservative nature of the migration of these compounds observed in initial simulations (discussed in the following section), concentrations were not changed after two years.

3.0 MODEL SIMULATIONS

3.1 Model Selection

The applicability of two different models that simulate fate and transport through the unsaturated zone were reviewed. **VS2DT** is a finite-difference hydrologic model capable of simulating two-dimensional flow and transport in variably-saturated porous media. It is part of a modeling package called VS2DTI, created by the United States Geological Survey (USGS), that can also simulate heat transport, and has a stand-alone post processor for viewing results (Hsieh, 2000; Healy, 1990; Healy, 1996; Lappala and others, 1987). The source code was written in FORTRAN, and can be compiled and run separately from the graphical pre- and post-processors, if desired.

HYDRUS 2D is also a vadose zone modeling program developed for simulating the two-dimensional movement of water, heat, and solute through the unsaturated zone. This modeling software was developed by the United States Salinity Laboratory operated by the Department of Agriculture.

Both models use the Richards equation to solve for the migration of fluid flow, and the advective-dispersion equation for solute transport. The mathematical functions developed by van Genuchten (1980), Brooks and Corey (1964), and Haverkamp (1977) are used to analyze relations between pressure head, moisture content, and relative hydraulic conductivity in the unsaturated zone. Both models can simulate flow and transport in unsaturated media and use mathematical flow equations widely accepted in the field. Both are accepted and used by the USGS, USDA, and other agencies.

VS2DT was ultimately selected for simulations because VS2DT is more applicable to modeling the unsaturated stratigraphic column, whereas HYDRUS is geared more towards agricultural applications in the shallow soil profile and root zone.

3.2 Model Assumptions

Based on what was learned about the Site in development of the conceptual model, the following basic assumptions were made in order to perform modeling simulations:

- Though depth to groundwater may vary depending on proximity to anthropogenic features, groundwater is assumed to be 100 feet BGS.

- Storage reservoirs will be constructed to accommodate at least 10 feet of water that will represent the pressure head applied to the pond bottom. Therefore, the caliche layer observed from approximately 3 to 7 feet BGS will be removed or broken up, and caliche will not be specifically introduced in initial simulations. However, to assist in understanding effects from construction variations such as lining the reservoirs, or constructing them above the caliche layer (thereby leaving it intact), a clay liner will be introduced in one simulation.

- Based on well drilling logs and boring logs, lenses of less permeable material are assumed to be non-contiguous and not continuous across the site.

- The lithology of the unsaturated zone is too complex to model layer by layer over the entire square mile site. Furthermore, the interfingering lenses of different material are discontinuous over the Site, and gradational from one lithologic unit to another with frequent interbedding of units. In light of this, a better modeling approach is to incorporate lenses of higher permeability and lower permeability into the model domain in order to provide a reasonable range of travel time and solute transport.

- Placement of an unlined storage reservoir will create a hydrologic groundwater mound beneath the Site over time. It is beyond the scope of this study to attempt to model or interpret the magnitude or extent of the mound.

- Once solute reaches the groundwater table, it will mix with the groundwater in some fashion. The flow regime and degree of mixing is a function of the geometry, flow characteristics, and water quality of the aquifer. If the groundwater flow gradient is low, or if the thickness of the aquifer is relatively thin (a small aquifer with slow-moving water), very little mixing can occur and solute concentrations are not appreciably reduced. If the groundwater flow gradient is high, or the aquifer is thick (a large aquifer with faster-moving water) a great deal of mixing can occur and solute concentrations decrease. It is beyond the scope of this study to interpret mixing or hydraulic effects to groundwater.

- The water is assumed to enter the subsurface from the bottom of the storage reservoirs, and the reservoirs are assumed to contain water throughout the simulation time. Therefore, there are no evapotranspiration effects to consider.
- Precipitation will fall onto the surface of the reservoir, and effects to total depth and reservoir water quality are negligible.
- For the purposes of the model simulations, TDS, chloride, and (for the most part) nitrate are considered conservative compounds in water, meaning that they migrate with the water with little sorption or biogeochemical degradation along the way.
- The intent of the model is to predict an estimated travel time for water and solute to migrate from the proposed storage reservoirs to groundwater. In order to achieve this with available data under the project time constraints, the contribution of water quality from other sources, such as any pore water existing in the arid soils, will not be considered.
- Due to the time constraints set at the outset of this project, a rigorous sensitivity analysis of the model to various input parameters cannot be performed. Mass balances within the model simulations provide quality assurance monitoring points to evaluate the performance of the simulations.

The specific model input parameters developed from the conceptual model developed to explain conditions at the site and the assumptions (above) are described in detail below.

3.3 Input Parameters

Input values and conditions used in the model simulations are summarized in Table 2 and are discussed below. Figure 3 is a schematic representing model input parameters that can be shown visually.

3.3.1 Basic Setup

Meters, days, and grams were selected as modeling units of length, time and mass. Simulations were set in a Cartesian coordinate system. Though the model used meters, lengths will be converted and discussed herein using feet. Model results are shown visually with a scale along the edges of the graphics. However the scale does not export with the graphic, and therefore is not shown in the figures in this report that illustrate results of the model simulations.

The two-dimensional model domain is 150 feet deep by 600 feet wide. A 10-foot deep by 500-foot wide depression was included along the top of the model domain to simulate the reservoir geometry[2]. Model grid cells were set at 5 feet deep by 20 feet wide.

Two years (730 days) was selected as the simulation time for most model runs. However the scenarios involving a clay liner were allowed to run for 20 years.

3.3.2 Solver

The solver is a set of input instructions used to solve the mathematical functions for each grid cell in the model for each time step in the simulation. Examples of solver input include the minimum and maximum number of times the model attempts to solve the function (iterations) in a time step before it halts the process, and total time steps in the simulation. The solver values necessary to run the simulation depend on the hydraulic function model selected. Choices included in VS2DTI include the van Genuchten model, the Brooks-Corey model, and the Haverkamp model. The van Genuchten model was selected for simulations, and solver values are shown in Table 2.

3.3.3 Lithologic Units

As discussed above, it is beyond the scope of this (or perhaps any) study to attempt to model each actual lens or layer with differing hydrogeologic characteristics throughout the unsaturated zone at this Site. Most of the domain was modeled as sandy silt. However, many of the well logs listed sand and silty sand near the groundwater interface. Therefore a layer of silty sand was placed at approximately 100 feet BGS. A layer of sand and gravel was placed in the sandy silt in the left portion of the domain, and a layer of silty clay was placed in the sandy silt in the right portion of the model domain. In this way, the effects of higher permeability (left side) and lower permeability lenses (right side) shown in the lithologic logs could be modeled, and the resulting effects on travel times could be observed in each simulation.

The input parameters for each model layer are shown in Table 2. The selection of saturated hydraulic conductivity (K_{sat}) was discussed in the conceptual model section. Data from the laboratory and *in situ* hydraulic conductivity testing performed at the Site were used in conjunction with the geologic assessment discussed above and the published values (Todd, 1980; and Freeze & Cherry, 1979) to identify K_{sat} values, porosity and the other hydraulic properties necessary for modeling simulations. Preference was given to the *in situ* testing. K_{sat} was set at 0.108 meters per day (m/day) for the sandy silt, 1 m/day for the silty sand, 0.0048 m/day for the silty clay, and 250 m/day for the sand and gravel.

The ratio of hydraulic conductivity in the vertical vs. horizontal direction (K_z/K_h) allows for anisotropy in the layers. K_z/K_h was set at 0.7 in the sandy silt to account for preferential horizontal flow along depositional bedding planes within the unsaturated zone. K_z/K_h was set to 1 for all other layers, as they are already being modeled as smaller discrete layers. Porosity and residual moisture content was estimated for each layer based on review of field data and literature values.

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[2] Heads greater than the depth of the simulated reservoir depression can be applied to the model domain, thus facilitating the 15-foot depth simulation.

Use of the van Genuchten function in the model solver requires values for two additional curve-fitting parameters (alpha and beta) for unsaturated conditions specific to lithologic units (not shown in Table 2). The default values offered in VS2DTI for the lithology selected lithology types were used. Values for alpha ranged from 0.5 in the silty clay to 4.31 in the sand and gravel, and values for beta ranged from 1.09 in the silty clay to 3.1 in the sand and gravel. [3]

It was assumed that the caliche layer identified from 4-8 feet BGS will be removed during excavation. However, some simulations were performed after introducing a low permeability compacted clay liner beneath the reservoir. Results for those simulations may provide information of the effects of lower permeability caliche as well.

3.3.4 Boundary Conditions

The initial flow regime was prepared by setting initial moisture content for each cell (Figure 3). The initial moisture content should be similar to expected natural conditions. As the model simulations begin, the moisture content equilibrates for each cell. Setting reasonable initial moisture contents assists in allowing the model to equilibrate more quickly. The initial moisture content was set at 30% just below the reservoir, at 40% (saturation) near the groundwater table, and ranging from 10% to 20% elsewhere. The initial moisture content reported for silty sand and sandy silt samples collected from boreholes B4, B5, B6, and B8 were also used (MTC, 2001).

Recharge was simulated by setting a specified total head of 10 feet in the reservoir. No flow boundaries were set at the top of the domain along the edges of the reservoir or along the sides of the domain down to 80 feet BGS. A possible seepage face was set along both sides from 80 to 100 feet BGS to simulate more natural conditions should mounding occur. Discharge to the aquifer was simulated along both sides beneath 100 feet BGS, and along the bottom of the domain by setting a specified total head of –101 feet BGS.

3.3.5 Transport

The average values reported for effluent in 2002 for TDS (570 mg/L), chloride (145 mg/L) and nitrate[3] (24.9 mg/L) were used as starting concentrations in the storage reservoir for the simulations (Table 1). The reclaimed water constituent concentrations in the storage reservoir were kept constant throughout the simulation. As mentioned in the assumptions, water quality from other sources, such as any pore water existing in the arid soils, was considered, and concentrations beneath the pond and in the groundwater in the model domain were initially set to 0.0 mg/L.

Compounds dissolved in water move through the aquifer by the physical processes of advection, dispersion, and molecular diffusion, as well as chemical reactions.

- Advection is the component of solute movement attributed to the velocity of flowing groundwater. This is calculated in the model using the discharge rate and the porosity of the media.
- Dispersion is a mechanical process that tends to `disperse', or spread, the compound mass in the X and Z directions along the advective path of the plume and acts to reduce the

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[3] Average total Kjeldahl nitrogen reported in 2002 was used, and it was conservatively assumed that all will be converted to nitrate.

mass concentration at the edges of the plume. Dispersion is caused by the tortuosity of the flow paths of the water as it travels through the interconnected pores of the soil. Dispersivity (the modeling term for dispersion) input parameters used in the base model simulation are shown in Table 2. Longitudinal dispersivity was set at 10 meters, and transverse dispersivity was set at 0.1 times longitudinal dispersivity (1 meter).

- Molecular diffusion is the process whereby ions move in the porous media under the influence of their own kinetic activity (Freeze and Cherry, 1999). Diffusion becomes significant at very low velocities, and is much more prevalent in clays (Devinny, 1990). The effects of diffusion are likely to be negligible on this scale. Nonetheless a value of 0.0001 square meters per day was set for all layers except the sand and gravel layer, where diffusion was set at zero.

- Chemical reactions from biogeochemical processes, such as sorption, biological degradation, volatilization, etc. were not considered in the simulations because only conservative compounds were being investigated.

4.0 RESULTS

4.1 Base Model

Using the assumptions and values for the model input parameters discussed above, a basic initial simulation was performed, which is referred to herein as the base model. Figures 4 through 10 show the simulation results at various time steps throughout the base model simulation. Figure 4 shows conditions after two hours of simulation. The degree of saturation is shown in the upper image. Blue represents fully saturated conditions, and red represents completely dry conditions. The groundwater table (blue) is clearly visible at approximately 100 feet BGS. Saturated soil, immediately beneath the reservoir, can also be seen as represented by the blue color.

The clay lens (right) has a higher volumetric water content as denoted by the blue coloration than the surrounding sandy silt. The sand and gravel lens (left) has a lower volumetric water content than the surrounding sandy silt as denoted by the orange coloration. This is due to the intrinsic low water holding capacity of sand and gravel and the low initial moisture content set in the model. The clay has a greater matric potential (suction) than the surrounding material and preferentially pulls moisture into the clay lens. The sand and gravel has a lower matric potential, therefore, the surrounding sandy silts above the lens retain moisture and the sandy silts below the lens pulls the initial moisture from the sand and gravel creating moister conditions immediately above and below the sand and gravel lens.

Flow velocity vectors are also shown as black lines in the figures. The vectors help to show the downward movement directly beneath the reservoir, and the flow interaction between the sand and gravel, and the sandy silt discussed above. Vectors also show a downward component of flow in the aquifer. This is a modeling artifact as the model adjusts to the initial conditions that were set, and goes away in the first two days of simulation.

The relative concentration of TDS is shown in the lower image of each figure. The VS2DTI program simulates changes in concentration in each cell based on the highest concentration introduced in the model. Red represents the maximum concentration (100%) and blue represents

0%. Therefore, when TDS is introduced at 570 mg/L in the reservoir, red corresponds to 570 mg/L. Very little dispersion has occurred.

Figures 4 and 5 also show the fluid and solute mass balance error for the time step at which the image was captured, as well as cumulative error for the entire simulation up to that point in time. The mass balance error is discussed in greater detail in the Quality Assurance section below.

Figures 5 through 10 show changing conditions throughout the base model simulation, including 5 days, 15, days, 25 days, 45 days, 70 days, and 85 days, respectively. Water seepage and solute from the reservoir reach the groundwater table in 70 to 100 days depending on location. Figure 9 shows the initial arrival, after 70 days, of the seepage front beneath the sand and gravel lens (left). Figure 10 shows subsequent arrival beneath the sandy silt (center) after 85 days of simulation. The simulated travel times through the unsaturated zone presented in this report are consistent with extensive field investigation conducted elsewhere in the Mohave Desert under similar conditions (Amjad, 1995).

The attenuating effects of the low-permeability silty clay are shown to the right Figure 9. The vector lines near the clay lens show how water preferentially migrates around the silty clay lens and continues downward along the edges. Review of the relative concentration in the same figure shows that solute has also migrated through the lower permeability lens, but at a slower rate.

Dispersion has very little effect on solute concentration in any of the simulations, and each of the compounds arrive at the ground water table at approximately the same concentration that they exhibit upon leaving the bottom of the storage reservoir. In most cases the gradient from zero to maximum concentration is within 5 to 10 feet. This ‘plug flow’ would be expected given the assumed conservative nature of the compounds, the migration rate, and the lack of other sources of moisture in the area. The gradient spreads somewhat once the seepage reaches the groundwater table.

Comparison of migration from 15 days to 25 days (Figure 6 and Figure 7) shows how solute concentrations are spread laterally in the sand and gravel layer, and reach the left model boundary after 45 days (Figure 8).

4.2 Variations on the Base Model Simulation

4.2.1 Increased Reservoir Depth

The reservoir depth was increased to 15 feet of head in one simulation, while all other input parameters remained the same (Table 2). The flow and solute transport regime were very similar to those of the base model. Water seepage and solute from the reservoir reached the groundwater table in 68 to 90 days depending on location, just a few days earlier than the base model run using a 10-foot head. Since the results were so similar, additional figures are not presented.

4.2.2 Decreased Reservoir Depth

The reservoir depth was decreased to 5 feet of head in one simulation, while all other input parameters remained the same. Again, the flow and solute transport regime were very similar to those of the base model. Water seepage and solute from the reservoir reach the groundwater table in 85 to 125 days, about 15 days later than the base model run using a 10-foot head. Since the results were so similar, additional figures are not presented.

4.2.3 Decreased Hydraulic Conductivity

As discussed above, the bedding described in the lithologic logs is often gradational, gradually changing from silty sand to sandy silt. Some of the K_{sat} values reported in the laboratory tests were lower than the value selected for the base model. Therefore, one simulation was run for which K_{sat} in the sandy silt was reduced by 50% to 0.05 meters per day. Water seepage and solute from the reservoir reached the groundwater table in 150 to 220 days, slightly more than twice the travel time for the base model. Aside from the time difference, the flow and transport regime looks very similar to the results shown for the base model. Therefore, additional figures are not presented.

4.2.4 Reservoir Lining

A 2-foot thick clay liner compacted to achieve a saturated hydraulic conductivity of 10^{-7} cm/sec was placed beneath the storage reservoir for two simulations. All other settings in the base model were maintained. In this way, a range of travel time, from an unlined reservoir to a well-lined reservoir could be determined with the limited times constraints. Figure 11 shows the addition of the clay liner. A close up of an area where the liner was breached in one simulation is shown. The breached scenario is discussed separately below. Figures 12 through 16 show conditions after 45 days, 250 days, 3 years, 10 years, and 20 years, respectively. The reservoir water finally reaches the groundwater table at approximately 20 years. Note that solute continues to migrate slowly downward through the unsaturated zone although conditions beneath the liner never become saturated. The clay lens to the right becomes saturated, and maintains saturation, due to its greater relative matric potential than the surrounding materials, illustrating how the moisture content can vary as water moves through different lithologic units.

There can be some variability introduced in a low-permeability clay liner during initial construction or maintenance over time. Therefore, for one of the simulations, a breach in the liner was placed in one model cell near the left edge of the storage reservoir (Figure 11). Figure 11 also shows a close up of the breached area after 27 days of simulation. Figures 17 and 18 show conditions after 45 days and 250 days, respectively. The importance of the horizontal spreading effects of the sand and gravel lens can be seen after 45 days when the breached water reaches the sand and gravel lens. The seepage water spreads across a wider area once it penetrates the sand and gravel lens. The breached water and solute reach the groundwater table after 250 days, rather than 20 years under the intact liner scenario.

As mentioned above, the presence of low-permeability caliche was not considered in the base model. However, results from the modeling scenarios showing a compacted clay liner provide good comparison if the caliche layer were intact. That is, the attenuating effects of the caliche on travel time would likely fall between the range identified by unlined base model and the lined simulations. Predicting migration through the caliche, as well as the effects of caliche on water quality would require further study and site-specific data.

4.3 Quality Assurance

Tracking the mass balance of both the water and the solute introduced into, and removed from, the model domain is one method to assess the integrity of modeling simulation.

Mass balance errors in flow and transport are tracked in VS2DTI, both for the entire model, and for each time step. Examples of the reported mass balance errors are shown in Figures 4 and 5. Error is typically high during the first time steps of simulation as the model takes the initial conditions set by the modeler, and applies the solver equations to begin adjusting conditions in each model grid cell. As shown in Figure 4, the model converged quickly within the first few hours of simulation. The fluid mass balance error decreased from over 90% in the first few minutes of simulation down to 17.8% for that particular time step. After 5 simulated days (Figure 5) the mass balance error for each time step errors decreased to 1.1%, which brings the total cumulative error down to 26%. In other words, if the error observed in the first few hours of simulated time as the model initially equilibrates were removed, most of the cumulative error for the simulation would be removed. The same discussion applies to the mass balance error for solute.

- The total fluid and solute mass balance errors for the base model simulation were - 4.5 % and –3.9%, respectively.

- Total fluid and solute mass balance errors for the 5-foot head simulation were 7.8 % and –3.3%, respectively.

- Total fluid and solute mass balance errors for the 15-foot head simulation were –0.56 % and –3.9%, respectively.

- Total fluid and solute mass balance errors for the reduced hydraulic conductivity simulations were 3.95% and –3.8%, respectively.

- Total fluid and solute mass balance errors for the breached liner simulation were 6.2 and –5.4 %, respectively at the time the leakage from the breach reached the groundwater table (about 250 days). However, the error steadily increased for the next 19 years to a maximum of 34% as the simulation was allowed to continue to observe migration from the unbreached portion of the reservoir. This was likely due to groundwater exiting the system in the aquifer once mounding occurs. The need to better understand the geometry and flow regime of the aquifer in order to understand mounding and solute mixing has already been discussed.

- Total fluid and solute mass balance errors for the liner simulation were –2.8 % and –5.1%, respectively.

Another helpful method to assure the quality of numeric simulation is to thoroughly assess the assumptions used to create the conceptual model. A significant portion of this report has been devoted to describing the assumptions used to reach a conceptual understanding of the system.

Due to time constraints, a sensitivity analysis of the model to specific input parameters (assumptions) could not be performed. However some of the scenarios have highlighted parameters for which the model appears to be sensitive (such as hydraulic conductivity and moisture content), and these parameters have been discussed.

5.0 CONCLUSIONS

Based on the base model simulation, water seepage and solute from the reservoir could reach the groundwater table, 100 feet below the Site, in 70 to 100 days depending on the specific lithologic units encountered. Using other simulations where saturated hydraulic conductivity in the sandy silt was reduced by 50% the predicted travel time ranged from 150 to 220 days. Due to the gradation of sandy silts to silty sands throughout the Site, results from these simulations should be combined, providing a reasonable range of predicted travel time from 70 to 220 days.

Simulations indicate that increasing or decreasing the head by 5 feet in the storage reservoir does not alter the predicted migration rate appreciably (expected rates range from 17 to 35 days longer for the 5-foot head simulation than the 15-foot head simulation). This is a relatively small change in travel time for a significant change in head.

The simulations were created and conducted within a short timeframe with limited data, to provide a range of travel time estimates, for seepage from two reservoir extremes, an unlined reservoir and a well-lined reservoir. A well-constructed clay liner could significantly retard leakage to the groundwater table. Model simulations show that a 2-foot thick clay liner compacted to a hydraulic conductivity of 10^{-7} cm/sec could slow the migration of reclaimed water including conservative solute in the water by more than 20 years. However, a breach in the integrity of the liner can significantly reduce the travel time to rates more similar to a pond with no liner. These travel time estimates ignored a shallow caliche layer that is present at the site. The modeling scenarios showing a compacted clay liner compare favorably to the expected travel time if the caliche layer were intact beneath the reservoir. That is, the caliche layer, while not as restrictive as the clay liner, would likely provide a travel time that falls between the range identified by unlined base model and the lined simulations. Predicting migration through the caliche, as well as the effects of caliche on water quality would require further study after acquisition of detailed site-specific data.

Migration through the unsaturated zone is very dependent on moisture content. There is a non-linear relationship between moisture content and hydraulic conductivity. It is difficult for water to migrate under very dry conditions. As moisture content increases, unsaturated hydraulic conductivity increases by orders of magnitude. Therefore, the biggest driver for travel time in the unsaturated zone in a desert is the moisture content of the media until it becomes saturated. Once the floor of the reservoir is saturated, hydraulic conductivity of the media reaches its maximum value, and the effects from a relative change in head are less significant. The resistance of the soil materials to flow far out-weighs the changes in pressure head in the pond. However, if a clay liner is placed at the bottom of the reservoir, the unsaturated zone beneath the liner remains unsaturated because it can conduct water faster than the seepage rate through the liner. In this way, the reclaimed water flowing to the groundwater table beneath a clay liner is slow because the seepage from the liner is slow, and the unsaturated zone remains in an unsaturated condition.

Mass balance of flow and solute within the model indicated that the model operated properly within the constraints of the input parameters. The model simulations converged quickly and showed very good mass balance of fluid and solute. Typical startup errors in mass balance of flow and solute were removed within the first few time steps of each simulation. The total flow mass balance error for all simulations ranged between plus or minus 5%, and the total solute mass balance error for all simulations ranged between –6% and –3%.

The simulated travel times through the unsaturated zone presented in this report are consistent with extensive field investigation conducted elsewhere in the Mohave Desert under similar conditions.

Model simulations predict that the TDS, chloride, and nitrate concentrations arrive at the ground water table at approximately the same initial concentration in the storage reservoir. Therefore, improvements to the water quality of the effluent introduced into the storage reservoirs would result in similar improvements in the seepage water reaching the groundwater table.

TDS, chloride, and nitrate were modeled as conservative compounds, meaning they migrate similarly to the flow of water with no adsorption or biogeochemical degradation. This assumption, while useful for the scope of this study ignores recent studies regarding nitrate performed by the USGS elsewhere in the Mohave Desert. The USGS studies suggest that nitrate concentrations can decline by as much as 50% due to microbial denitrification as water moves through he unsaturated zone (Amjad, 1995). However the USGS study pertained to a different site (several septic systems) under different conditions. Other variables, such as existing pore water, other nearby water sources, and soil geochemistry could also affect the water quality of migrating seepage. Collection of local field data to assess water quality at various depths and moisture contents in the unsaturated zone would be very helpful in determining the extent of degradation and potential effects to groundwater.

Future chlorination for disinfection of the Lancaster WRP reclaimed water will cause chloride and TDS concentrations to increase. Due to the conservative nature of these compounds in groundwater, the effects of chlorination or other future treatment changes affecting reclaimed water quality (such as nitrogen removal) will become evident in groundwater quality rapidly if there is no pond liner. These changes should be easy to observe through a well-designed and operated groundwater-monitoring program.

The intent of this study was to provide a preliminary estimate of travel time and solute migration through the unsaturated zone under limited time constraints set by the client. It was beyond the scope of this study to interpret mixing or hydraulic interaction with the groundwater. The flow regime and degree of mixing is a function of the geometry, hydraulics, and water quality of the aquifer. CES recommends the collection of additional site-specific data about the aquifer in order to determine potential effects from reservoir seepage.

The results of this modeling effort are based on assumptions from data collected from lithologic logs of well borings and exploratory borings near and at the proposed storage reservoir site. Some shallow borings at the proposed pond site provided a limited view of the soils but not a complete view of the subsurface to the groundwater table. Simplifications, generalizations, and professional judgment estimates had to be made from published data about flow hydraulics, lithologic bedding, soil chemistry, liner permeability and thickness, and operating depths. Actual conditions at the Site may be more complex or different than the model simulations and actual results will vary from the model results. Therefore, the results and interpretations contained in this report are indications of what might be expected under the model conditions and should be used with those limitations in mind. If a more precise assessment of solute migration is desired, CES highly recommends the collection of additional site-specific data to address the generalizations listed above prior to designing or constructing storage reservoirs.

Due to time constraints, a rigorous sensitivity analysis was not performed. However travel time is clearly sensitive to hydraulic conductivity. Based on the site-specific data provided, the values selected for modeling simulations are appropriate. However, if more accurate site-specific values are desired, a pumping test could be performed in one of the existing monitoring wells that are located at the Lancaster WRP south of the Site. The pumping test would provide an overall hydraulic conductivity value in the lower portion of the unsaturated zone near the groundwater table.

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TABLES

Table 1. Lancaster Reclaimed Water Quality Worksheet for Impacts Due to Chlorination[1]

Scenario	**NO_3**[5] mg/L	Ca mg/L	Mg mg/L	Na mg/L	**Cl** mg/L	Ca meq/L	Mg meq/L	Na meq/L	Cl meq/L	**TDS** mg/L	Estimated EC umho/cm	Salts Load lbs/MG	Leaching Req'mt %	SAR
Average[2]	**24.9**	37.3	12.7	149	**145**	1.87	1.05	6.48	4.09	**570**	891	4754	9.8%	5.37
Chlorinated Effluent[3]	**8.0**	37.3	12.7	169	**175**	1.87	1.05	7.33	4.94	**626**	978	5223	10.8%	6.07
Worst-Case[4]	**31.9**	37.3	12.7	149	**158**	1.87	1.05	6.48	4.46	**870**	1359	7256	15.7%	5.37
Chlorinated Effluent[3]	**8.0**	37.3	12.7	169	**188**	1.87	1.05	7.33	5.30	**926**	1447	7725	16.9%	6.07

NOTES:

1 Assumed chlorine demand (dosage) is 30 mg/L using sodium hypochlorite. Abbreviations are as follows: Ca = calcium; Mg = magnesium; Na = sodium; TDS = total disssolved solids; EC = electrical conductivity (estimated by TDS/0.64); Cl = chloride; SAR = sodium adsorption ratio; mg/L = milligrams per liter; meq/L = milliequivalents per liter; lbs/MG = pounds per million gallons; Leaching Req'mt = leaching requirement with a desired soil ECe of 2.0 mmho/cm (Westcot and Ayers, 1985).

2 Single values for Ca, Mg and Na, and average values for Cl and TDS from 2002.

3 Addition of sodium hypochlorite at a rate equivalent 30 mg/L Cl2 (19.5 mg/L Na, 30 mg/L Cl, and 56.2 mg/L TDS) to average effluent concentrations.

4 Single values for Ca Mg and Na, and highest values for Cl and TDS from 2002.

5 Nitrate calculated using total Kjeldahl nitrogen in 2002. Estimated concentration from future tertiary treatment at Lancaster Water Reclamation Plant.

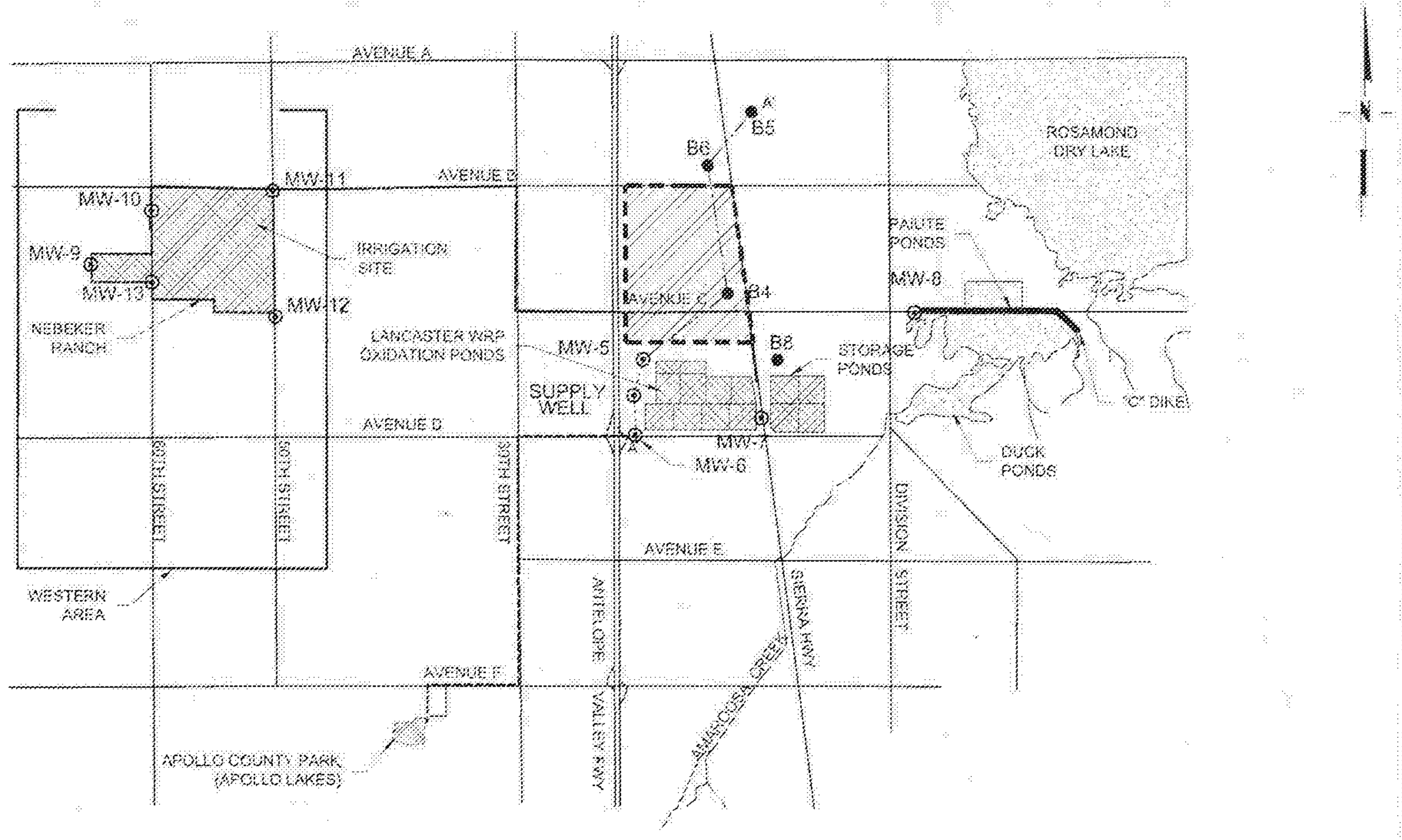
Table 2. Model Input Parameters [1]

Basic Setup							
Units	Meters, Days, Grams						
Coordinates	Cartesian Coordinates						
Initial Flow	Set Moisture Content						
Hydraulic Solver	van Genuchten Model						
Chemical Transport	No adsorption or ion exchange						
Initial Moisture Content	15 to 20 % in unsaturated zone, 40% at groundwater table						
Initial Domian Concentration	0 milligrams						
Initial Reservoir Concentration	570 milligrams per liter						
Layers	**Flow**				**Transport**		
	Ksat	**Kz / Kh**	**Porosity**	**RMC**	**Dlong**	**Dlat**	**Cdiff**
	(m/day)		(%)	(%)	(meters)	(meters)	(msq/day)
Sandy Silt	0.108	0.7	45	0.067	10	1	1.00E-04
Silty Sand	1	1	40	0.02	10	1	1.00E-04
Sand & Gravel	250	1	37	0.02	10	1	0
Silty Clay	0.0048	1	36	0.7	10	1	1.00E-04
Clay Liner	1.00E-04	1	42	0.7	10	1	1.00E-04
Boundary Conditions				**Type**			
Reservoir	Specified total head, 10 feet						
Reservoir Edges	No flow						
Sides from 0 to 80 feet	No Flow						
Sides from 80 to 100 feet	Possible Seepage Face						
Sides below 100 feet	Specified total head, -101 feet						
Bottom	Specified total head, -101 feet						
Solver							
Relaxation Parameter	0.7						
Minimum iterations/ time step	2	each					
Maximum iteration/time step	200	each					
Minimum time steps	20000	each					
Closure criterion for head	0.2	meters					
Closure criterion for solute	0.01	grams					

Notes

1 Input parameters used in the VS2DT model software for the Base Model simulation. Abbreviations:
Ksat = Saturated hydraulic conductivity
Kz / Kh = ratio of vertical vs horizontal hydraulic conductivity
m/day = meters per day
RMC = Residual Moisture Content
Dlong = Longitudinal Dispersion in meters
Dlat = Latitudinal Dispersion in Meters
Cdiff = Molecular Diffusion in square meters per day

FIGURES



EXPLANATION

▨ Proposed Storage Reservoirs
- - - Location of Geologic Cross Section
● B8 Borehole
⊙ MW-7 Well

0 6000 FEET
(SCALE AND LOCATIONS ARE APPROXIMATE)

(SOURCE: MODIFIED FROM LACSD AREA MAP)

PROJECT NUMBER:	2423006
DATE:	3/12/2004
DWG BY: LSH	DWG NO: 2423006F1.dwg
PROJECT MANAGER:	RAC
REVISED:	

County Sanitation District of Los Angeles County:
Seepage Study

Figure 1. Location of Proposed Storage Reservoirs

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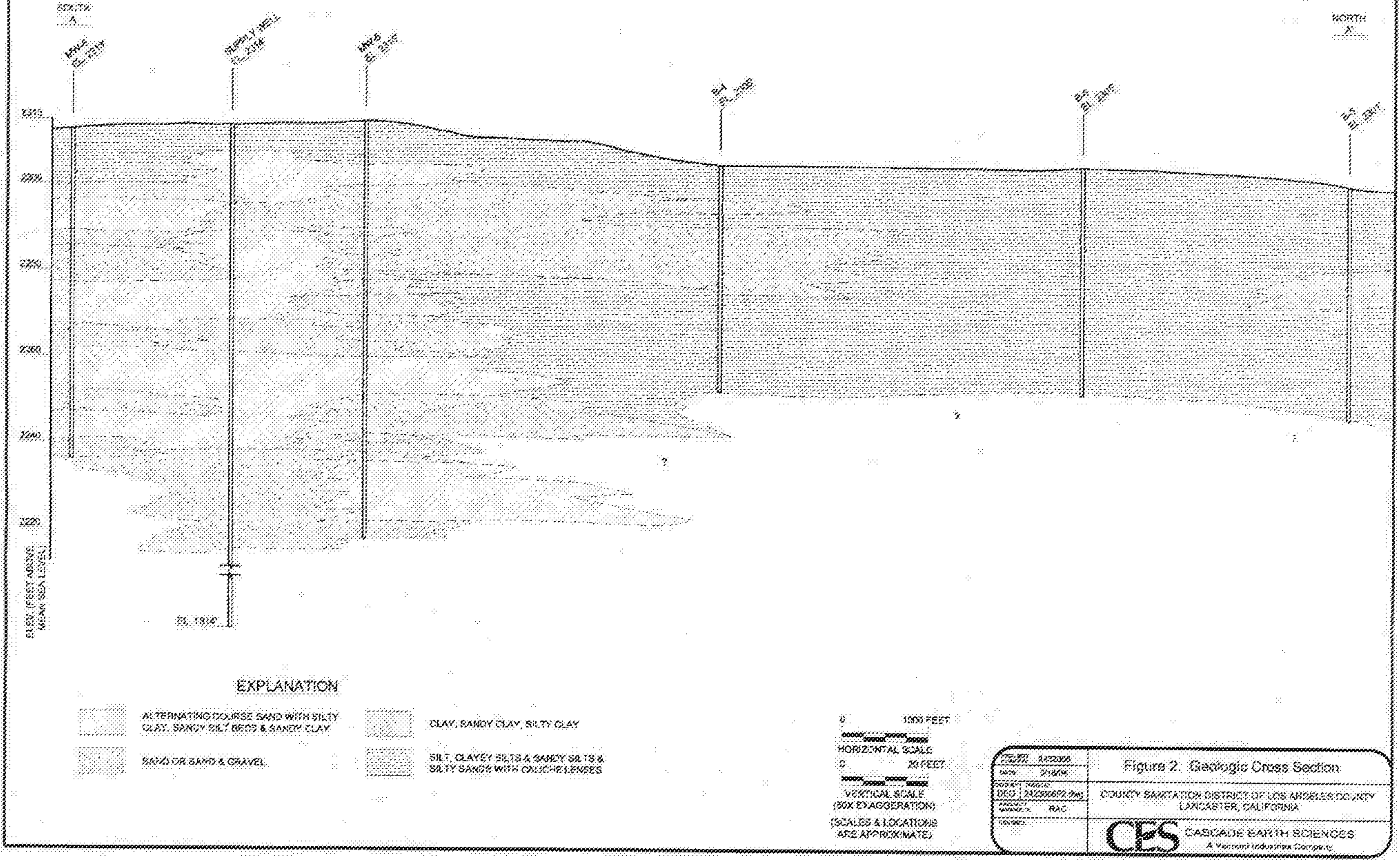
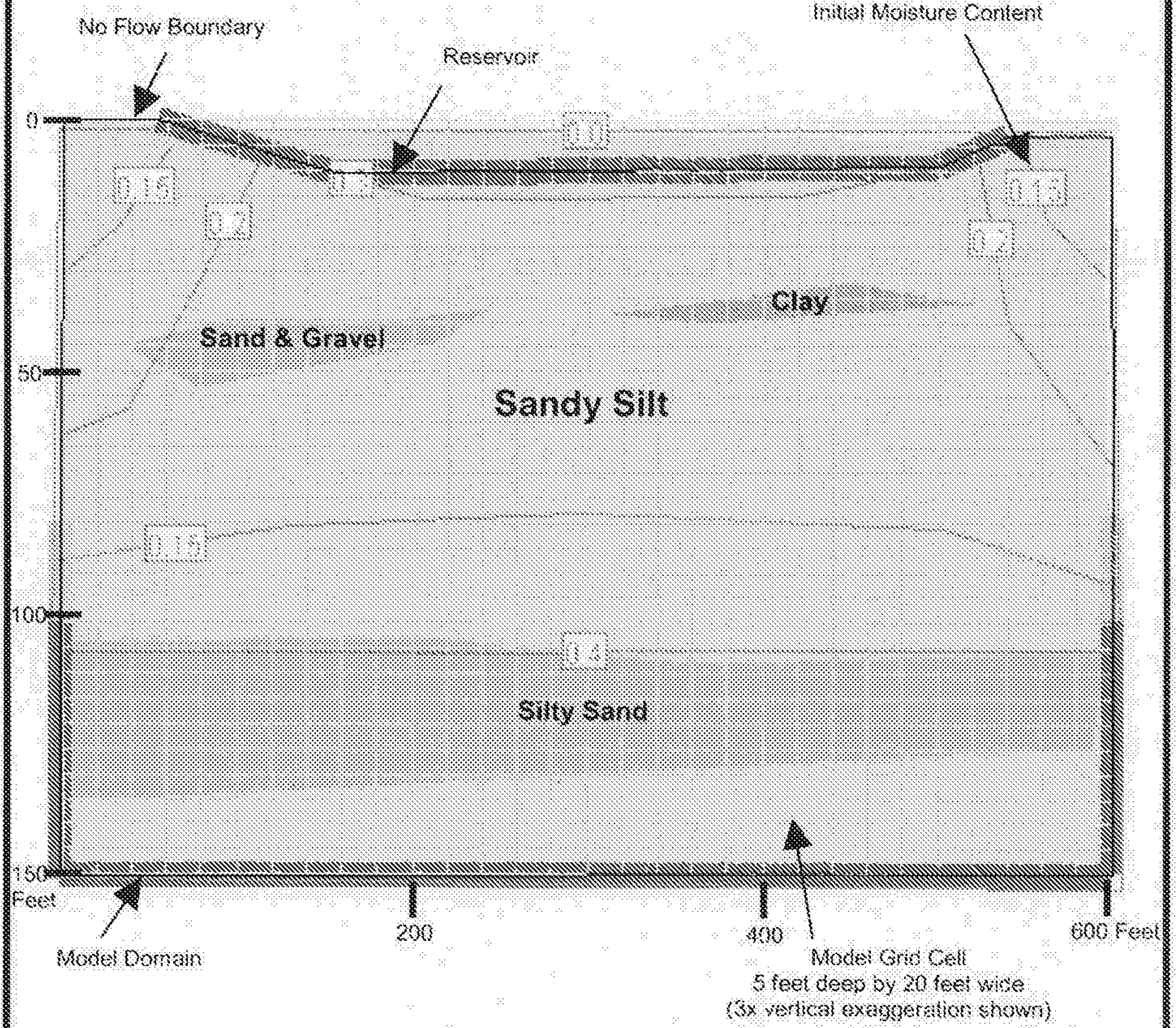
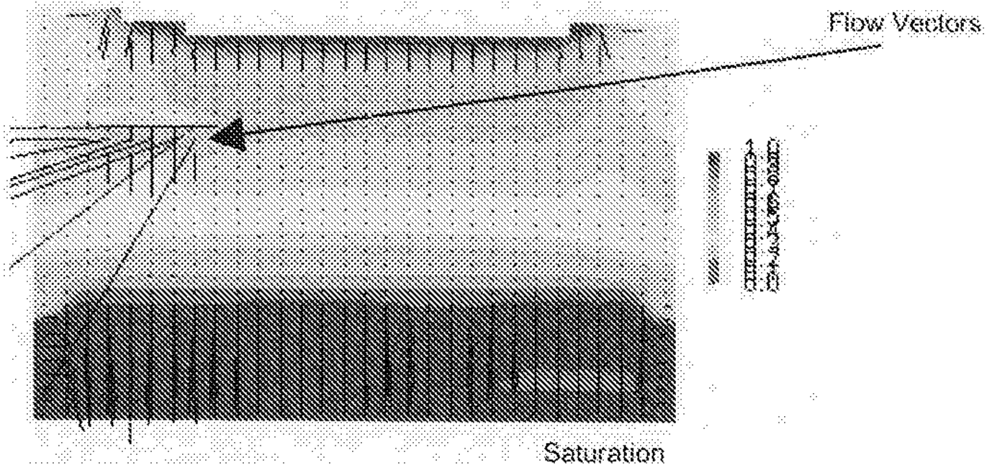


PROJECT NUMBER 2422006	**Figure 2. Geologic Cross Section**
DATE 2/18/04	
DEG 2422006F2.dwg	COUNTY SANITATION DISTRICT OF LOS ANGELES COUNTY LANCASTER, CALIFORNIA
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Vectren Industries Company



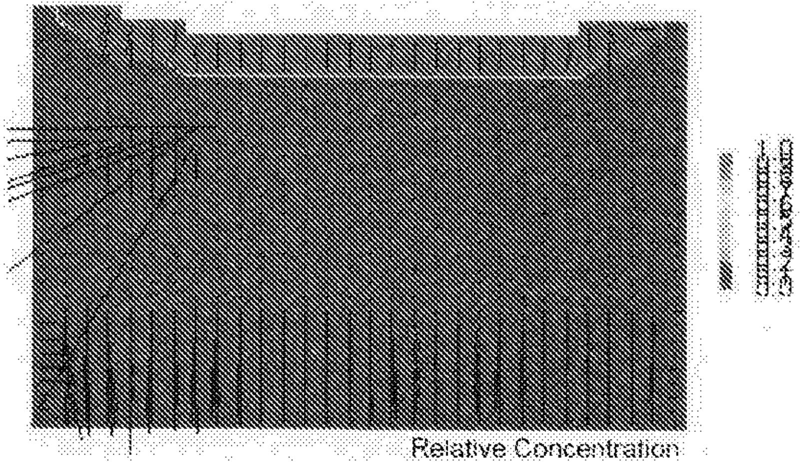
Source: Basemodel input from VS2DTI

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWN: DWG NO:	Figure 3. Model Input Schematic
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



Time = 0.10102266

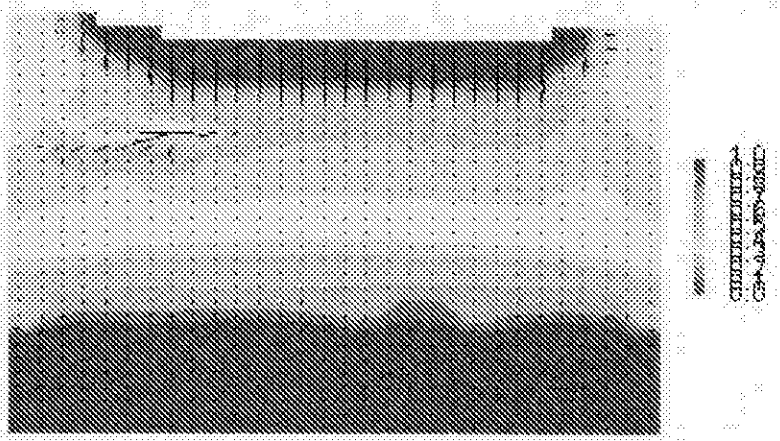
Mass Balance Error	Total for Simulation	Rate for this step
Fluid	-87.23%	17.83%
Solute	-75.57%	-1.20%



Time = 0.10102266 (days)

Mass Balance Error	Total for Simulation	Rate for this step
Fluid	-87.23%	17.83%
Solute	-75.57%	-1.20%

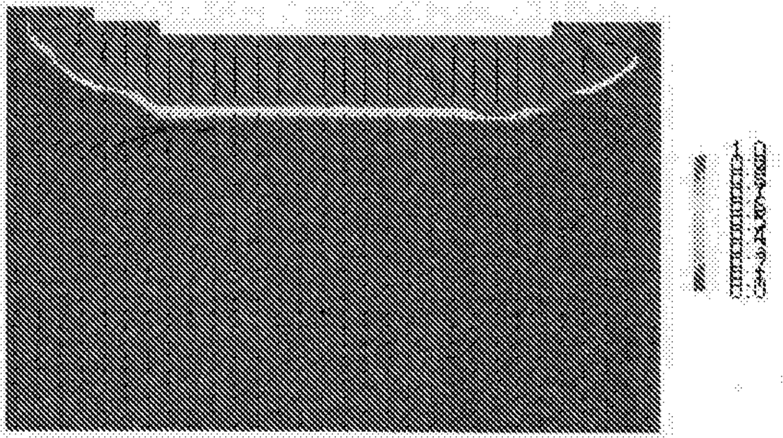
PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWG. DWG NO.	Figure 4. Base Model: 2 Hours
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



Saturation

Time = 5.465713

Mass Balance Error	Total for Simulation	Rate for this step
Fluid	-25.68%	1.12%
Solute	-18.28%	-1.34%

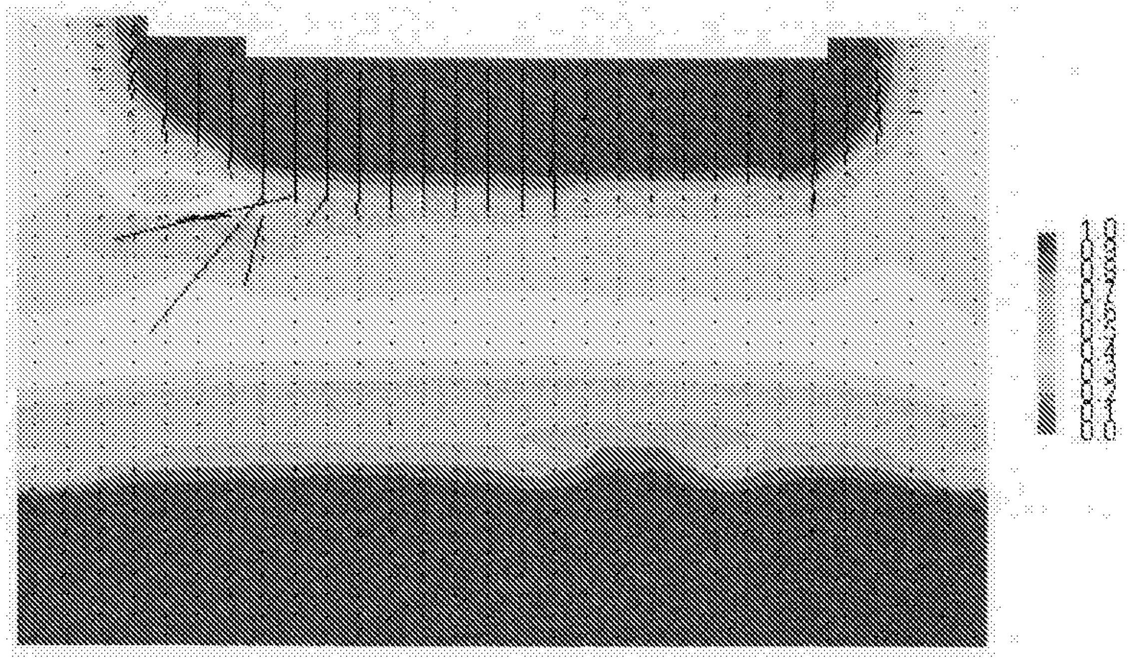


Relative Concentration

Time = 5.465713 (days)

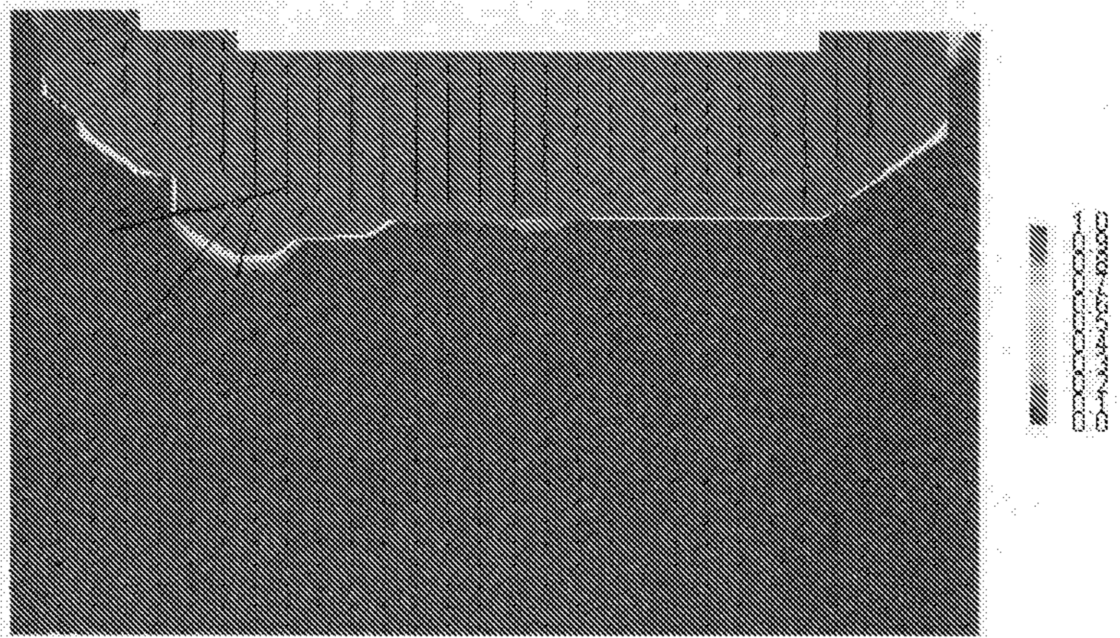
Mass Balance Error	Total for Simulation	Rate for this step
Fluid	-25.68%	1.12%
Solute	-18.28%	-1.34%

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWG. DWG NO.	Figure 5. Base Model: 5 Days
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



Saturation

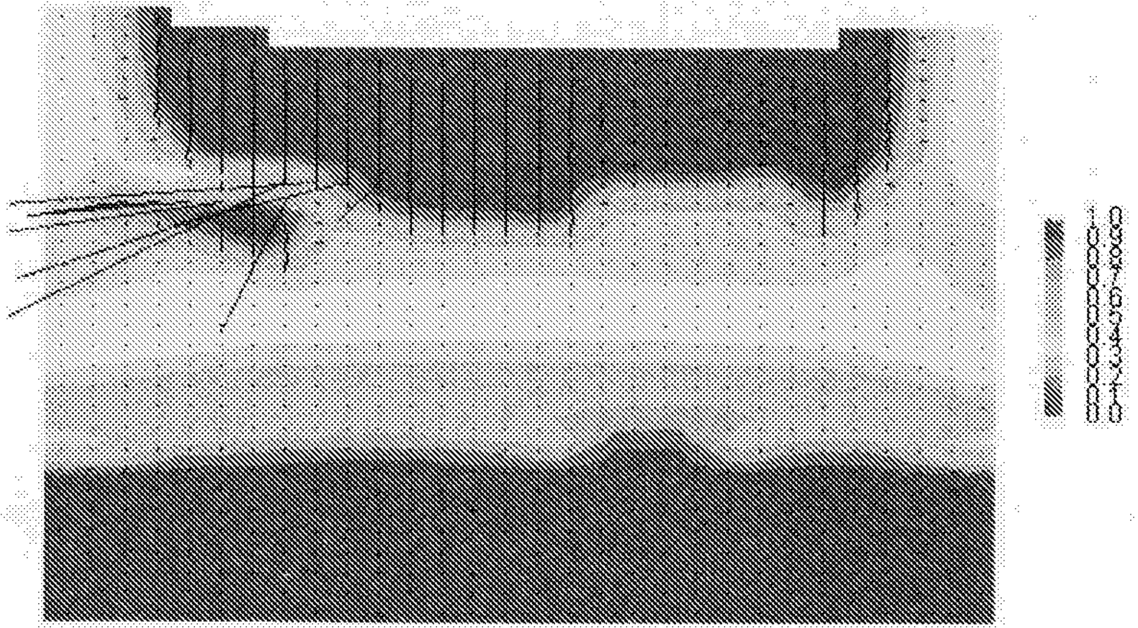
Time = 15.0086155



Relative Concentration

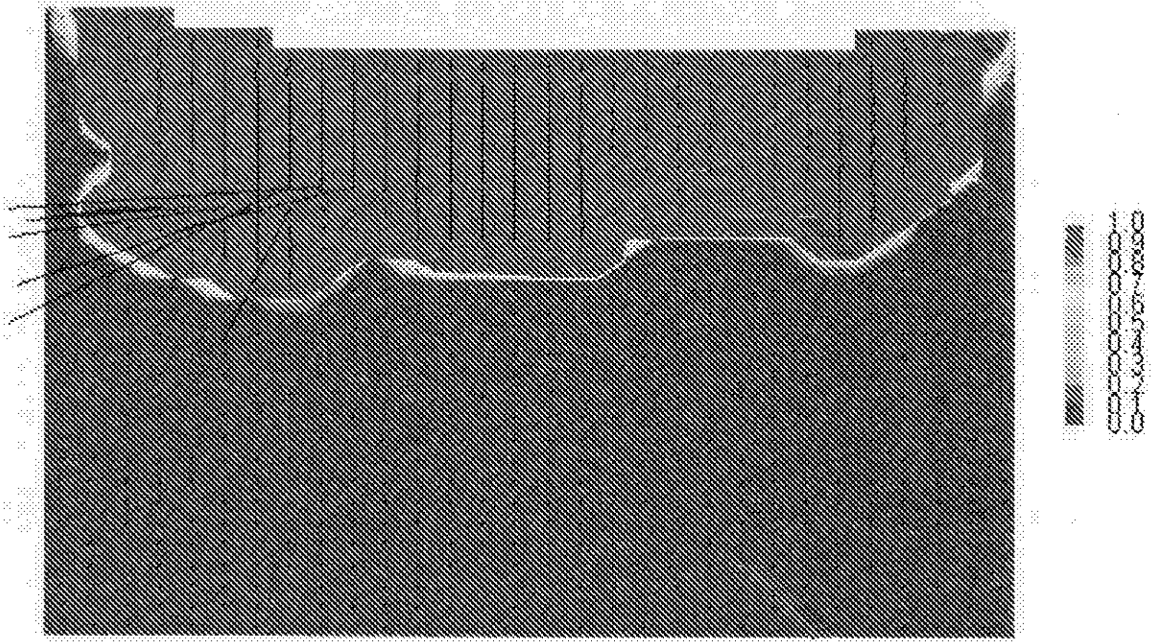
Time = 15.0086155
(days)

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWG / DWG NO	Figure 6. Base Model. 15 Days
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



Saturation

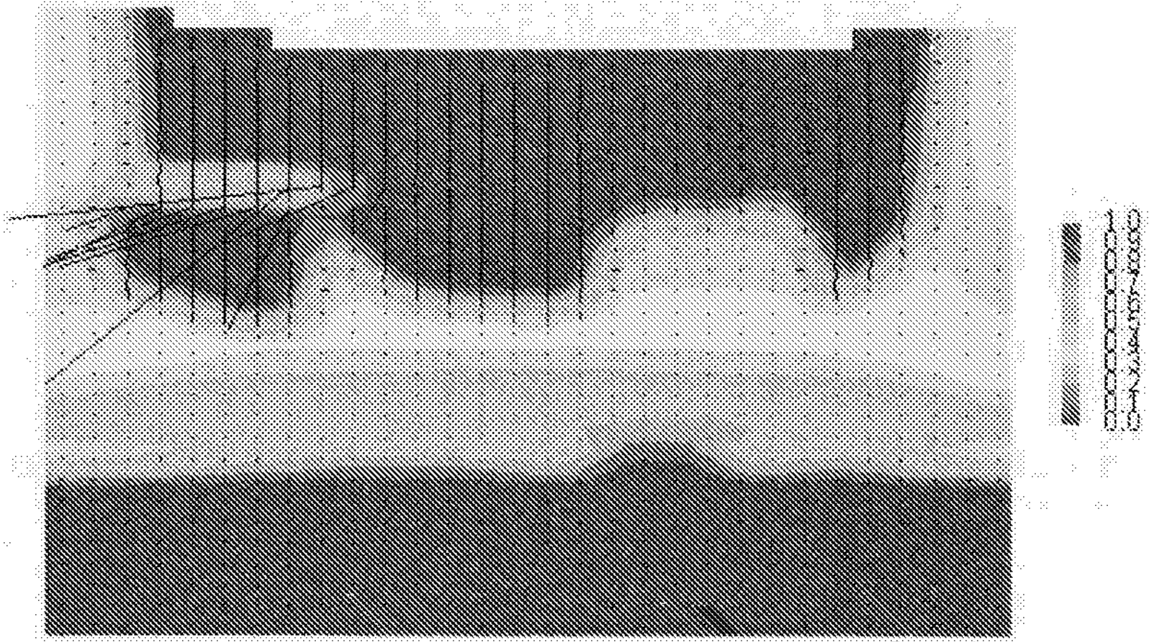
Time = 25.111208



Relative Concentration

Time = 25.111208
(days)

PROJECT NUMBER: 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE: March 2004	
DWG / DWG NO	Figure 7. Base Model: 25 Days
PROJECT MANAGER: RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



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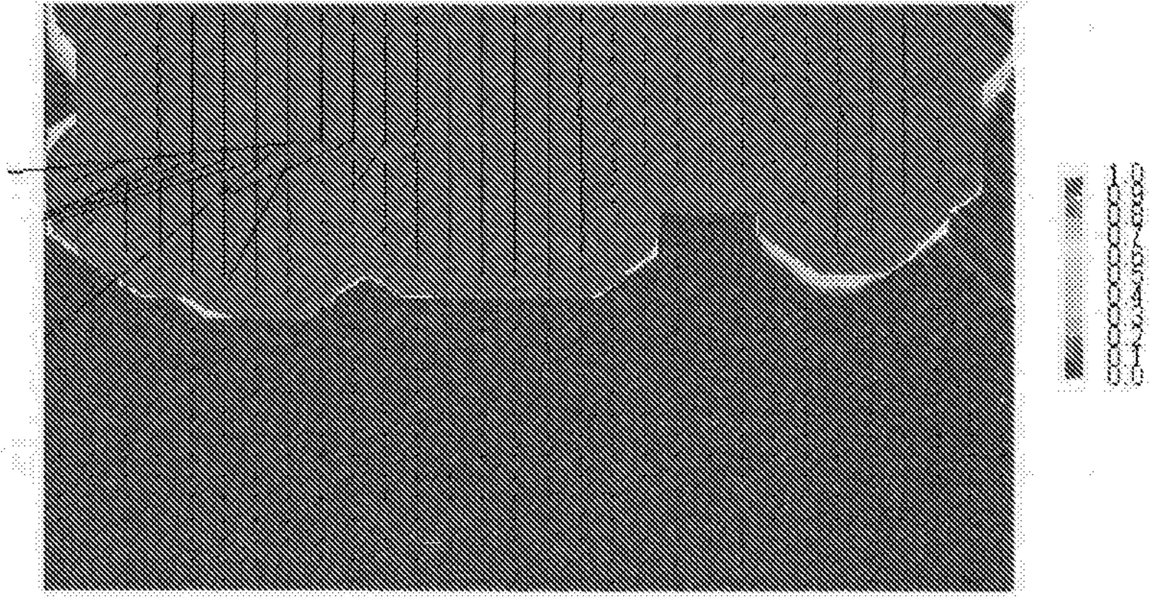
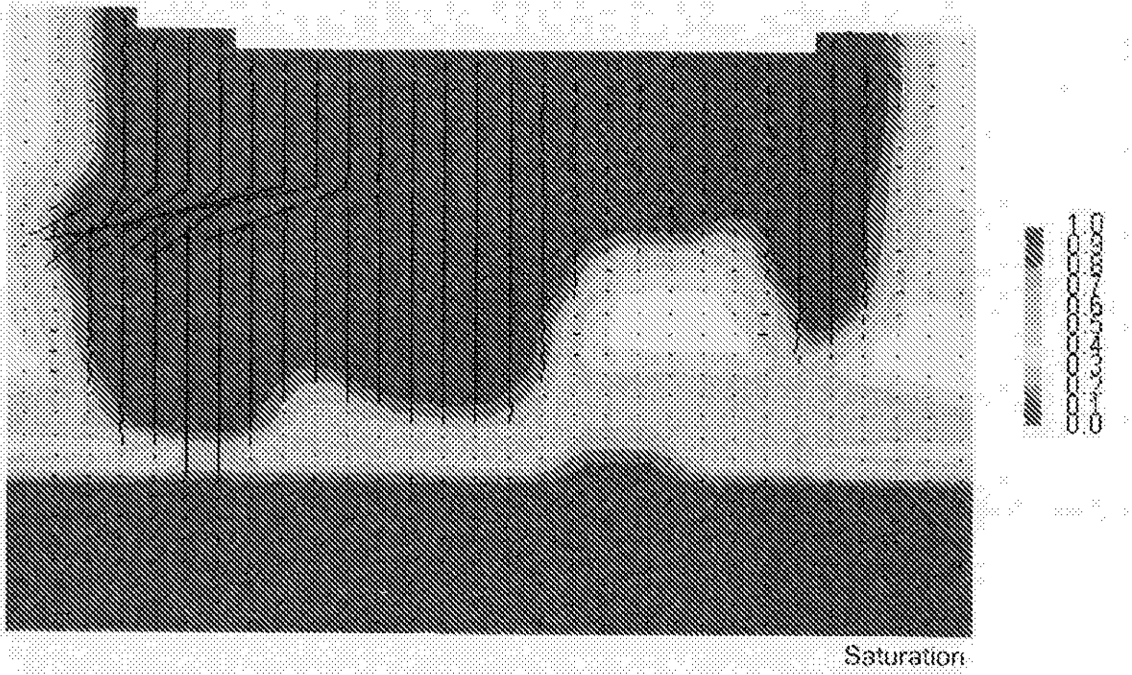


Relative Concentration

Time = 45.019077
(days)

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWG DWG NO.	Figure 8. Base Model: 45 Days
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



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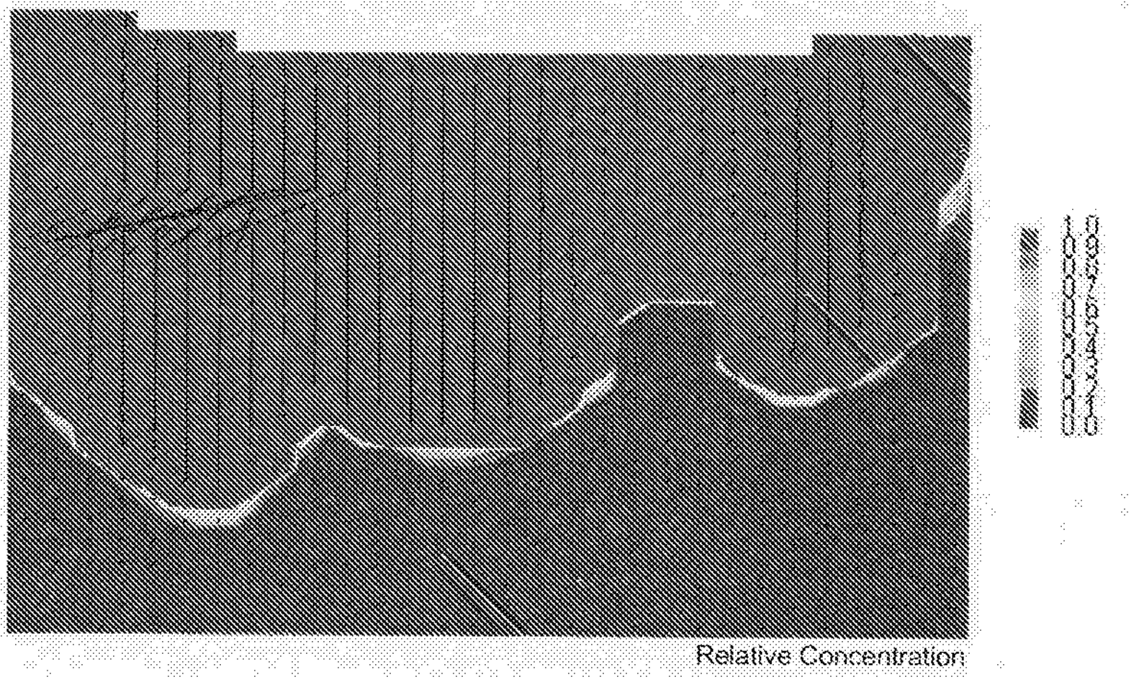

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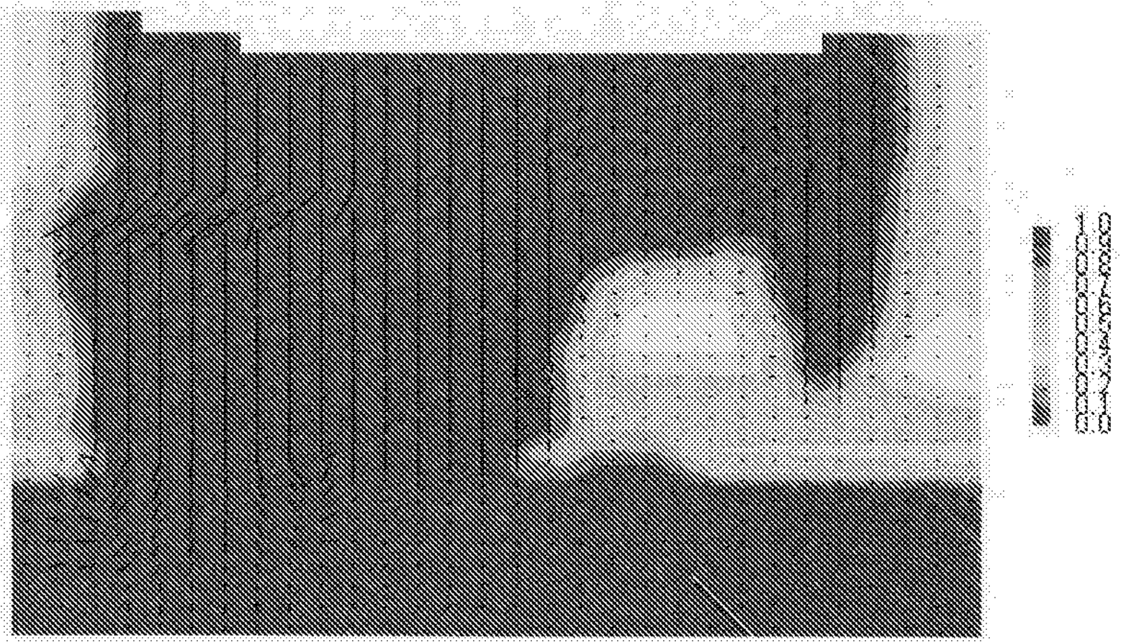
(days)

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County Seepage Study
DATE March 2004	
DWG. | DWG NO	Figure 9. Base Model: 70 Days
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



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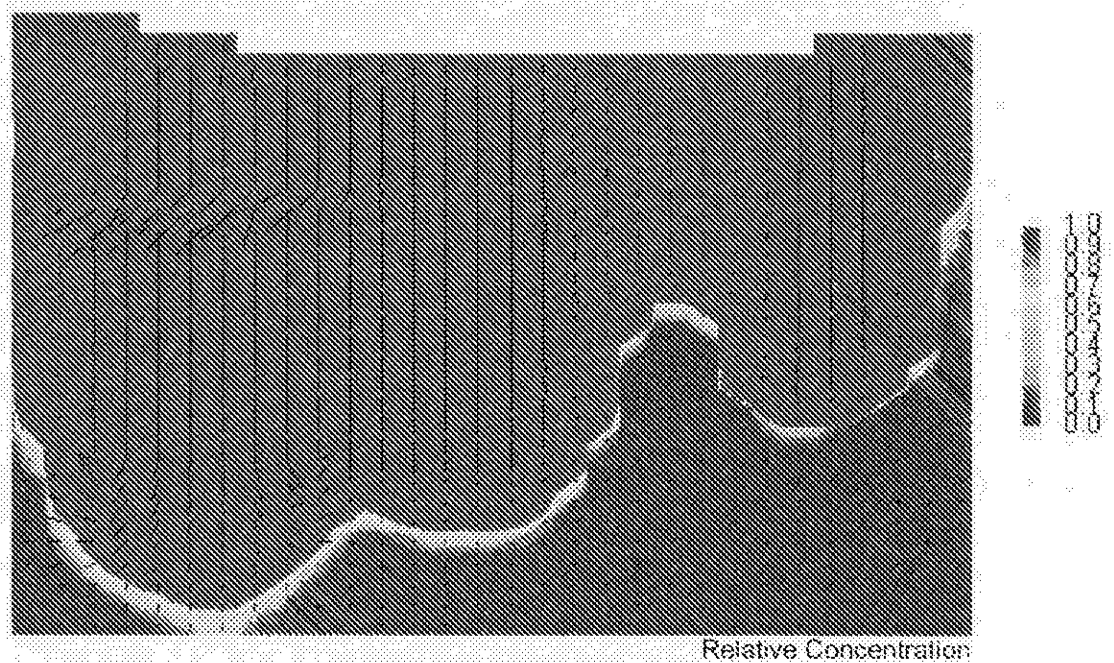
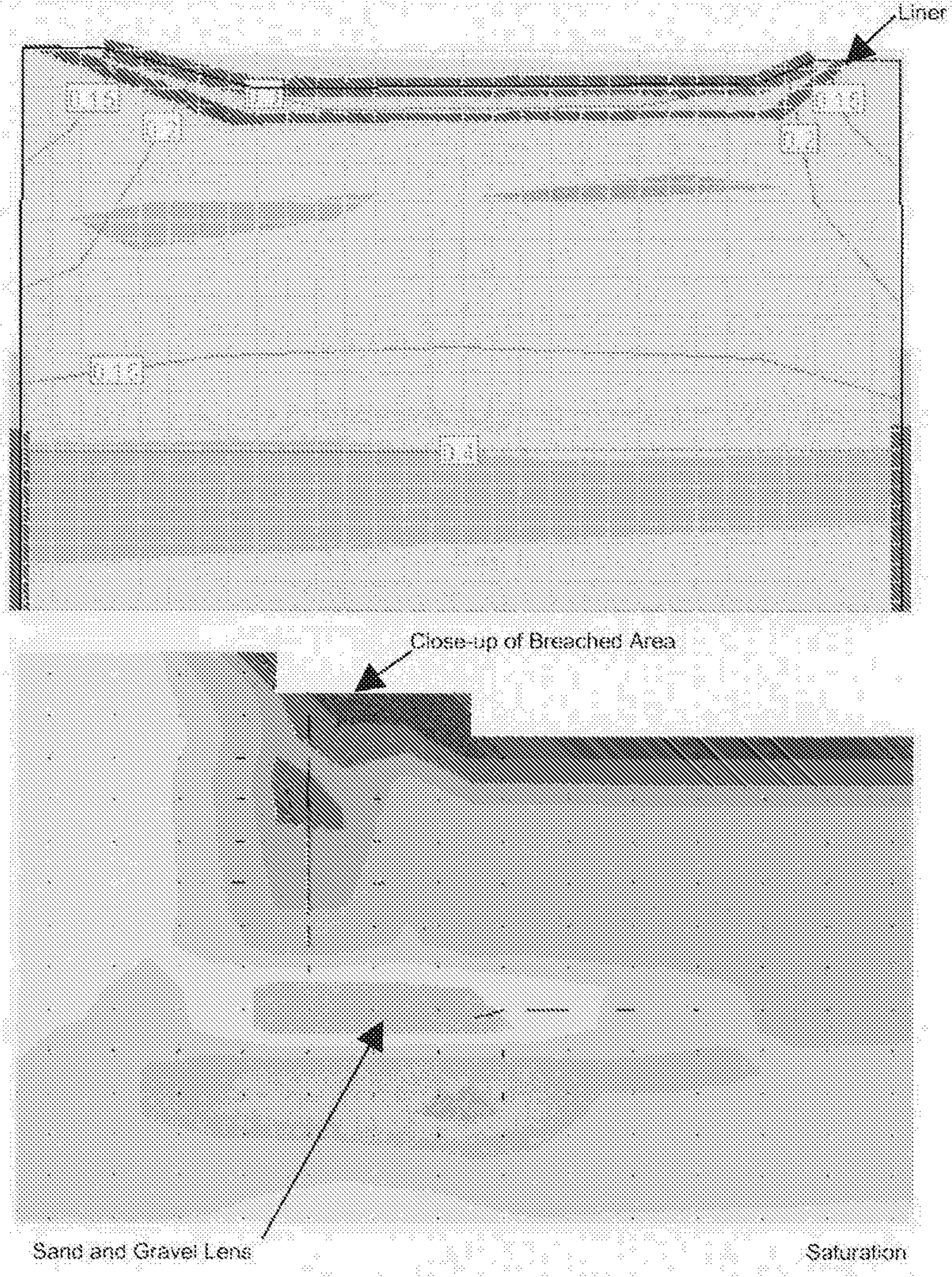


Relative Concentration

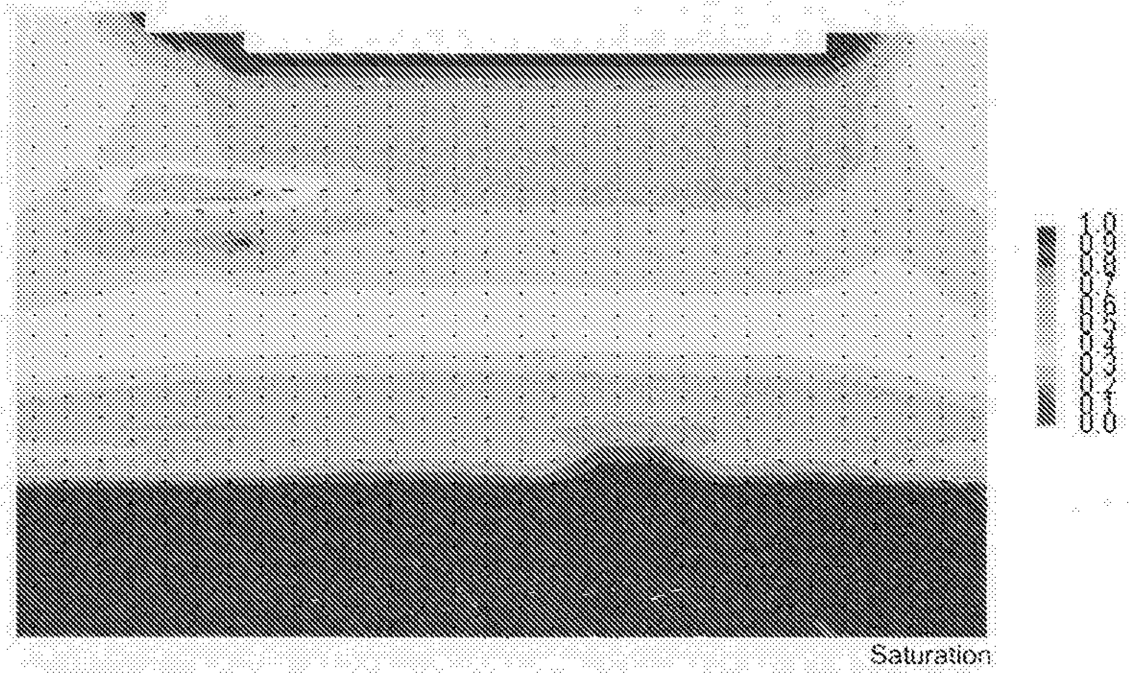
Time = 85.500946

(days)

PROJECT NUMBER: 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE: March 2004	
DWG | DWG NO:	Figure 10. Base Model: 85 Days
PROJECT MANAGER: RAC	
REVISED:	CES CASCADE EARTH SCIENCES A Valmont Industries Company



PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWG. DWG NO.	Figure 11. Addition of Clay Liner with Breach
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



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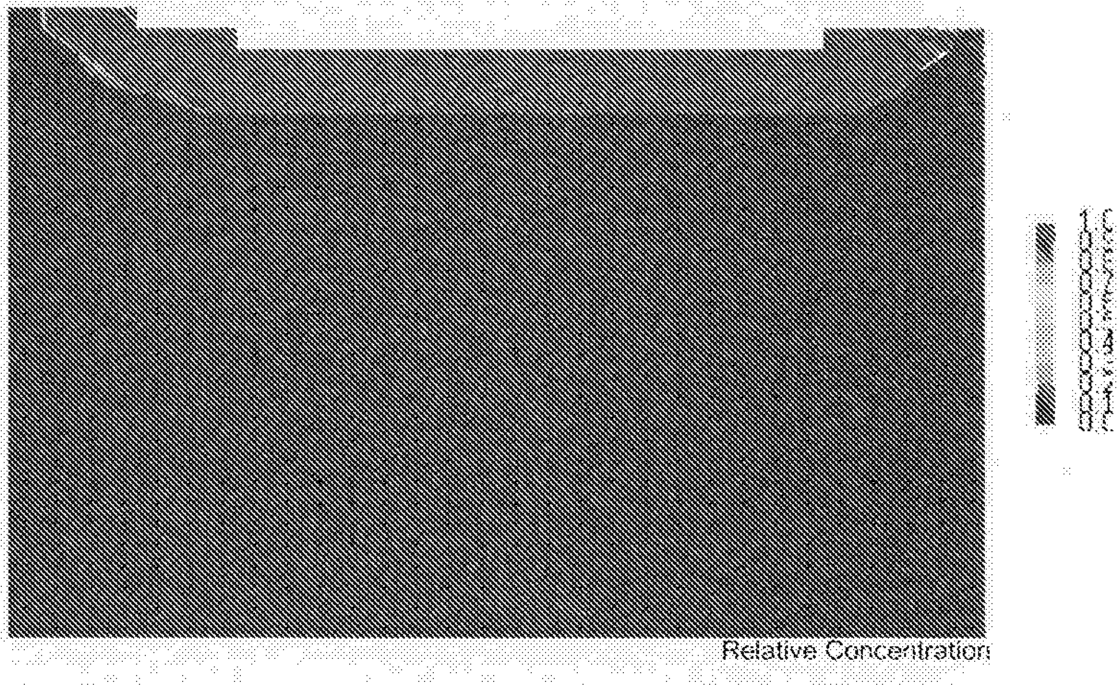
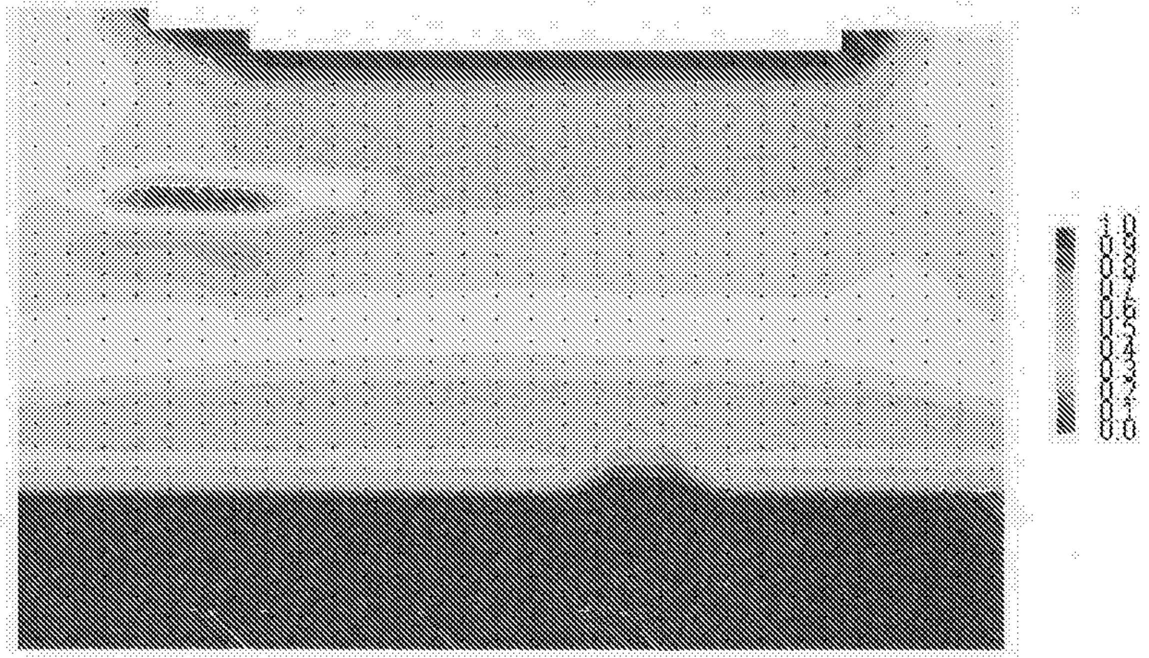


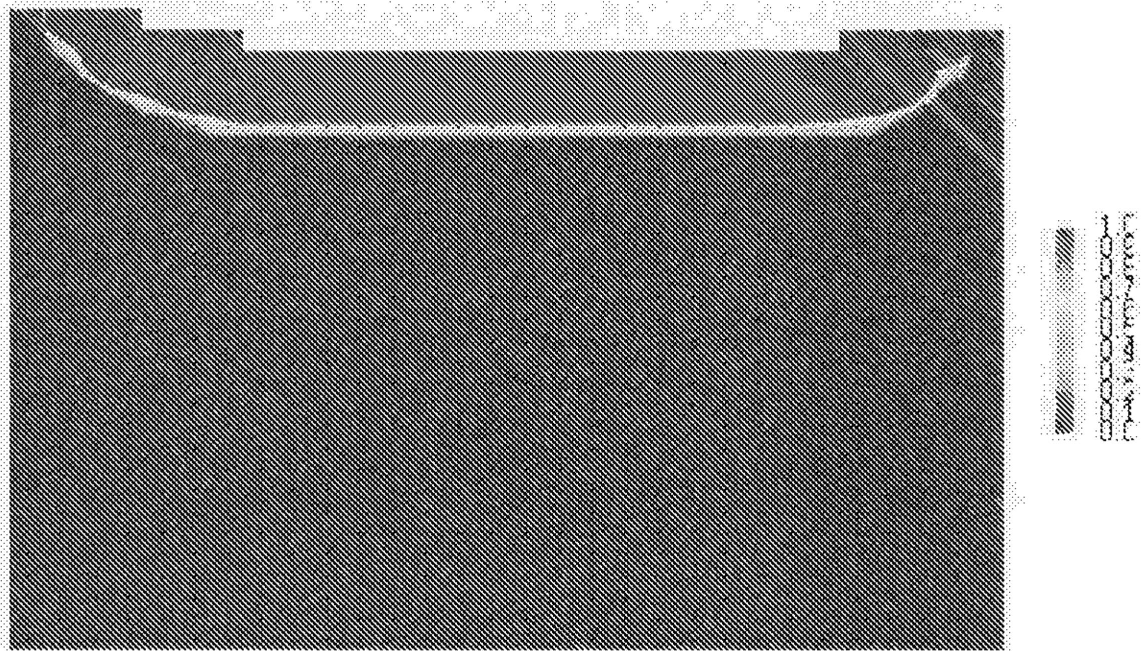
Time = 45.340694
(days)

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWG. DWG.NO.	Figure 12. Liner: 45 Days
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



Saturation

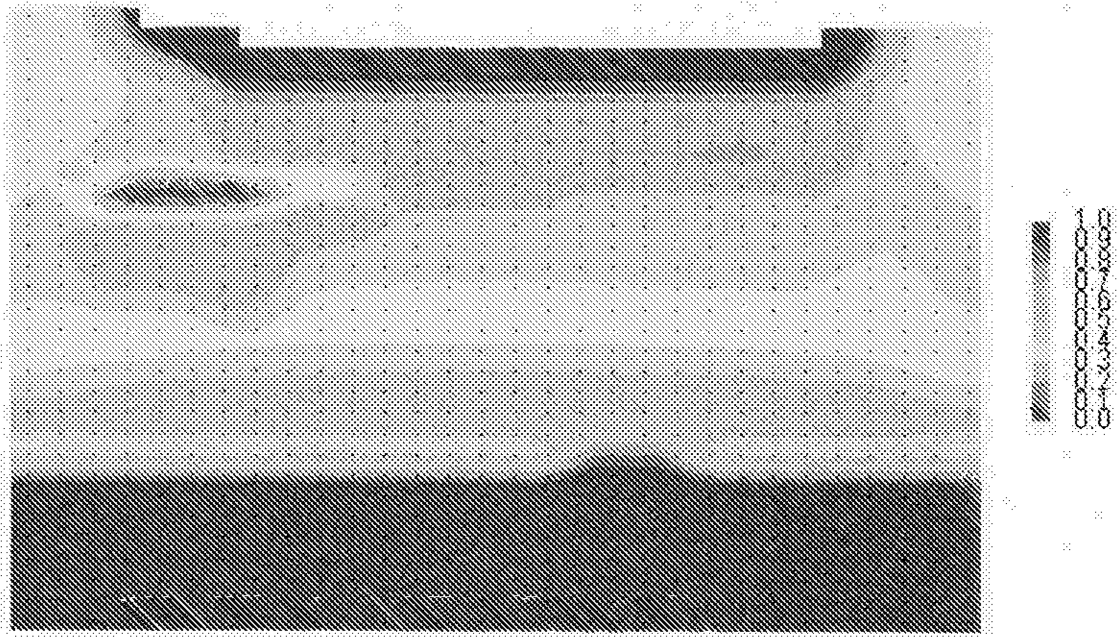
Time = 250.3407



Relative Concentration

Time = 250.3407
(days)

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE: March 2004	
DWN: DWG NO:	Figure 13. Liner: 250 Days
PROJECT MANAGER: RAC	
REVISED:	CES CASCADE EARTH SCIENCES A Valmont Industries Company



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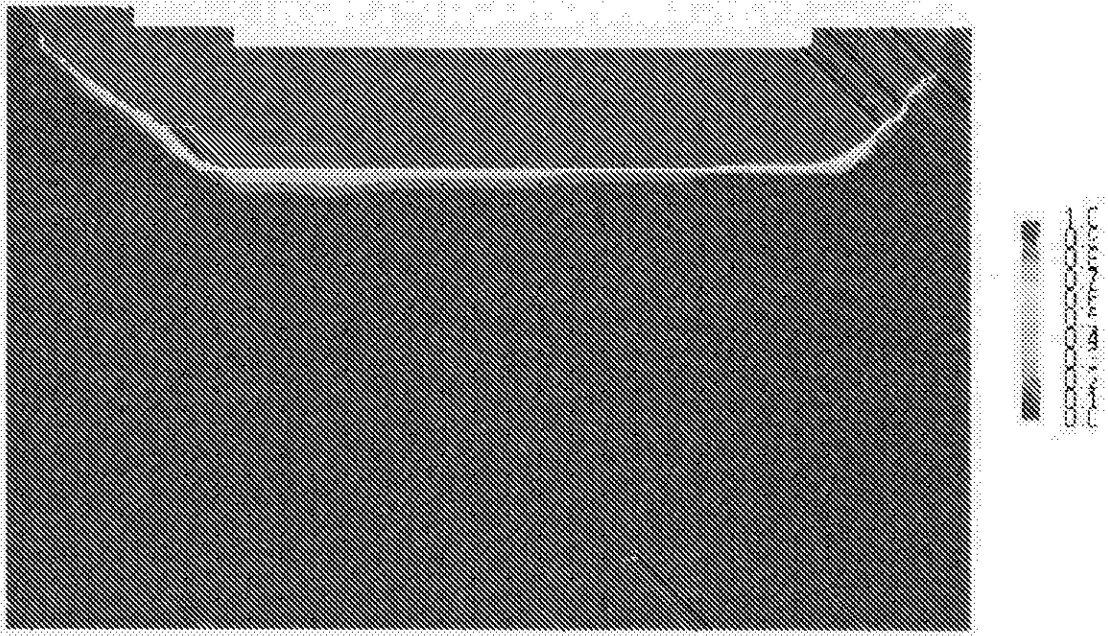
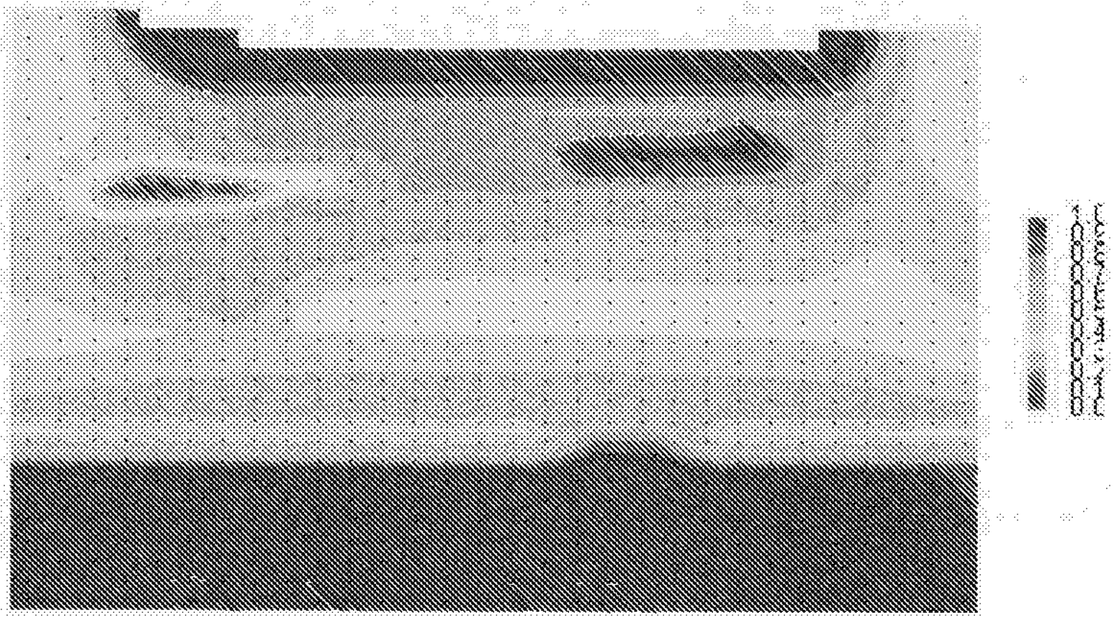


Relative Concentration

Time = 1095.3407
(days)

PROJECT NUMBER: 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE: March 2004	
DWG: DWG.NO.:	Figure14. Liner: 3 Years
PROJECT MANAGER: RAC	
REVISED:	CES CASCADE EARTH SCIENCES A Valmont Industries Company



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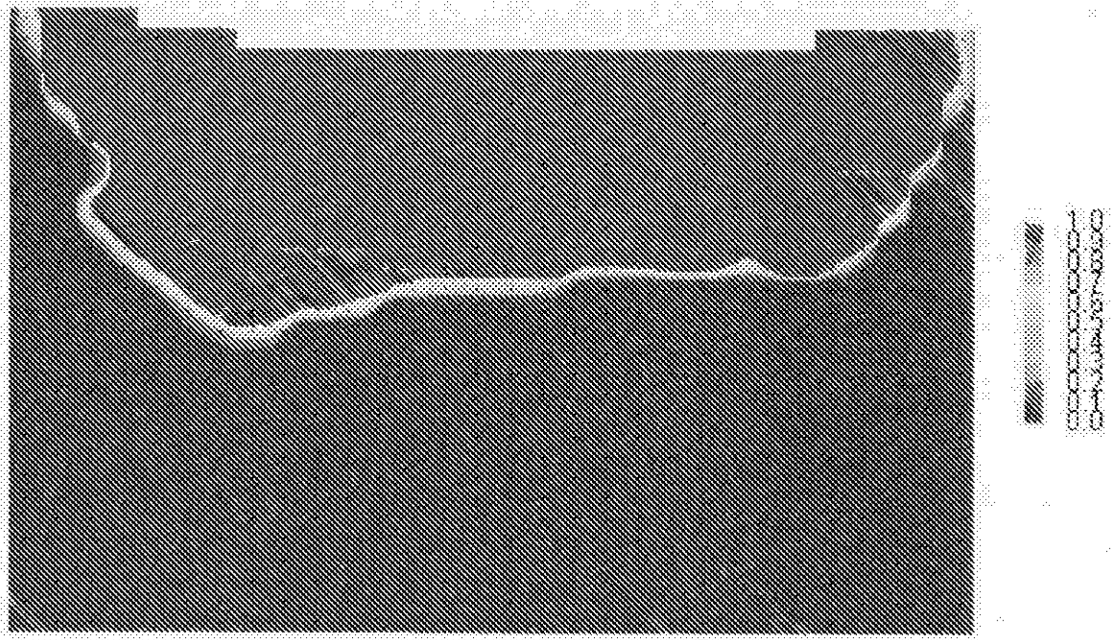
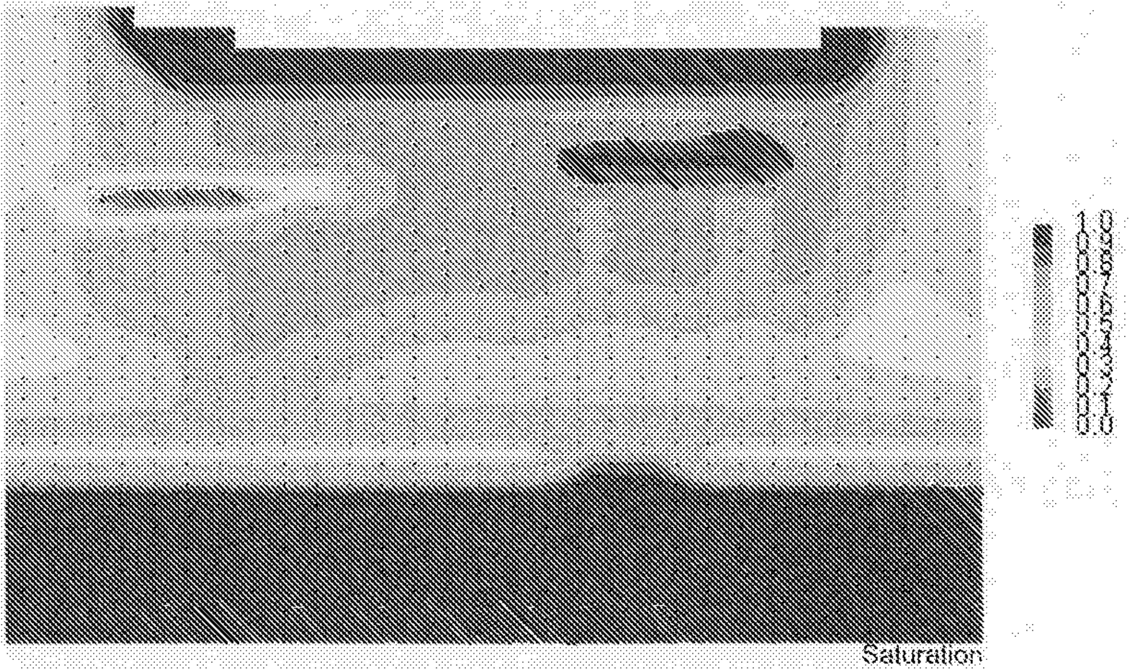


Relative Concentration

Time = 3650.3406
(days)

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWG DWG NO	Figure 15. Liner: 10 Years
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



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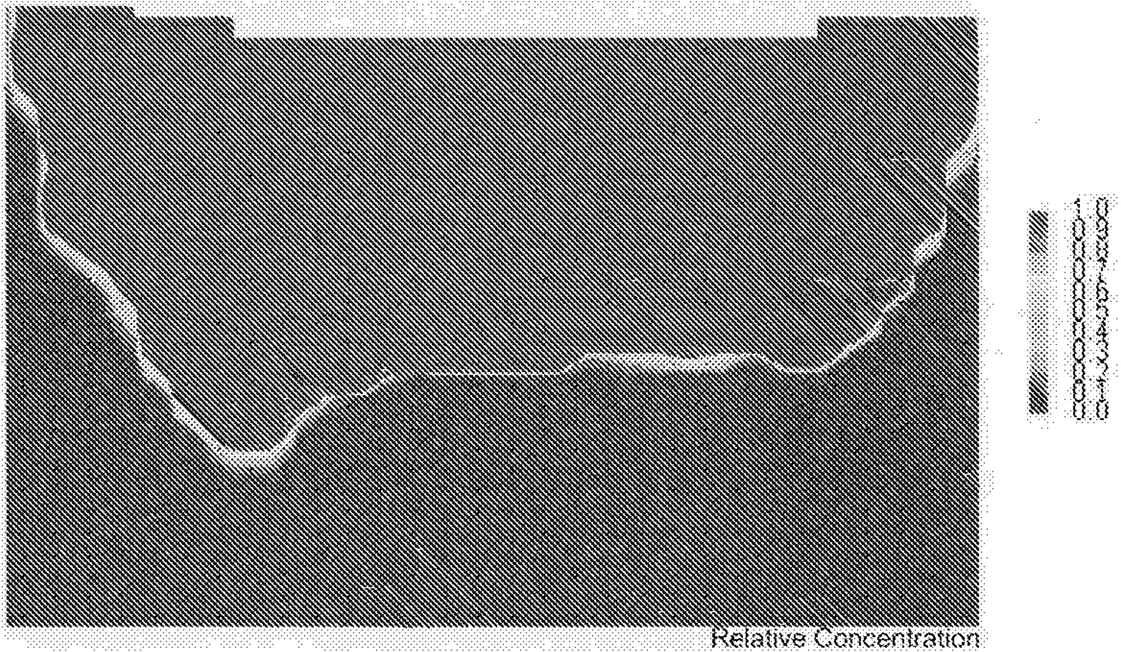
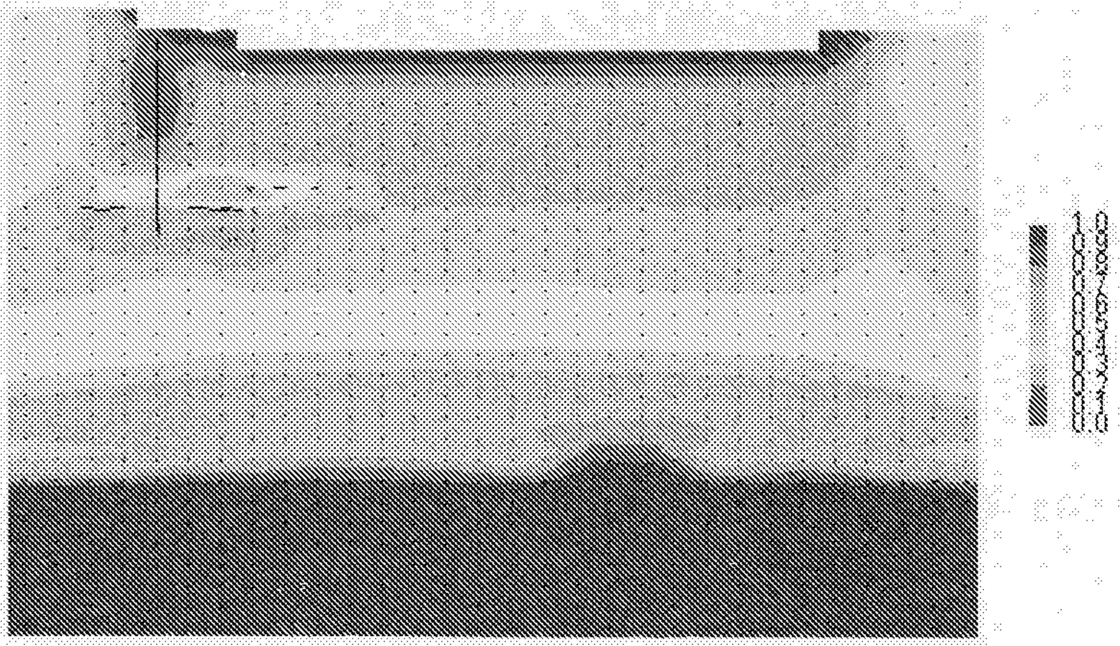


Time = 7300.0
(days)

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWG DWG NO	Figure 16. Liner: 20 Years
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company



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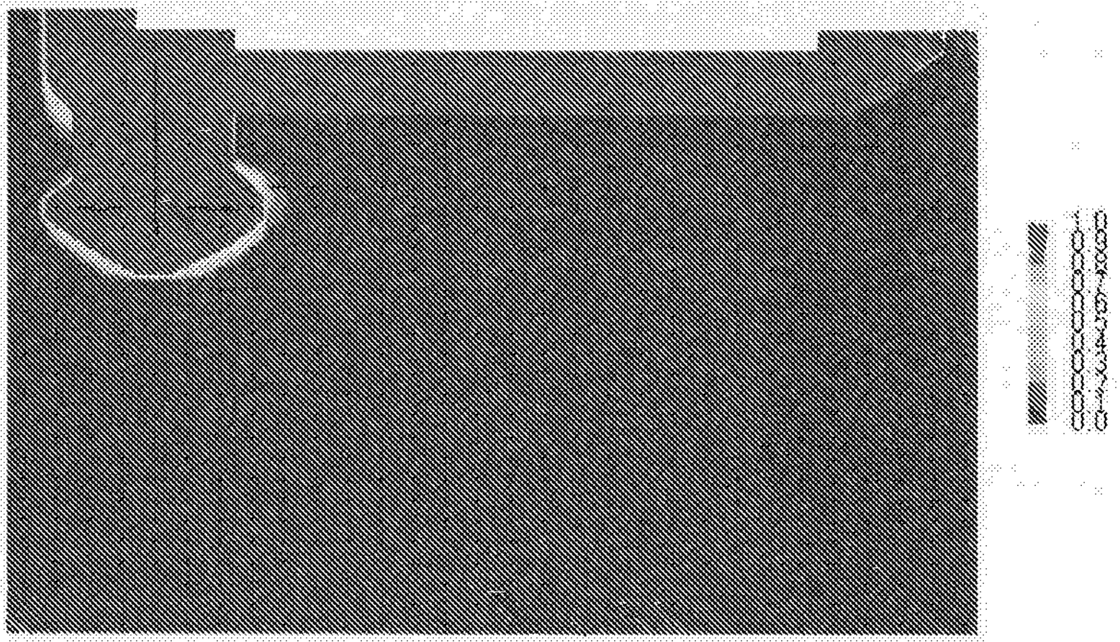
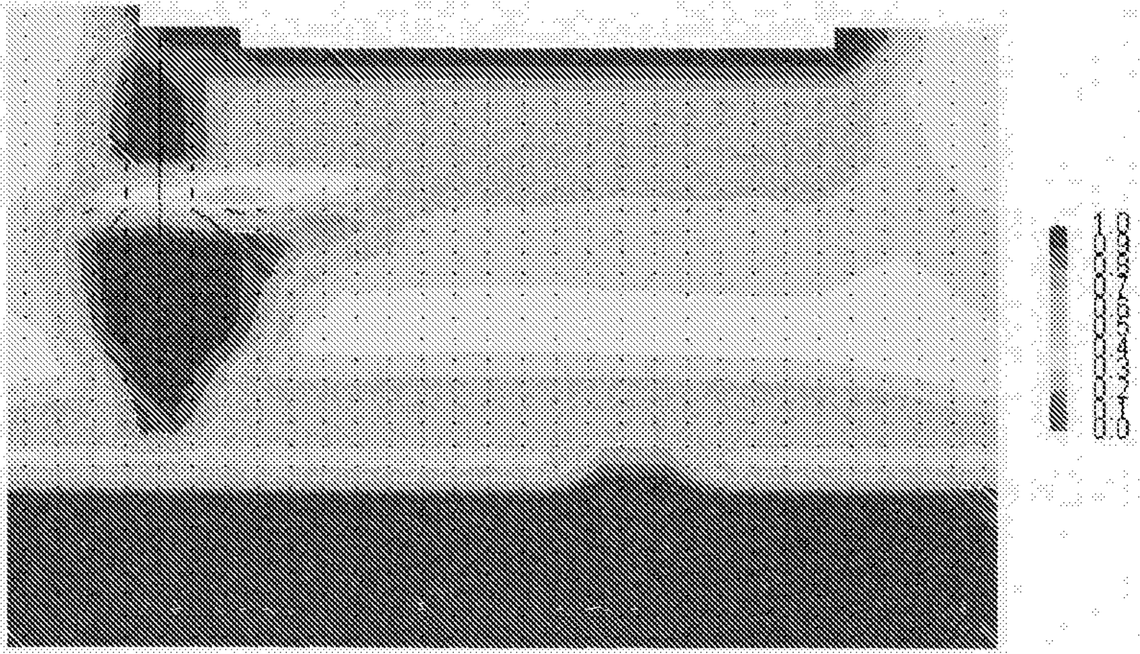


Relative Concentration

Time = 44.93372
(days)

PROJECT NUMBER: 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE: March 2004	
DWN: DWG NO:	Figure 17. Breached Liner: 45 Days
PROJECT MANAGER: RAC	
REVISED:	CES CASCADE EARTH SCIENCES A Valmont Industries Company



Saturation

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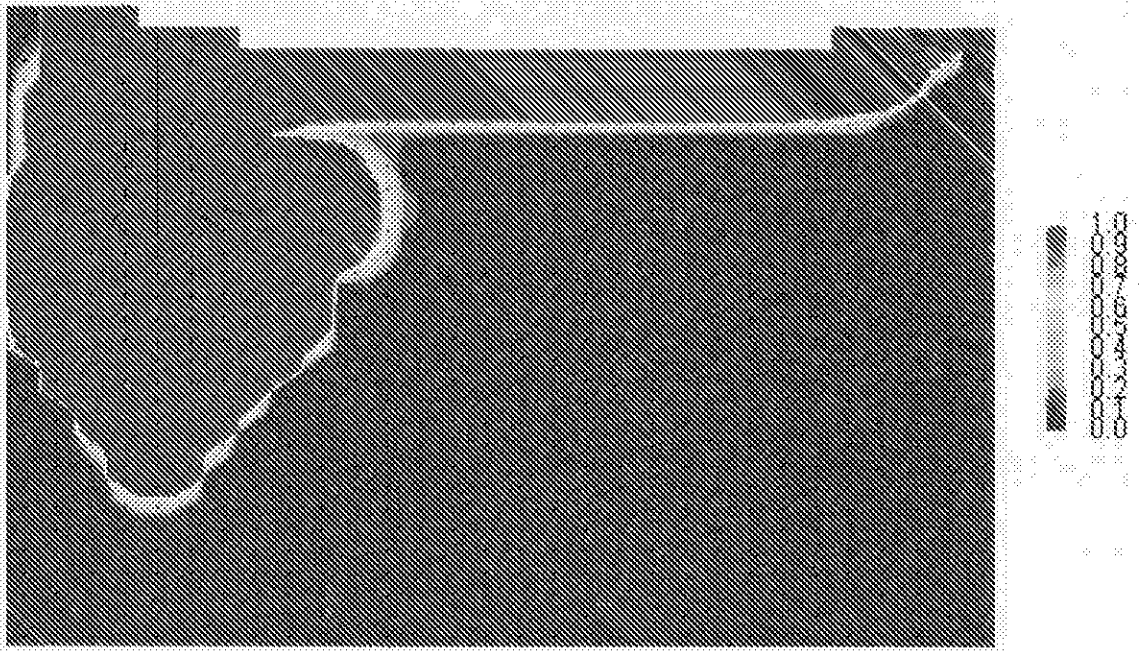


Relative Concentration

Time = 249.63304
(days)

PROJECT NUMBER 2423006	County Sanitation District of Los Angeles County: Seepage Study
DATE March 2004	
DWG DWG NO.	Figure 18. Breached Liner: 250 Days
PROJECT MANAGER RAC	
REVISED	CES CASCADE EARTH SCIENCES A Valmont Industries Company

APPENDICES

Appendix A. Well Logs and Borehole Logs
Appendix B. Summary of Hydraulic Testing Results of Geologic Materials

Appendix A.

Well Logs and Borehole Logs

QUINTUPLICATE
RETAIN THIS COPY

WATER WELL DRILLERS REPORT

(Sections 7076, 7077, 7078, Water Code)

STATE OF CALIFORNIA

Do Not Fill In
№ 27168
State Well No.
Other Well No.

(1) OWNER:

Name County sanitation District No. 14
Address 2020 Beverly Blvd.
Los Angeles. Calif.

(2) LOCATION OF WELL:

County L.A. Owner's number, if any
R. F. D. or Street No. 2000 ft. north of Ave. D
and approx. 100 ft east of 20th St.
East. Lancaster

(3) TYPE OF WORK (check):

New well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☐ Municipal ☒
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☒
Cable ☐
Dug Well ☐

(6) CASING INSTALLED:

SINGLE ☒ DOUBLE ☐

From ft. to	ft.	Diam.	Gage or Wall
220 ft. Solid			
300 ft. perforated			
8" casing			

If gravel packed

Diameter of Bore	from ft.	to ft.

Type and size of shoe or well ring
Size of gravel:
Describe joint

(7) PERFORATIONS:

Type of perforator used
Size of perforations in., length, by in.

From ft. to	ft.	Perf. per row	Rows per ft.

(8) CONSTRUCTION:

Was a surface sanitary seal provided? ☒ Yes ☐ No To what depth 100 ft.
Were any strata sealed against pollution? ☒ Yes ☐ No If yes, note depth of strata
From ft. to ft.
Method of Sealing

(9) WATER LEVELS:

Depth at which water was first found 85 ft.
Standing level before perforating ft.
Standing level after perforating ft.

(10) WELL TESTS:

Was a pump test made? ☒ Yes ☐ No If yes, by whom? driller
Yield: 538 gal./min. from 138 ft. draw down after hrs.

(11) WELL LOG:

Total depth 500 ft. Depth of completed well 470 ft.

Formations: Describe by color, character, size of material, and structure.

ft. to	ft.	
0	5	top soil-clay streaks
5	18	sandy clay streaks
18	24	sand-gravel
24	45	sandy clay streaks
45	52	soft clay
52	75	clay-sand streaks
75	98	sand-gravel-rocks
98	106	" " "
106	130	sand-rocks
130	165	sand-gravel-clay streaks
165	220	coarse sand-clay streaks
220	278	clay-sand-gravel
278	295	sand
295	302	sandy clay-gravel
302	340	sand-gravel-clay streaks
340	380	" " "
380	400	coarse sand
400	407	sand-gravel
407	413	rocks-sand
413	418	sandy clay
418	440	sand-gravel-clay streaks
440	462	sandy fine clay
462	500	fine sand & gravel

Work started 3/19/58 19 , Completed 4/9/58 19

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best my knowledge and belief.

NAME Rottman Drilling Co.
(Person, firm, or corporation) (Typed or printed)
Address 121 W. Ave. I Lancaster
California
[SIGNED]
Well Driller
Dated 4/10/58 19

BORING LOG

MW

Lancaster Water
Reclamation Plant

Name— Lancaster Water Reclamation Plant
No. 5103 Field log of Boring No. 5 Sheet 1 of 3

NW Corner of Recl. Plant Facility		ELEVATION AND DATUM 2315	
Layne Western	DRILLER Bill Mehlhorn	DATE STARTED 11/24/87	DATE FINISHED 11/24/87
Drill Systems AP 1000 Percussive Hamme		COMPLETION DEPTH (FT) 95'	ROCK DEPTH (FT)
AND TYPE CASING 4"SS Blank Type 304 0-45'		NO. OF SAMPLES DIST. 1	UNDIST. 4 CORE
TION 4"SS 0.02" Slotted Type 316L 45-95'		WATER DEPTH (FT) FIRST 45	COMPL. 65 24 HRS. 65
PERFORATION 12-30 Silica Sand 40-96' -		LOGGED BY: PH/WM	CHECKED BY: PH
Bentonite Pellets 35-40' Volclay Grout 3-35' Concrete 0-3'			

DESCRIPTION	GRAPHIC LOG Litho-logy	GRAPHIC LOG Well Comp. Dtls.	SAMPLES No.	SAMPLES Type	SAMPLES Blow Count	Drilling rate/time	P.H.C. Odor	REMARKS
an silty fine sand, white treaks and layers of caliche or ypsum.	SM	Concrete				9:00		
an silty sand slightly layer rains than above.	SM							
an interbedded sands and silty ands, fine grained.	SP SM							
an silty sands and silty clays nterbedded dry.	SP SM							
	SP SM							
ine gravel. Clean subrounded slightly silty medium sand with ine gravel, tan, dry.	SP SP							
Tan Medium sand with fine gravel moist.	SP	Volclay Grout Solid Casing		☒		9:26		3%
Tan sandy clay, moist to wet, 6" layer soft clay.	CL							
Tan sand, moist.	SP							
Gravelly sand, up to 1" diameter rock.	SP							
Tan sandy clay, moist, white caliche streaks about 15% of profile.	CL							
Moist to wet, clayey sand, tan medium to fine grained.	SC							
Tan sandy clay, wet, caliche.	SC							
Tan medium sand to fine gravel, some silt, moist	SP	Bent Pellets						

Patricia K. Haggerty

PATRICIA K.
HAGGERTY
4169

oject Name Lancaster Water Reclamation Plant

BORING LOG

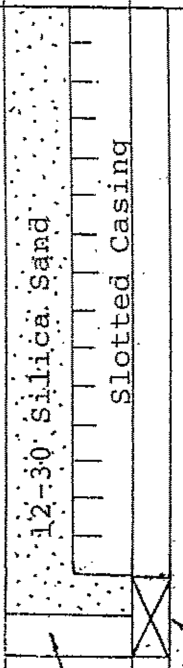
oject No. 5103 Field log of Boring No. 5 Sheet 2 of 3

(FEET)	DESCRIPTION	GRAPHIC LOG Litho-logy	Well Comp. Dtls.		SAMPLES No. Type	Blow Count	Drilling rate/time	P.H.C. Odor	REMARKS
	Tan silty sand to fine gravel, wet.	SM	Bent. Pellets	Solid Casing					
0	Greyish tan to tan sandy clay, moist to wet, some fine gravel grains subrounded.	CL	12-30 Silica Sand		☒		9:53		13.7% moisture
5	Tan, medium to coarse sand, saturated.	SP		Slotted Casing					▽ Perched Water
	Tan silty clay, moist to wet.	CL							
0	Tan silty medium to coarse grain sand. Moist to wet.	SP							
	Tan silty clay.	CL							
5	Tan silty sand, medium to coarse grained. With clay interbedded, moist.	SM							
	Tan silty clay, moist to wet. Layers of medium to coarse sand within.	CL SP							
0	Tan, medium to coarse sand, moist to wet.	SP			☒		10:37		9.7%
	Silty clay layers.	CL							
5	Tan silty sand, fine gravel, saturated - good flow.	SM							▼ ,Groundwater level after 24 hrs
	Tan silty medium to coarse sand, saturated.	SP							
70									
	Tan coarse sand clean, saturated.	SP							
75	Tan silty clay layer 6".	CL							
	Tan coarse to medium sand, fine gravel, saturated.	SP							
80	Tan sandy clay, moist to wet.	CL			☒		11:12		12.7%

BORING LOG

ject Name Lancaster Water Reclamation Plant
ject No. 5103 Field log of Boring No. 5 Sheet 3 of 3

DESCRIPTION	GRAPHIC LOG Litho-logy	GRAPHIC LOG Well Comp. Dtls.	SAMPLES No.	SAMPLES Type	SAMPLES Blow Count	SAMPLES Drilling rate/time	P.H.C. Odor	REMARKS
Tan sandy clay, moist, tan to light brown sandy clay, moist to wet, thin saturated, coarse sand layers within.	CL SP CL							
Tan medium to coarse sand, slightly silty, saturated.	SM							
Tan sandy to silty clay, moist to wet.	CL							
Tan medium to coarse sand, saturated, interbedded, silty clay layers.	SP CL							
Tan medium to coarse sand,	SP							
BORING TERMINATED AT 97'			☒	Bag		11:50		A.M. 11/24/87



BORING LOG

MW

Name Lancaster Water Reclamation Project

t No. 5103 Field log of Boring No. 6 Sheet 1 of 3

ON SW Corner of Reclamation Plant		ELEVATION AND DATUM	
G Layne Western	DRILLER Bill Mehlhorn	DATE STARTED 12/5/87	DATE FINISHED 12/5/87
ENT Drill Systems AP 1000 Percussive Hamme		COMPLETION DEPTH (FT) 100'	ROCK DEPTH (FT)
ER AND TYPE L CASING 4"SS Blank Type 304 0-50'		NO. OF SAMPLES DIST.	UNDIST. 3 CORE
ATION 4"SS 0.02" Slotted Type 316L 50-100'		WATER DEPTH (FT) FIRST 66	COMPL. 76 24 HRS. 63
F PERFORATION L 12-30 Silica Sand 45-102'		LOGGED BY: No [illegible] DM/RF	CHECKED BY: [illegible] PH
F Bentonite Pellets 40-45' Volclay Grout 3-40' Concrete 0-3'			

DESCRIPTION	GRAPHIC LOG Litho-logy	Well Comp. Dtls.		SAMPLES No.	Type	Blow Count	Drilling rate/time	P.H.C. Odor	REMARKS
Silty sand, light brown, moist, (fine to coarse grained) with caliche.	SM	Concrete	Solid Casing				12:00		
		Volclay Grout							
From 13', grades to coarse gravelly sand (fine gravels), dry, loose.	SP								
Brown silty fine sand with some clay and caliche stringers. Moist.	SM								
Brown silty sand. Fine to coarse grain. Moist.	SM				⊠	14	13:40		15.8%
@ 25', olive grey clay seam.	CL								
Below, fine to medium grain sand with thin silt/clay interbeds. Color is olive. Moist.	SP								
Brown fine to coarse grain sand. Moist.	SP								
Light brown coarse, gravelly sand with thin silt/clay interbeds. Slightly moist to dry, loose.	SP								

REGISTERED GEOLOGIST
Patricia K. Haggerty
PATRICIA K. HAGGERTY
4 30
STATE OF CALIFORNIA

t Name Lancaster Water Reclamation Project

BORING LOG

ct No. 5103 . Field log of Boring No. 6

Sheet 2 of 3

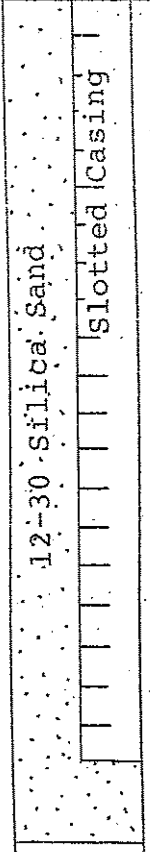
DESCRIPTION	GRAPHIC LOG		SAMPLES			P.H.C. Odor	REMARKS
	Litho-logy	Well Comp. Dtls.	No. Type	Blow Count	Drilling rate/time		
Brown clay sand with thin layers of silty clay, moist.	CL	Bentonite Pellets Solid Casing	☒	37	14:00		5%
Brown clayey sand continues as above.							
Light brown medium to coarse sand. Slightly moist, loose.	SP	12-30 Silica Sand					
Brown silty fine sand with beds of brown sandy clay. Clay is moist and soft.	SM	Slotted Casing					
From 60', sand is locally wet.	SP		☒	40	14:30		16.8%
Light brown coarse, gravelly sand. Wet.	SP						▼ Groundwater level after 24 hrs.
From 66-67', groundwater. (Perched zone).							∇ 66
Brown fine to coarse grain sand with thin interbeds of brown, stiff sandy clay.	SP CL						
Light brown gravelly sand. Wet.	SP						
From 76', groundwater.							∇ Groundwater encountered.

t Name Lancaster Water Reclamation Project

BORING LOG

t No. 5103 Field log of Boring No. 6 Sheet 3 of 3

DESCRIPTION	GRAPHIC LOG Litho-logy	GRAPHIC LOG Well Comp. Dtls.	SAMPLES No., Type	SAMPLES Blow Count	SAMPLES Drilling rate/time	P.H.C. Odor	REMARKS
From 80', grades to brown medium grain sand. Continues to be saturated.	SP						
Saturated sand continues as above.	SP						
From 84', soil includes zone of coarse gravelly sand and thin silt/clay seams. Remains saturated.	SP						
END BORING @ 102'							



MW

ct Name Lancaster Water Reclamation Project

ct No. 5103

Field log of Boring No. 7

Sheet 1 of 3

G ION East Side - Reclamation Plant		ELEVATION AND DATUM	
NG Y Layne Western	DRILLER Bill Mehlhorn	DATE STARTED 12/10/87	DATE FINISHED 12/11/87
NG MENT Drill Systems AP 1000 Percussive Hamme		COMPLETION DEPTH (FT) 80'	ROCK DEPTH (FT)
TER AND TYPE LL CASING 4"SS Blank Type 304 0-60'		NO. OF SAMPLES DIST.	UNDIST. 4 CORE
OF RATION 4"SS 0.02" Slotted Type 316L 60-80'		WATER DEPTH (FT) FIRST 25'	COMPL. 47 24 HRS. 51
OF PERFORATION FILL 12-30 Silica Sand 55-82'		LOGGED BY: PH/WM/VDM	CHECKED BY: PH
OF Bentonite Pellets 50-55' Volclay Grout 3-50' Concrete 0-3'			

DESCRIPTION	GRAPHIC LOG Litho-logy	GRAPHIC LOG Well Comp. Dtls.	SAMPLES No.	SAMPLES Type	Blow Count	Drilling rate/time	P.H.C. Odor	REMARKS
Tan silty sand, dry, some gravel.	SM	Concrete						
Tan silty fine sand, damp.	SM	Volclay Grout Solid Casing						
Grey brown clayey sand to sandy clay, damp.	SC CL							
Grey brown silty slightly clayey sand, moist.	SC							
Sandy clay layer.	CL							
Tan medium to coarse sand, moist to wet.	SP							
Dark grey brown silty sand.	SM							
Tan medium coarse sand, moist to wet.	SP			☒	13	7:55		9%
Greenish tan silty sand, saturated, medium to coarse grained.	SM							
Blue grey sandy clay, moist.	CL							
Blue grey, clayey sand, saturated.	SC							8:20 - 9:10 Stopped to consult with Steve Purdy
Grey tan sand, saturated.	SP							@ 25', first encountered groundwater
Greyish tan sand, medium to coarse, saturated.	SP							
Grey brown sandy clay, clayey to silty sand, interbeds, saturated.	CL SM							
Grey brown to tan sands, medium to coarse grained.	SP							9:30-10:40 Consulting

APPROVED
COUNTY SANITATION DISTRICTS
OF LOS ANGELES COUNTY
NOV 16 1988
CHARLES W. CARRY, CHIEF ENGR. & GEN. MGR
BY ph

Patricia K. Haggerty
PATRICIA K. HAGGERTY
1159

SANTA FE SOILS Inc.

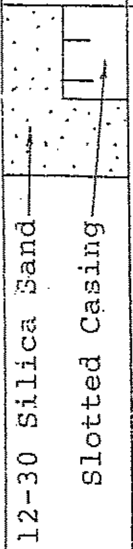
ect Name Reclamation Project

ect No. 5103. Field log of Boring No. 7 Sheet 2 of 3

DESCRIPTION	GRAPHIC LOG		SAMPLES				REMARKS
	Litho-logy	Well Comp. Dtls.	No. Type	Blow Count	Drilling rate/time	P.H.C. Odor	
Grey brown sandy clay, moist.	CL	Solid Casing					
Brown silty clay, moist to wet.	CL	Volclay Grout	☒	15	9:30		22%
Tan medium to coarse sand.	SP						
Tan silty sand and gravel, saturated.	SP						
Gray tan clay.	CL						
Tan silty to clayey sand, saturated.	SM SC						
Tan silty sand, saturated.	SM						
Tan to grayish tan silty clay, soft.	CH	Bentonite Pellets					∇ Groundwater level after 24 hours
Tan silty sand, grades to coarse clean sand.	SM SP	12-30 Silica Sand					
Clayey sand to sandy clay layer. Silty sand below, medium to coarse sand, saturated.	CL SM SP	Slotted Casing	☒	44	11:22		22%
Tan sandy clay.	CL						
Gray clay.	CH						
Tan medium coarse sand, saturated.	SP						
Tan sand, coarse grained with gravel, saturated, abundant water.	SP						
Tan medium to coarse sand and gravel, abundant water.	SP						

SANTA FE SOILS inc.

ect Name Reclamation Project
ect No. 5103 . Field log of Boring No. 7 Sheet 3 of 3

DESCRIPTION	GRAPHIC LOG		SAMPLES					REMARKS
	Litho-logy	Well Comp. Dtls.	No.	Type	Blow Count	Drilling rate/time	P.H.C. Odor	
Tan sandy clay @ 79'				☒				
END DRILLING @ 82'						12:00		Bag Sample
SET CASING @ 80'								

PROJ. NAME: CSDLAC LANCASTER WRP
PROJ. LOCATION: Ave. C & Sierra Hwy.
DATE: 02-28-01
EXC. METHOD: 8" Hollow Stem Auger

PROJECT NO.: 01B00201
BORING NO.: 4
ELEVATION: 2305'+/-
GW DEPTH: Not Encountered

SAMPLE DEPTH (ft)/ TYPE/	BLOW-COUNT (blows/ foot)	MOIST. CONTENT (%)	DRY DENSITY (pcf)	TESTS REPT'D ELSE-WHERE	Feet	Visual Classification
					1	[ML] Light brown silt w/ some clay & trace fine sand & occasional caliche layer, MED. STIFF
					2	
					3	
					4	
5.0/SS	20	6.1	106	A	5	At 5.5' hit hard object, move boring 5' north
-7/DST	--	--	--	DCSHR	6	
					7	Grdaing w/ more caliche
7.8/SS	44	2.3	106	DO	8	[SW] Light brown w/ brn. mottling fine-coarse sand, MED. DENSE
					9	
					10	[ML] Light brown clayey fine sandy silt w/ trace caliche lenses MED. STIFF
10.5/SS	39	8.5	--	S	11	
					12	
					13	
					14	[SP] Lt brown fine-medium sand grading to fine-coarse sand MED. DENSE
					15	
16.0/SS	41	1.1	117	OH	16	
					17	
					18	Grading to fine-medium sand
					19	
					20	
21.0/SS	44	4.4	100		21	Grading to fine-coarse sand
					22	
					23	
					24	Grading w/ trace caliche
25.7/SS	36	9.9	120		25	
					26	
					27	
					28	
					29	
					30	[ML] Light brown fine sandy clayey silt, STIFF

Log Continued on Next Page

PROJ. NAME: CSDLAC LANCASTER WRP
PROJ. LOCATION: Ave. C & Sierra Hwy.
DATE: 02-28-01
EXC. METHOD: 8" Hollow Stem Auger

PROJECT NO.: 01B00201
BORING NO.: 4
ELEVATION: 2305'+/-
GW DEPTH: Not Encountered

SAMPLE DEPTH (ft)/ TYPE/	BLOW-COUNT (blows/ foot)	MOIST. CONTENT (%)	DRY DENSITY (pcf)	TESTS REPT'D ELSE-WHERE	Feet	Visual Classification
31.0/SS	52	14.1	119		31	
					32	
					33	
					34	
					35	Grading to light brown gray fine-med. clayey silt w/
36.0/SP	27	--	--	A	36	occasional fine-med. sand lenses and silty clay lenses
					37	MED. STIFF
					38	
					39	
					40	
41.0/SS	21	9.3	121		41	
					42	
					43	[SM] Light brown silty fine sand, LOOSE
					44	
					45	
46.0/SP	13	--	--		46	
					47	
					48	[ML] Brown fine sandy silt, LOOSE
					49	
50.8/SS	17	11.9	116		50	
					51	Boring completed at depth of 51.5 feet

Need [illegible]

PROJ. NAME: CSDLAC LANCASTER WRP
PROJ. LOCATION: 10th St. West, 0.5 mi S Ave A
DATE: 03-02-01
EXC. METHOD: 8" Hollow Stem Auger

PROJECT NO.: 01B00201
BORING NO.: 5
ELEVATION: 2301'+/-
GW DEPTH: Not Encountered

SAMPLE DEPTH (ft)/ TYPE/	BLOW-COUNT (blows/ foot)	MOIST. CONTENT (%)	DRY DENSITY (pcf)	TESTS REPT'D ELSE-WHERE	Feet	Visual Classification
					1	[SM] Light brown silty fine sand w/ some clay caliche lenses
					2	DENSE
					3	
					4	
5.0/SS	78	10.9	121	A	5	
-7/DST	--	--	--	DCSHR	6	
					7	Grading w/ fine-med. sand
8.0/SS	94	4.1	118	DO	8	
					9	
					10	Grading MED. DENSE
1.0/SS	39	2.8	110	H	11	
					12	
					13	
					14	Grading DENSE
5.5/SS	85	5.0	99	0	15	
					16	
					17	
					18	
					19	[SP] Light Brown Fine-med. sand w/ some 1/8" gravel & trace silt
					20	MED. DENSE
1.0/SS	46	2.9	115		21	
					22	
					23	
					24	Grading w/ increased silt
					25	
6.0/SS	50	13.1	116		26	
					27	
					28	[SM] Light brown clayey silty fine sand, moist, MED. DENSE
					29	
					30	

Log Continued on Next Page

PROJ. NAME: CSDLAC LANCASTER WRP
PROJ. LOCATION: 10th St. West, 0.5 mi S Ave A
DATE: 03-02-01
EXC. METHOD: 8" Hollow Stem Auger

PROJECT NO.: 01800201
BORING NO.: 5
ELEVATION: 2301'+/-
GW DEPTH: Not Encountered

SAMPLE DEPTH (ft)/ TYPE/	BLOW-COUNT (blows/ foot)	MOIST. CONTENT (%)	DRY DENSITY (pcf)	TESTS REPT'D ELSE-WHERE	Feet	Visual Classification
31.0/SS	43	17.3	113	H	31	
					32	
					33	
					34	Grading w/ layers of fine-med. sand
35.5/SP	38	14.7	--	S	35	
					36	
					37	
					38	
					39	
					40	
41.0/SS	34	14.4	87		41	Grading wet, LOOSE
					42	
					43	
					44	
45.5/SP	26	--	--		45	Grading MED. DENSE
					46	
					47	
					48	Grading moist
					49	
50.5/SS	34	15.2	98		50	
					51	Boring completed at depth of 51.5 feet

PROJ. NAME: CSDLAC LANCASTER WRP
PROJ. LOCATION: Ave. B & Sierra Hwy.
DATE: 03-01-01
EXC. METHOD: 8" Hollow Stem Auger

PROJECT NO.: 01B00201
BORING NO.: 6
ELEVATION: 2305'+/-
GW DEPTH: Not Encountered

SAMPLE DEPTH (ft)/ TYPE/	BLOW-COUNT (blows/ foot)	MOIST. CONTENT (%)	DRY DENSITY (pcf)	TESTS REPT'D ELSE-WHERE	Feet	Visual Classification
					1	[SM] Light brown clayey silty fine sand w caliche lenses, MED. DENSE
					2	
					3	
					4	
5.0/SS	34	7.0	103	A	5	
-7/DST	--	--	--	DCSAHR*	6	
					7	Grading w/ increased fine sand
8.0/SS	32	10.7	113	OH	8	
					9	Grading w/ less fine sand
					10	
11.0/SS	39	14.4	108	D	11	
					12	
					13	
					14	
15.7/SS	32	7.4	116	O	15	
					16	
					17	
					18	
					19	Grading w/ occasional 8" silty fine-med. Sand layers, DENSE
					20	
20.8/SS	49	7.0	113	H	21	
					22	
					23	
					24	
					25	Grading w/ layers of very fine sand w/ trace silt
26.0	60	4.1	120		26	
					27	
					28	[ML] Light brown very fine sandy clayey silt w/ caliche lenses MED. STIFF
					29	
					30	

Log Continued on Next Page

PROJ. NAME: CSDLAC LANCASTER WRP
PROJ. LOCATION: Ave. B & Sierra Hwy.
DATE: 03-01-01
EXC. METHOD: 8" Hollow Stem Auger

PROJECT NO.: 01800201
BORING NO.: 6
ELEVATION: 2305'+/-
GW DEPTH: Not Encountered

SAMPLE DEPTH (ft)/ TYPE/	BLOW-COUNT (blows/ foot)	MOIST. CONTENT (%)	DRY DENSITY (pcf)	TESTS REPT'D ELSE-WHERE	Feet	Visual Classification
31.0/SS	33	11.3	121	A	31	
					32	
					33	
					34	[SM] Light brown clayey silty fine-med. sand, moist, LOOSE
					35	
35.5/SP	20	16.3	--	S	36	
					37	
					38	
					39	
					40	Grading w/ layers of fine-med. sand
41.0/SS	42	4.5	125		41	DENSE
					42	
					43	
					44	Grading to silty fine-coarse sand w/ caliche lenses &
45.0/SP	42	--	--		45	cemented nodules
					46	
					47	
					48	[ML] Light brown fine-med. sandy silt, moist, MED. DENSE
					49	
					50	
51.0/SS	29	22.3	104		51	Boring completed at depth of 51.5 feet

PROJ. NAME: CSOLAC LANCASTER WRP
PROJ. LOCATION: 10th St. West, 0.5 mi S Ave C
DATE: 03-01-01
EXC. METHOD: 8" Hollow Stem Auger

PROJECT NO.: 01B00201
BORING NO.: 8
ELEVATION: 2301'+/-
GW DEPTH: 33 feet

SAMPLE DEPTH (ft)/ TYPE/	BLOW-COUNT (blows/ foot)	MOIST. CONTENT (%)	DRY DENSITY (pcf)	TESTS REPT'D ELSE-WHERE	Feet	Visual Classification
					1	[SM] Light brown silty clayey fine sand w/ trace caliche, MED. DENSE
					2	
					3	
					4	
5.0/SS	38	4.6	110	DA	5	
4-7/DST	--	--	--	DCSAHR	6	
					7	Grading w/ increased caliche, DENSE
8.0/SS	64	5.2	119	OH	8	
					9	
					10	
10.7/SS	64	--	--	OS	11	Grading slightly porous w/ no caliche
					12	
					13	
					14	Grading to brown-gray fine sandy silt w/ layers of fine-medium sand
					15	
16.0/SS	47	3.9	112	H	16	
					17	
					18	[ML] Gray fine sandy silt, MED. DENSE
					19	
					20	
21.0/SS	46	5.2	109		21	
					22	
					23	
					24	
					25	Grading moist, LOOSE
26.0/SS	14	24.0	102		26	
					27	
					28	
					29	
30/SS	16	NR	NR		30	Water seepage noted at 30'

Log Continued on Next Page

PROJ. NAME: CSDLAC LANCASTER WRP
PROJ. LOCATION: 10th St. West, 0.5 mi S Ave C
DATE: 03-01-01
EXC. METHOD: 8" Hollow Stem Auger

PROJECT NO.: 01800201
BORING NO.: 8
ELEVATION: 2301'+/-
GW DEPTH: 33 feet

SAMPLE DEPTH (ft)/ TYPE/	BLOW-COUNT (blows/ foot)	MOIST. CONTENT (%)	DRY DENSITY (pcf)	TESTS REPT'D ELSE-WHERE		Feet	Visual Classification
						31	
						32	Gray brown medium-coarse sandw/ some silt, wet, LOOSE
					▼	33	Water level at 33' after 30 min.
						34	
						35	
36.0/SP	10	20.5	--	$		36	
						37	
						38	
						39	[SM] Gray brown silty fine sand w/ fine-med. sand layers, wet
40.5/SP	16	--	--			40	LOOSE
						41	
						42	
						43	
						44	Grading w/ some 1/4" gravel
45.5/SP	8	21.0	--	$		45	
						46	
						47	
						48	
						49	Grading to olive brown silty fine-med. sand, MED. DENSE
50.5/SP	26	--	--			50	
						51	Boring completed at depth of 51.5 feet

Appendix B.

Summary of Hydraulic Testing Results of Geologic Materials

MTC ENGINEERING, INC. Geotechnical & Environmental Consultants

419 S. Pine St., #C • San Gabriel, CA 91776
Tel: (626) 287-6416 • Fax: (626) 287-0560
Toll Free 1 (888) MTC-ENGR • E-mail: mtcengr@pacbell.net

SUMMARY OF HYDRAULIC CONDUCTIVITY TEST RESULTS
ASTM D 5084

PROJECT NAME: COUNTY SANITATION DISTRICTS KTL NO.: 01-110-001

PROJECT NO.: 31-29-IT CLIENT: **Aldrich Geotech**

DATE: 04-16-01 SUMMARIZED BY: K. Tan

BORING NO	SAMPLE NO	DEPTH (ft)	INITIAL MOISTURE (%)	DRY DENSITY (pcf)	FINAL MOISTURE (%)	EFFECTIVE STRESS (psi)	HYDRAULIC CONDUCTIVITY (cm/sec)
1	1A	4-7	9.4	126.4	12.3	3	9.7E-07
2	1A	3-7	8.2	111.6	18.4	3	3.0E-07
3	1A	3-7	11.0	113.8	18.2	3	2.2E-07
4	1A	4-7	9.9	120.8	17.8	3	7.8E-08
5	1A	4-7	6.0	120.3	16.6	3	6.5E-07
6	1A	4-7	7.3	116.6	17.3	3	2.6E-07
7	1A	4-7	7.4	119.6	15.1	3	2.3E-07
8	1A	4-7	5.8	122.6	13.7	3	1.5E-05
9	1A	4-7	8.0	127.9	13.2	3	2.3E-06
1	2	8.0	10.2	102.8	22.7	3	1.8E-05
2	4	16.5	10.5	106.8	21.3	3	2.0E-05
3	2	8.0	7.9	102.7	23.9	3	2.7E-05
4	4	16.0	1.2	149.3	12.2	3	1.5E-03
5	3	11.0	2.4	108.4	17.5	3	4.1E-04
5	5	21.0	2.8	117.6	17.5	3	7.7E-06
5	7	31.0	13.8	115.6	16.9	3	9.5E-07
6	2	8.0	9.8	108.7	20.2	3	1.2E-04
6	5	20.8	6.0	109.2	18.5	3	3.9E-04
7	1	5.0	7.0	101.1	21.9	3	3.0E-05
7	4	16.0	12.7	100.8	26.2	3	2.7E-05
8	2	8.0	5.9	116.2	17.4	3	5.7E-06
8	4	16.0	2.3	112.6	21.8	3	4.5E-06
9	1	4.0	10.8	112.6	14.9	3	4.6E-06
9	2	8.0	8.5	103.9	16.0	3	8.8E-04
9	4	15.5	5.3	105.3	16.8	3	1.2E-03

7.
open hole

FIELD PERMEABILITY TEST (SHALLOW WELL PERMEAMETER METHOD)
BORING B-5
LANCASTER WATER RECLAMATION PLANT PRELIMINARY EVAPORATION POND SITING STUDY

Date	Time	Elapsed Time		Water Height		Reservoir Volume		Volume	Accumulative
		minutes	hours	Inches	cm	cm^3	Liters (L)	Difference (L)	Difference (L)
12-Mar-01	11:07	0	0	31.25	79.38	203,581	203.58	0.00	0.00
12-Mar-01	11:17	10	0.17	30.50	77.47	198,695	198.70	4.89	4.89
12-Mar-01	11:27	20	0.33	29.00	73.66	188,923	188.92	9.77	14.66
12-Mar-01	11:37	30	0.50	27.50	69.85	179,152	179.15	9.77	24.43
12-Mar-01	11:47	40	0.67	25.50	64.77	166,122	166.12	13.03	37.46
12-Mar-01	11:57	50	0.83	24.50	62.23	159,608	159.61	6.51	43.97
12-Mar-01	12:07	60	1.00	23.13	58.74	150,650	150.65	8.96	52.93
12-Mar-01	12:17	70	1.17	21.63	54.93	140,878	140.88	9.77	62.70
12-Mar-01	12:27	80	1.33	20.63	52.39	134,364	134.36	6.51	69.22
12-Mar-01	12:37	90	1.50	19.50	49.53	127,035	127.03	7.33	76.55
12-Mar-01	12:47	100	1.67	18.25	46.36	118,891	118.89	8.14	84.69
12-Mar-01	12:57	110	1.83	17.25	43.82	112,377	112.38	6.51	91.20
12-Mar-01	13:07	120	2.00	16.25	41.28	105,862	105.86	6.51	97.72
12-Mar-01	14:10	183	3.05	11.50	29.21	74,918	74.92	30.94	128.66
12-Mar-01	14:18	191	3.18	32.25	81.92	210,096	210.10	0.00	128.66
12-Mar-01	15:48	281	4.68	23.00	58.42	149,836	149.84	60.26	188.92
12-Mar-01	16:18	311	5.18	21.13	53.66	137,621	137.62	12.21	201.14
12-Mar-01	16:48	341	5.68	19.50	49.53	127,035	127.03	10.59	211.72

Well radius,r(meters): 0.15 ? Water temp,°C = 19
Depth of test well, meters): 1.45
Depth of water source to bottom of test layer, H(meters): 1.14 114 cm
Height of water in well,h(meters): 0.3

a = r/H = 0.13
B = h/H = 0.26
C = (0.0196)/(0.13)(0.26)= 0.58
V = 1.02
q = 22.80 x 1000 = 22,801 cm^3/hr
k = (C)(V)(q)/(H)^2(3600) = .006 2.88E-04 cm/sec

12040

FIELD PERMEABILITY TEST (SHALLOW WELL PERMEAMETER METHOD)
BORING B-6
LANCASTER WATER RECLAMATION PLANT PRELIMINARY EVAPORATION POND SITING STUDY

Date	Time	Elapsed Time		Water Height		Reservoir Volume		Volume	Accumulative
		minutes	hours	inches	cm	cm^3	Liters (L)	Difference (L)	Difference (L)
12-Mar-01	14:45	0	0	32.75	83.19	213,353	213.35	0.00	0.00
14-Mar-01	7:35	2450	40.83	29.75	75.57	193,809	193.81	19.54	19.54
14-Mar-01	17:00	3015	50.25	29.25	74.30	190,552	190.55	3.26	22.80
15-Mar-01	14:40	4315	71.92	27.75	70.49	180,780	180.78	9.77	32.57
16-Mar-01	9:50	5465	91.08	26.50	67.31	172,637	172.64	8.14	40.72
16-Mar-01	10:50	5525	92.08	26.50	67.31	172,637	172.64	0.00	40.72
16-Mar-01	12:50	5645	94.08	26.50	67.31	172,637	172.64	0.00	40.72
16-Mar-01	14:50	5765	96.08	26.38	66.99	171,823	171.82	0.81	41.53

Well radius,r(meters): 0.15

Water temp,°C = 19

Depth of test well, meters): 1.52

Depth of water source to bottom of test layer, H(meters): 1.22 122 cm

Height of water in well,h(meters): 0.3

a = r/H = 0.12

B = h/H = 0.25

C = (0.0171)/(0.12)(0.25)= 0.57

V = 1.02

q = 0.37 x 1000 = 371 cm^3/hr

k = $(C)(V)(q)/(H)^2(3600)$ = 4.02E-06 cm/sec

FIELD PERMEABILITY TEST (SHALLOW WELL PERMEAMETER METHOD)
BORING B-8
LANCASTER WATER RECLAMATION PLANT PRELIMINARY EVAPORATION SITING STUDY

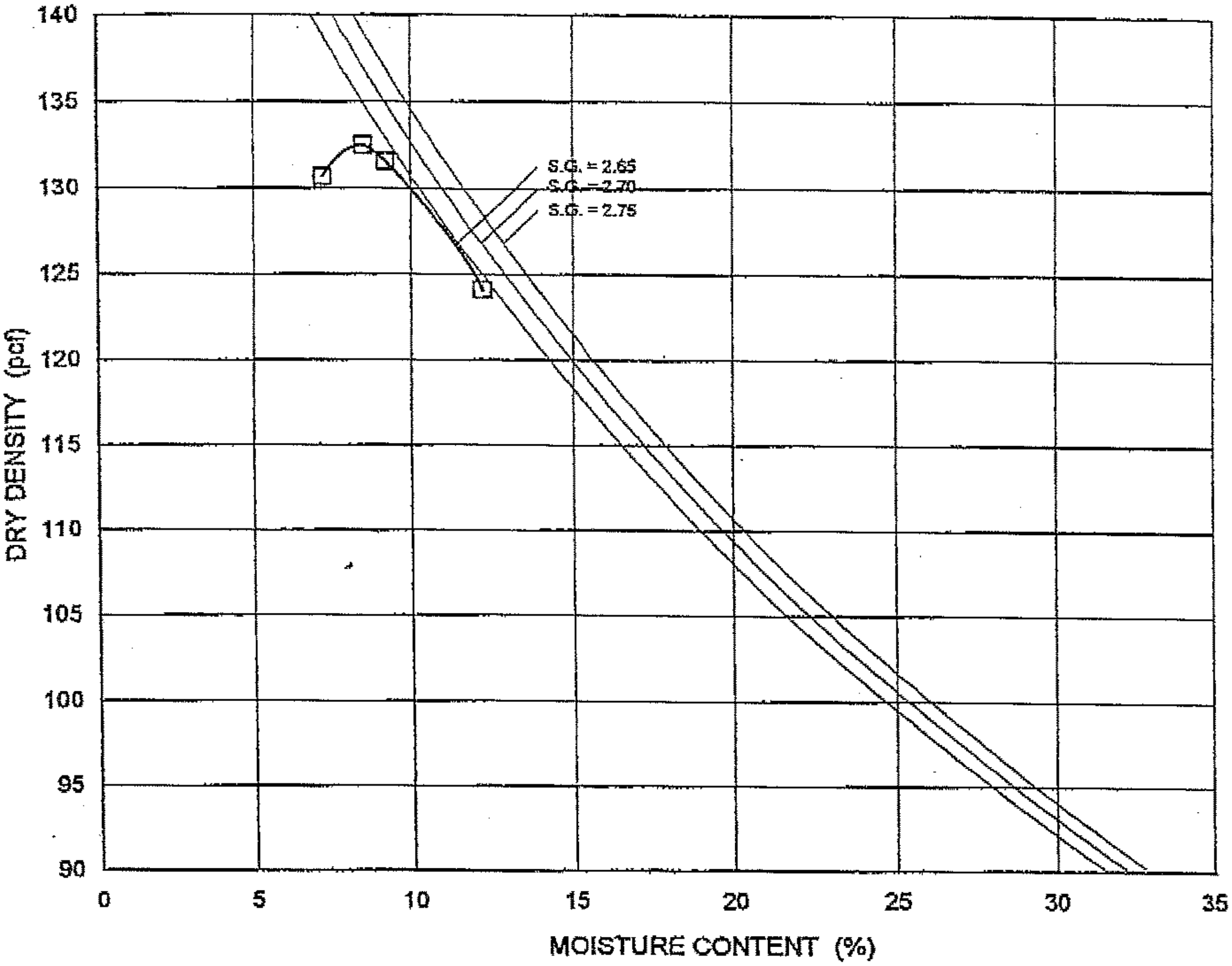
Date	Time	Elapsed Time		Water Height		Reservoir Volume		Volume	Accumulative
		minutes	hours	inches	cm	cm^3	Liters (L)	Difference (L)	Difference (L)
14-Mar-01	15:45	0	0	31.63	80.33	206,024	206.02	0.00	0.00
14-Mar-01	17:25	100	1.67	30.00	76.20	195,438	195.44	10.59	10.59
16-Mar-01	9:30	2505	41.75	15.50	39.37	100,976	100.98	94.46	105.05
16-Mar-01	10:30	2565	42.75	15.25	38.74	99,348	99.35	1.63	106.68
16-Mar-01	12:30	2685	44.75	15.00	38.10	97,719	97.72	1.63	108.31
16-Mar-01	15:30	2865	47.75	14.25	36.20	92,833	92.83	4.89	113.19

Well radius,r(meters): 0.15 Water temp,°C = 19
Depth of test well, meters: 1.46
Depth of water source to bottom of test layer, H(meters): 1.16 116 cm
Height of water in well,h(meters): 0.3

a = r/H = 0.13
B = h/H = 0.26
C = (0.0196)/(0.13)(0.26)= 0.57
V = 1.02
q = 2.23 x 1000 = 2,227 cm^3/hr
k = $(C)(V)(q)/(H)^2(3600)$ = 2.67E-05 cm/sec

MODIFIED PROCTOR

(ASTM D1557)



Location:	B8/1A
Depth (ft):	4-7
Soil Type:	SM
Optimum Moisture Content (%):	9.0
Maximum Dry Density (pcf):	132.5

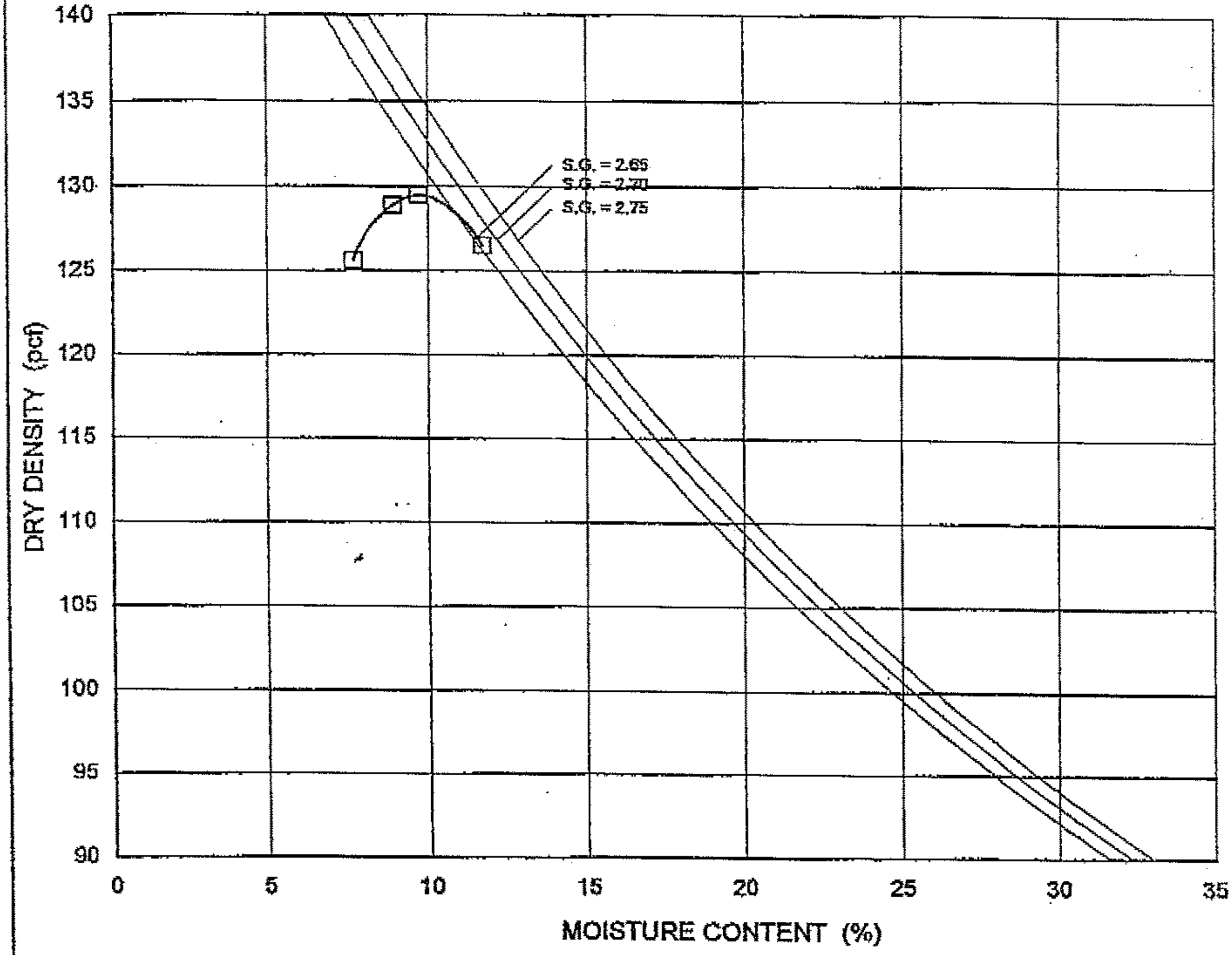
Date: 4/01

Prepared By: ML/AP

MTC ENGINEERING, INC.	Project Name	Project Number	Plate
419 South Pine Street, Suite C San Gabriel, CA 91776 Tel: (626)287-8416; Fax: (626)287-0560	County Sanitation District of Los Angeles County	31-29-1T	CM-8

MODIFIED PROCTOR

(ASTM D1557)



Location:	B6/1A
Depth (ft):	4-7
Soil Type:	SM
Optimum Moisture Content (%):	9.7
Maximum Dry Density (pcf):	129.5

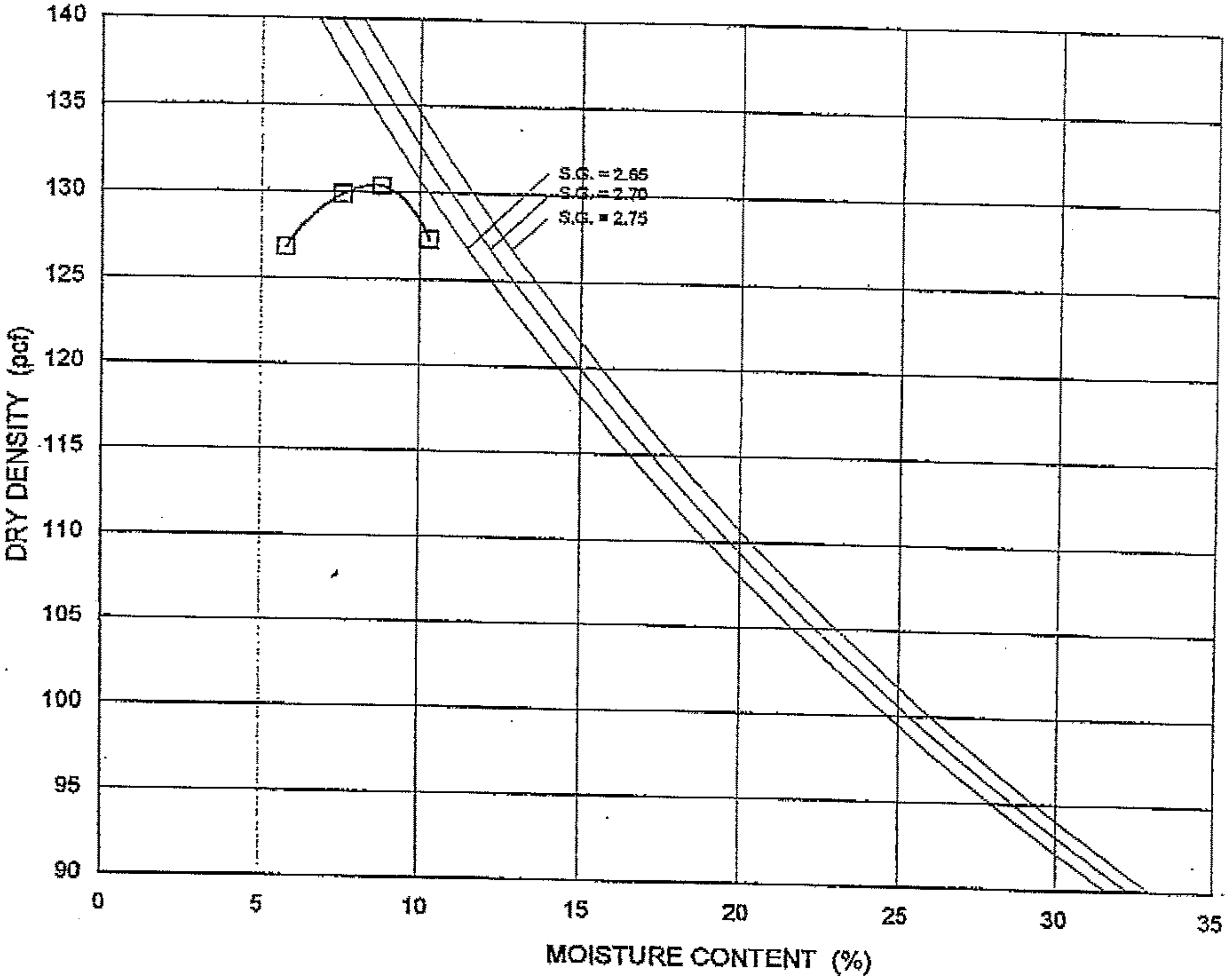
Date: 4/01

Prepared By: ML/AP

MTC ENGINEERING, INC.	Project Name	Project Number	Plate
419 South Pine Street, Suite C San Gabriel, CA 91776 Tel: (626)287-8416; Fax: (626)287-0560	County Sanitation District of Los Angeles County	31-29-1T	CM-6

MODIFIED PROCTOR

(ASTM D1557)



Location:	B5/1A
Depth (ft):	4-7
Soil Type:	SM
Optimum Moisture Content (%):	8.8
Maximum Dry Density (pcf):	130.4

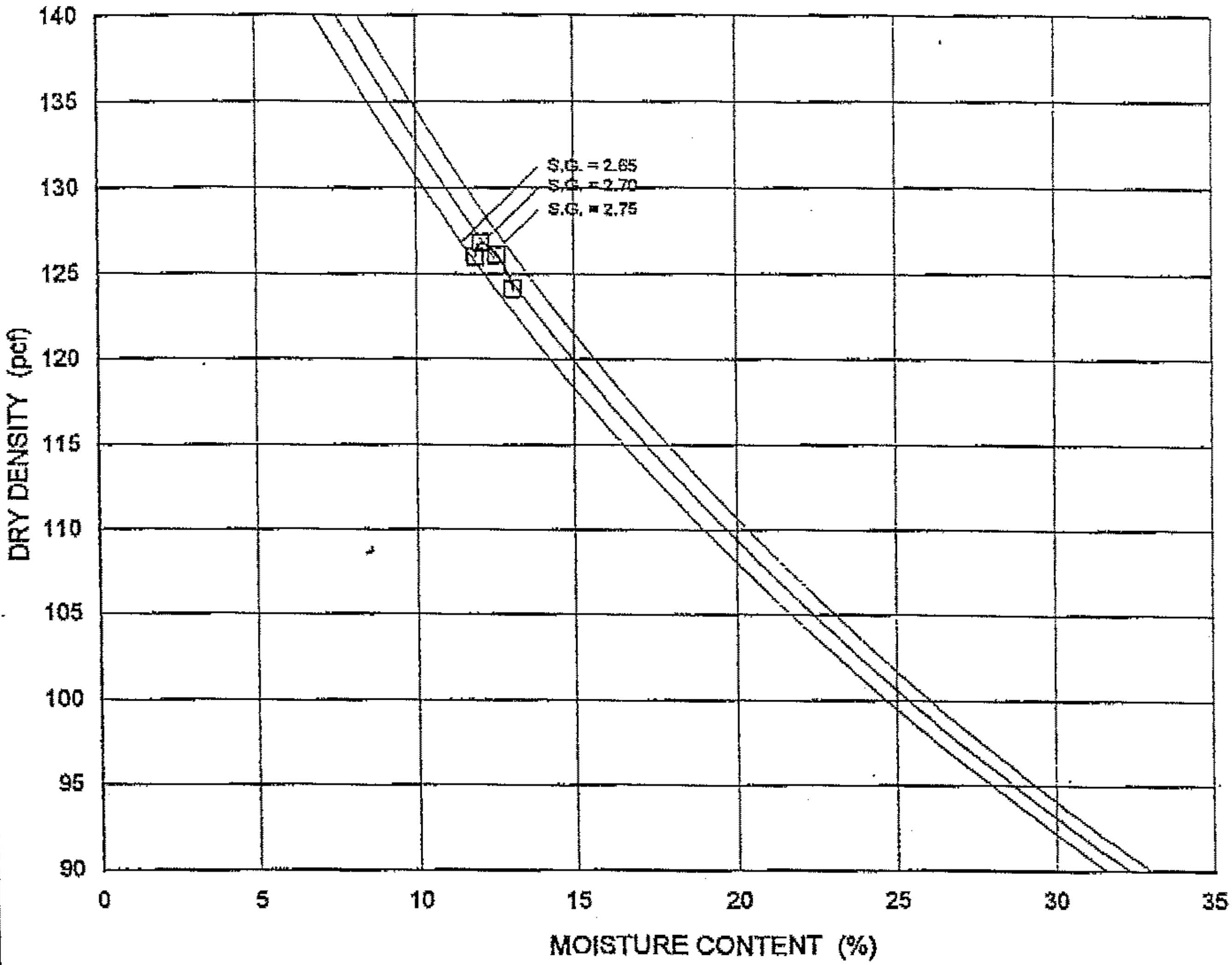
Date: 4/01

Prepared By: ML/AP

MTC ENGINEERING, INC.	Project Name	Project Number	Plate
419 South Pine Street, Suite C San Gabriel, CA 91776 Tel: (626)287-8416; Fax: (626)287-0560	County Sanitation District of Los Angeles County	31-29-1T	CM-5

MODIFIED PROCTOR

(ASTM D1557)



Location:	B4/1A
Depth (ft):	4-7
Soil Type:	ML
Optimum Moisture Content (%):	12.1
Maximum Dry Density (pcf):	126.8

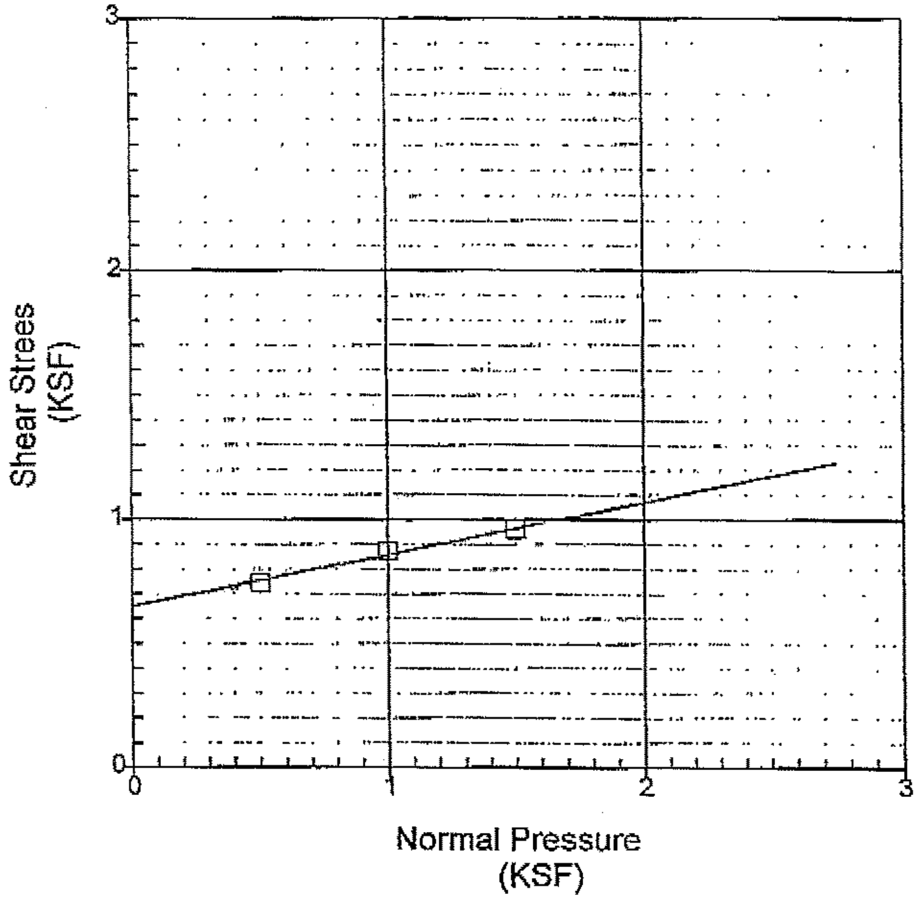
Date: 4/01

Prepared By: ML/AP

MTC ENGINEERING, INC.	Project Name	Project Number	Plate
419 South Pine Street, Suite C San Gabriel, CA 91776 Tel: (626)287-8416; Fax: (626)287-0560	County Sanitation District of Los Angeles County	31-29-1T	CM-4

DIRECT SHEAR

(ASTM D3080)



☐	Peak Value	Cohesion (psf) = 650	Friction Angle (degree) = 12.5
■	Residual Value	Cohesion (psf)	Friction Angle (degree)

Location:	B-5
Depth (ft):	4-7'
Soil Type:	SM
Initial Moisture Content (%):	8.8
Dry Density (pcf):	117.36

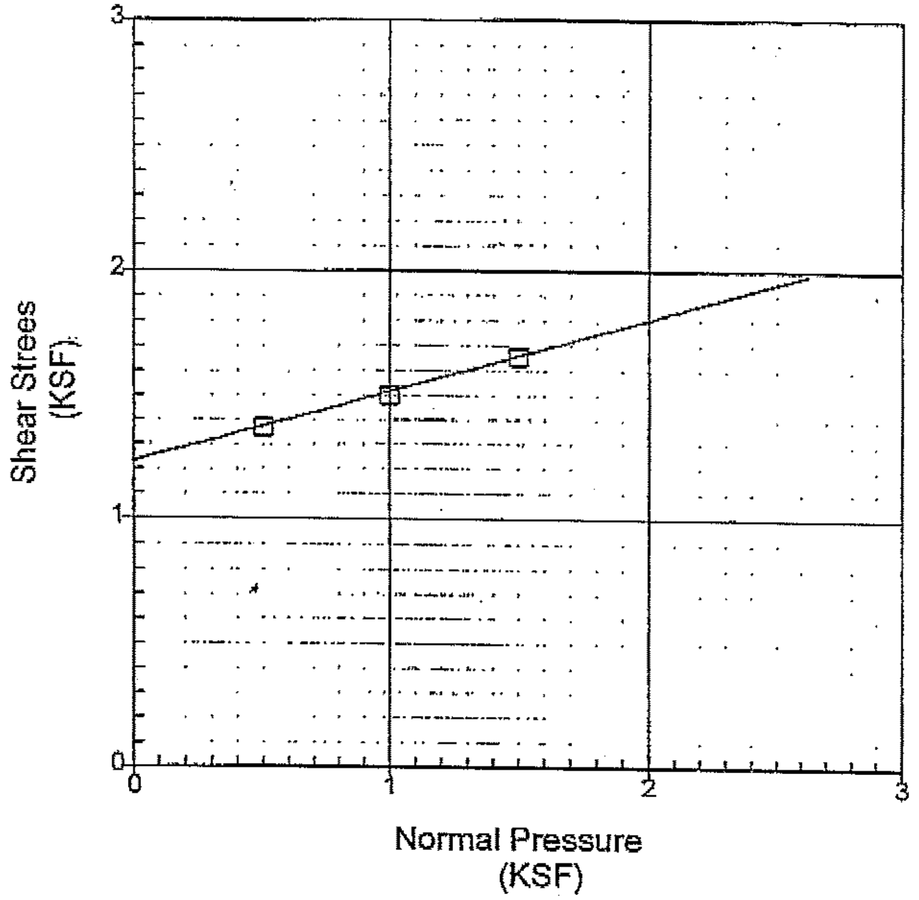
Date: 3/01

Prepared by: AT

MTC ENGINEERING, INC.	Project Name	Project Number	Plate
419 South Pine Street, Suite C San Gabriel, CA 91776 Tel: (626)287-8416; Fax: (626)287-0560	County Sanitation District of Los Angeles County	31-29-1T	DS-5

DIRECT SHEAR

(ASTM D3080)



□	Peak Value	Cohesion (psf) = 1210	Friction Angle (degree) = 16.0
■	Residual Value	Cohesion (psf)	Friction Angle (degree)

Location:	B-4
Depth (ft):	4-7'
Soil Type:	ML
Initial Moisture Content (%):	12.1
Dry Density (pcf):	114.12

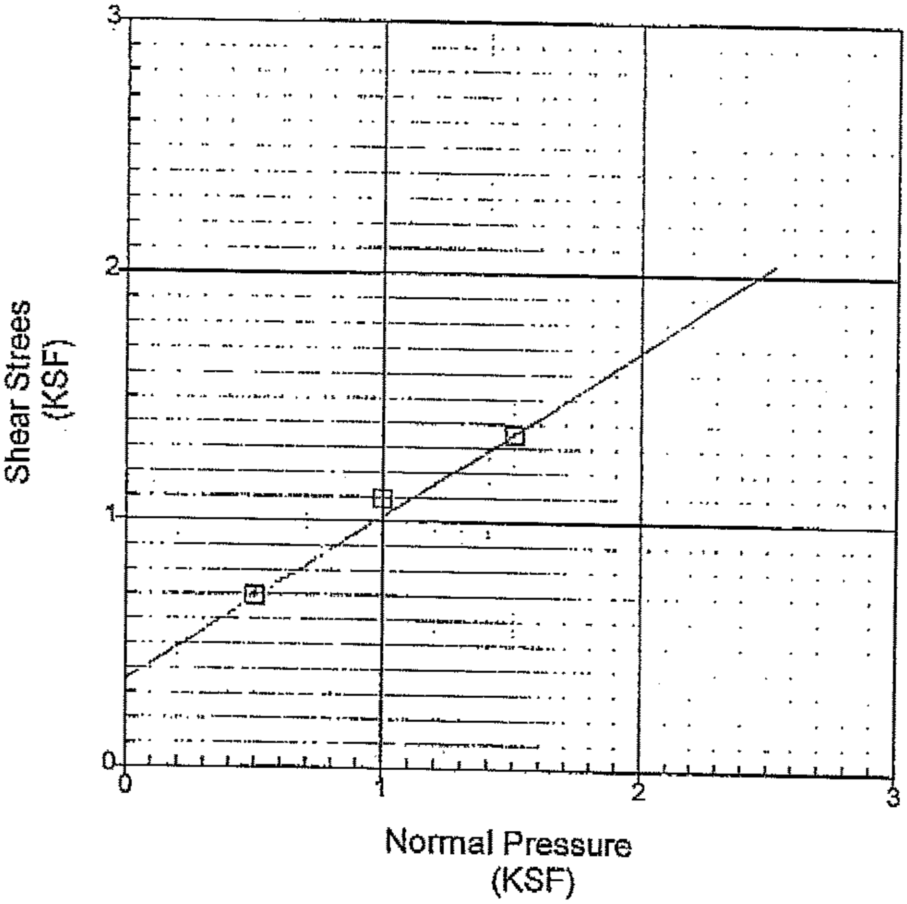
Date: 3/01

Prepared by: AT

MTC ENGINEERING, INC.	Project Name	Project Number	Plate
419 South Pine Street, Suite C San Gabriel, CA 91776 Tel: (626)287-8416; Fax: (626)287-0560	County Sanitation District of Los Angeles County	31-29-1T	DS-4

DIRECT SHEAR

(ASTM D3080)



☐ Peak Value	Cohesion (psf) = 360	Friction Angle (degree) = 34.0
■ Residual Value	Cohesion (psf)	Friction Angle (degree)

Location:	B-8
Depth (ft):	4-7'
Soil Type:	SM
Initial Moisture Content (%):	9.0
Dry Density (pcf):	119.25

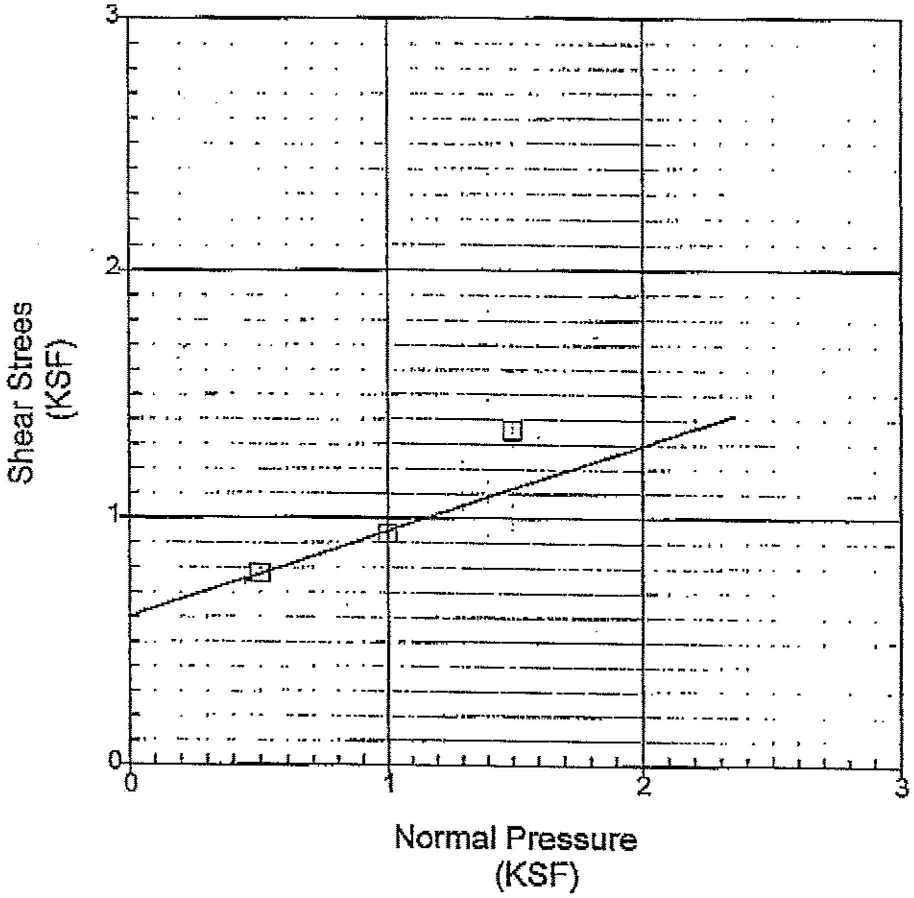
Date: 3/01

Prepared by: AT

MTC ENGINEERING, INC.	Project Name	Project Number	Plate
419 South Pine Street, Suite C San Gabriel, CA 91776 Tel: (626)287-8416; Fax: (626)287-0560	County Sanitation District of Los Angeles County	31-29-1T	DS-8

DIRECT SHEAR

(ASTM D3080)



☐ Peak Value	Cohesion (psf) = 600	Friction Angle (degree) = 19.0
■ Residual Value	Cohesion (psf)	Friction Angle (degree)

Location:	B-6
Depth (ft):	4-7'
Soil Type:	SM
Initial Moisture Content (%):	9.7
Dry Density (pcf):	116.55

Date: 3/01

Prepared by: AT

MTC ENGINEERING, INC.	Project Name	Project Number	Plate
419 South Pine Street, Suite C San Gabriel, CA 91776 Tel: (626)287-8416; Fax: (626)287-0560	County Sanitation District of Los Angeles County	31-29-1T	DS-6

(oscillations in a body of water due to earthquake induced ground shaking) resulting in flooding is considered low.

PHYSICAL, HYDRAULIC AND CHEMICAL TESTING RESULTS OF GEOLOGIC MATERIALS

Selected soil samples obtained during drilling were submitted to MTC Engineering, Inc. in San Gabriel for soil classification by grain size analysis (ASTM D422) and Atterberg Limits (ASTM D4318), moisture content (ASTM D2216), compaction (ASTM D1557), direct shear (ASTM D3080), consolidation (ASTM D2435), vertical hydraulic conductivity (ASTM D5084) and soil chemistry including pH, electrical conductivity, resistivity, and major ions: calcium, magnesium, sodium, sulfate, chloride, bicarbonate and carbonate. Laboratory reports of the geotechnical and geochemical testing performed on the soil samples are presented in Appendix B.

Soil Classification

During drilling and test pit excavation operations, soils were preliminarily classified through visual field classification methods. These methods however, are subjective and are not always consistent from observer to observer. To verify field classifications laboratory soil classification was conducted by MTC Engineering, Inc. on selected soil samples obtained during drilling using the USCS. Selected coarse-grained soil samples were classified in the laboratory by grain size analysis using ASTM D422. Selected fine-grained soils were classified in the laboratory using Atterberg Limits (ASTM D4318). The soils encountered in the borings and the test pits consisted predominantly of fine-grained silty sands and sandy silts with lesser amounts of sand, silt and clay or mixtures of these materials (e.g., sandy clay).

Test holes drilled by CH2M Hill in August 2001 in the immediate vicinity of the ponds encountered silty sand (SM) and clayey sand (SC) with lesser amounts of sand (SP), sandy silt (ML) and sandy clay (CL) to depths of approximately 30 feet. Deeper soils below a depth of approximately 30 feet to a maximum depth of about 102 feet in the immediate vicinity of the ponds are more variable and generally contain a much greater proportion of sands (SP/SW) with decreasing amounts of sandy and silty clay (CL), sandy silt (ML) and silty sand (SM) depending on location.

Hydraulic Conductivity

The hydraulic conductivities (permeabilities) of the soils in the areas of potential development were evaluated in three ways. Field tests of in-place soils were conducted using the U.S. Bureau of Reclamation shallow well permeameter method (USBR Method 7305-89). These tests provide a reasonable average (horizontal and vertical) of in-place permeability of soils in the approximate depth interval of the pond bottoms. The field permeameter tests are designed to take into account the effects of soil layering, including layers of greater or lesser permeability along the one- to five -foot depth of the boreholes excavated for this analysis. The tests are influenced by the soils below the 5-foot hole bottom since percolation travels downward also. The results of the shallow well permeameter tests are shown in Table 3.

TABLE 3. SHALLOW WELL PERMEAMETER TESTS

BORING NO.	LOCATION	PERMEABILITY (cm/sec)
1	Ave. E &.15th St. West	1.7E-04
2	Ave. D & 50th St. West	**
3	Ave. C & SR 14	2.0E-05
4	Ave. C & Sierra Hwy.	4.3E-06
5	10th St. West, 0.5 mi. S of Ave. A	2.9E-04
6	Ave. B & Sierra Hwy.	4.0E-06
7	Ave. B & 30th St. West	5.0E-05
8	10th St. West, 0.5 mi. S of Ave. C	2.7E-05
9	Ave. D & Sierra Hwy.	**

** Denotes: Shallow wells drew water more quickly than setup could maintain a constant head.

It should be noted that the results show relatively higher permeabilities in B1 and B5, and that B2 and B9 transmitted water so quickly that a constant head could not be maintained. This indicates that there are pervious sand layer(s) in a significant portion of the proposed pond areas.

Summary calculation sheets for each of the shallow well permeameter tests performed, with the exception of B2 and B9, due to reasons described above, are included in Appendix A.

Laboratory tests on undisturbed soil samples were run to estimate vertical permeabilities of in-situ soils. It is generally expected that these tests would provide lower range permeabilities since layering of the soil formations are roughly horizontal and horizontal permeabilities would be greater than vertical permeabilities. However, the presence of thin sand layers in a sample may cause a higher permeability than expected. The results are quite variable showing a range of permeabilities from 1.2E-03 to 9.5E-07cm/sec.

Laboratory tests on samples remolded to approximately 90 to 95 relative compaction were also run to estimate permeabilities of re-compacted soils in dikes and/or pond bottoms. It is generally accepted that these tests would provide reasonable estimates of average permeabilities since the kneading action of the re-compaction tend to alleviate differences between horizontal and vertical laminations. The results of the test range from 1.5E-05 to 7.8E-08 cm/sec., with an average of all tests of 2.2E-06 cm/sec. The results of the tests are shown as the 1A series tests on the MTC Engineering, Inc. reports, "Summary of Hydraulic Conductivity Test Results" in Appendix B. Table 4 provides a summary of the shallow well permeameter test results and the laboratory hydraulic conductivity test results for the undisturbed and remolded soil samples.

TABLE 4
SUMMARY OF FIELD PERMEABILITY AND LABORATORY HYDRAULIC CONDUCTIVITY TEST RESULTS
PROPOSED LWRP RECYCLED WATER STORAGE/EVAPORATION PONDS SITING STUDY

Boring No.	Depth (ft)	Lab Hydraulic Conductivity (cm/sec)(a)	Field Permeability (cm/sec)(b)
1	4-7(c)	9.70E-07	
	1-5		1.74E-04
	8	1.80E-05	
2	3-7(c)	3.00E-07	
	1-5		(d)
	16.5	2.00E-05	
3	3-7(c)	2.20E-07	
	1-5		2.03E-05
	8	2.70E-05	
4	4-7(c)	7.80E-08	
	1-5		4.30E-06
	16	1.50E-03	
5	4-7(c)	6.50E-07	
	1-5		2.88E-04
	11	4.10E-04	
	21	7.70E-06	
	31	9.50E-07	
6	4-7(c)	2.60E-07	
	1-5		4.02E-06
	8	1.20E-04	
	20.8	3.90E-04	
7	4-7(c)	2.30E-07	
	1-5	3.00E-05	4.95E-05
	16	2.70E-05	
8	4-7(c)	1.50E-05	
	1-5		2.67E-05
	8	5.70E-06	
	16	4.50E-06	
9	4-7(c)	2.30E-06	
	4	4.60E-06	
	1-5		(d)
	8	8.80E-04	
	15.5	1.20E-03	

Notes:

(a) Hydraulic conductivity testing performed by MTC Engineering, Inc per ASTM D5084.

(b) Field permeameter testing performed by Aldrich Geotechnical, Inc. and NCI per USBR Method 7305-89.

(c) Remolded in the laboratory. All other laboratory hydraulic conductivity tests performed on Undisturbed samples.

(d) Unable to maintain fluid level and estimate field permeability due to the excessive decline in the water level surface during testing in borings B2 and B9.

Soil Chemistry

Shallow soil samples obtained in the borings at a depth range of 3 to 7 feet were tested for corrosivity to below grade metallic elements and sulfate attack on Portland cement in concrete. The tests performed included resistivity (As received and Minimum), pH (Caltrans method 643), electrical conductivity (Caltrans method 424), cations and anions, including soluble chloride (Caltrans method 422) and soluble sulfate (Caltrans method 417). At the present time, it is not known what facilities are planned that require this information. Notwithstanding, the laboratory results are herein transmitted to the Districts in the event these data prove useful in the design of the proposed facilities. The soil corrosivity results are presented on the M.J. Schiff and Associates Table 1, "Laboratory Tests on Soil Samples", in Appendix B. Presented following are discussions of the chemical analyses performed and interpretations.

Soil pH

Soil pH in the shallow soils tested ranged between 7.7 and 9.7, indicating slightly to strongly alkaline conditions. Alkaline soils are common in desert environments and, more specifically, near or on desert playas such as nearby Rosamond Dry Lake where evaporation is greatest and evaporite mineralization is prevalent.

Soil Electrical Conductivity and Resistivity

Soil electrical conductivity is a measure of the capability of a given soil to transmit electric current. A soil with a high conductivity value will be able to transmit more electric current than a soil with a low conductivity. Another way to describe the capability of a given soil to transmit electric current is through the soil's resistivity. Soil resistivity is a measure of the resistance of a given soil to the transmission of electric current. Soil resistivity is inversely proportional to soil electrical conductivity. Resistivity and conductivity are used to assess the corrosive potential of soil on metals. A soil with a low resistivity (high electrical conductivity) can cause an electrolytic reaction to occur between the soil and metals in contact with the soil.

Soil resistivity values ranged between 780 ohm-centimeter (ohm-cm) at B4 to 23,500 ohm-cm at B8 and averaged 5,842 ohms-cm. Table 5 shows the relationship between soil resistivity and the degree of corrosivity to normal grade steel.

Table 5

General Guidelines for Degree of Corrosivity to Normal Grade Steel Relative to Soil Resistivity

Soil Resistivity (ohm-cm)	Degree of Corrosivity
10,000 +	Low
10,000 - 2,000	Moderate
2,000 - 1,000	Severe
1,000 - 1	Very Severe

As indicated in Table 5, the degree of corrosivity at the site varies considerably from very severe at B4 to low at B8. The majority of the soils sampled (B2, B3, B5, B6, and B7) exhibit a moderate degree of corrosivity to normal grade steel. Shallow soils at B1 and B9 exhibit a severe degree of corrosivity. The higher the degree of corrosivity the greater the potential to corrode any exposed or unprotected ferrous materials such as exposed reinforcement in foundations and concrete slabs.

Soluble Sulfate

Soluble sulfate testing was performed to determine if soluble sulfates were present in shallow soils at concentrations which may be considered corrosive to certain types of concrete. The results of the chemical testing indicate soluble sulfate ranged between 88 and 1,239 milligrams per liter (mg/L) at B7 and B4, respectively, and averaged 376 mg/L. Table 6 shows the relationship between soluble sulfate concentrations and relative levels of sulfate attack on normal concrete. A potential mitigation measure for the moderate level of corrosion due to soluble sulfate attack in the shallow soils at B4 is to use sulfate-resistant cement in foundation concrete.

Table 6

General Guidelines for Soil Corrosivity of Normal Concrete to Soluble Sulfate

Level of Soluble Sulfate in Soil (mg/L)	Degree of Corrosivity
0 - 1,000	Low
1,000 - 2,000	Moderate
2,000 - 5,000	Severe
5,000 +	Very Severe

As indicated in Table 6 and the data presented in Appendix B, the degree of corrosivity due to soluble sulfate at the site is typically low although the sample at B4 exhibits a moderate degree of corrosivity to normal concrete.

Soluble Chloride

Soluble chloride testing (Caltrans method 422) was performed to identify the potential for soil corrosivity of normal grade steel such as rebar in concrete footings or foundations. Soluble chloride concentrations ranged between 50 mg/L at B2 and 2,655 mg/L at B4, and averaged 560 mg/L. Table 7 shows the relationship between soluble chloride concentrations and the relative degree of corrosivity to normal grade steel.

Table 7

General Guidelines for Soil Corrosivity of Normal Grade Steel to Soluble Chloride

Level of Soluble Chloride in Soil (mg/L)	Degree of Corrosivity
0 - 200	Low
200 - 700	Moderate
700 - 1,500	Severe
1,500 +	Very Severe

As indicated in Table 7, and the data presented in Appendix B, the degree of corrosivity at the site relative to soluble chloride varies considerably from low at B2, B5, B7 and B8 to very severe at B4. The majority of the soils sampled exhibit a low to moderate degree of corrosivity to normal grade steel. Shallow soils at B1, B3, B6, and B9 exhibit a moderate degree of corrosivity.

The higher the degree of corrosivity the greater the potential to corrode any exposed or unprotected ferrous materials such as exposed reinforcement in foundations and concrete slabs.

POTENTIAL SOIL BORROW AREAS

The field investigation of the proposed project area was designed to bracket all areas of possible expansion. In general, the soil conditions of the investigated areas would be considered representative of borrow soils for use in the construction of all of the ponds being proposed. Bulk samples of the soils in each of the borings were obtained in the depth interval that was considered most likely to be excavated for use in construction of pond dikes or pond bottom liners, from three or four to seven feet below grade. These samples were tested for pertinent properties for use as compacted fill. The tests included compaction characteristics, shear strength, classification related tests, hydraulic conductivity, and corrosivity. The results of geotechnical testing are presented in Appendix B. Specific summaries of the results and discussions of their relationship to the proposed construction are presented in other sections of the report. These include the sections Hydraulic Conductivity, Foundation Design, Pond Construction, and Dike Slope Stability. As discussed later, the probable borrow soils have favorable compaction characteristics, adequate strength for dike stability and foundation support, and show reasonably low permeabilities in a homogenized and compacted state. The soils may be termed moderately aggressive from a corrosion potential standpoint.

CONCLUSIONS AND RECOMMENDATIONS

General

The proposed construction of recycled water storage/evaporation ponds in the areas studied is considered feasible from a geotechnical standpoint. The soil and groundwater conditions in the area are suitable for the construction of the proposed ponds. The ponds may be constructed by excavating the basin areas, homogenizing the excavated soils, and placing the soils as compacted fill. The area soils are adequate for borrow material and show sufficient strength and impermeability as compacted fill. Hence, the proposed dike slopes will be sufficiently stable. It should be noted that although the site soils when remolded exhibit low permeabilities, they include many sand lenses with higher permeabilities. Therefore, in order to reduce seepage from the ponds, the soils in the pond bottoms will require sealing by processing the soil bottoms and replacing the soil as compacted fill or using a synthetic liner. The structures related to the proposed ponds may be supported by foundations which will be subject to tolerable settlements. Foundations should be placed in firm native soils or recompacted fill. For specific pond design or foundation support of structures, additional investigation will be required.

Foundation Design

At the present time, it is unknown what facilities/installations will require foundations and of what type. It is assumed that structures such as buildings, pumping facilities and retaining structures will be designed with spread footings bearing on either native or re-compacted soils. For structures with moderate to high overturning moments, drilled shaft foundations should be considered. Footings should be founded in firm native soils or engineered recompacted fill. For preliminary design purposes, a net bearing value of 2,000 pounds per square foot may be used for spread footing design. This bearing pressure should result in tolerable settlements in the medium dense or stiff soils. In areas with looser or softer near-surface soils, over-excavation and replacement with compacted fill may be necessary to limit settlements. However, it is recommended that after additional information is known for the planned installations, additional site specific investigation should be performed.

CLOSURE

This report presents recommendations pertaining to the subject site based on the assumption that the subsurface conditions do not deviate appreciably from those disclosed in our exploratory borings and test pits. In view of the general geology of the area, the possibility of different conditions must be considered. It is the responsibility of the Owner or Contractor to bring any unexpected conditions observed during construction to the attention of the Engineering Geologist or Geotechnical Engineer. In this way, any required supplemental recommendations could be made at a minimum of delay to the schedule.

The findings and recommendations of this report were prepared in accordance with generally accepted professional principles and practice in the fields of soil mechanics and foundation engineering. This warranty is in lieu of all other warranties, either expressed or implied.