Case Study Abstract

Kansas Underground Storage Tank (UST) Site
Salina, KS

Site Name and Location: Kansas UST Site Salina, KS	**Geophysical Technologies:** Electrical conductivity	**CERCLIS #** Not applicable
Period of Site Operation: Unknown **Operable Unit:** Not applicable		**Current Site Activities:** Long-term Monitoring
Point of Contact: Wesley McCall, 913-825-1842	**Geological Setting:** Low conductivity clays overlying sandy water-bearing units	**Technology Demonstrator:** Geoprobe Systems Salina, KS
Purpose of Investigation: Characterize the subsurface stratigraphy and identify structures that could influence groundwater flow patterns		
Number of Images/Profiles Generated During Investigation: 10 conductivity logs to depths ranging from 50 to 60 feet below ground surface		
Results: The survey identified a continuous confining clay layer overlying and upper and lower aquifer. A contour of the contact surface between the upper aquifer and the confining clay layer was generated and a topographic high was identified that might create a migration pathway for LNAPLs to the northwest, a direction that is opposite from the generalized groundwater flow to the east.		

Kansas Underground Storage Tank (UST) Site

EXECUTIVE SUMMARY

The Kansas Underground Storage Tank (KS UST) site is located within the city limits of Salinas, KS adjacent to an exit off Interstate 70. The site is situated in a light commercial area, with service stations, motels and restaurants on the adjacent lots. The study area was 160,000 square feet in size and is situated behind a former service station where the KS Department of Environment and Health suspected than an unidentified source of groundwater contamination existed.

Groundwater contamination was discovered at the site during a Phase II investigation, conducted in support of a real estate transaction on a nearby property. Groundwater monitoring in the area established a plume of petroleum hydrocarbons moving toward the east. However, contamination was detected in several wells to the north of the suspected source area, as well. The geophysical investigation was conducted in 1995 as a cost-effective method for characterizing the subsurface stratigraphy.

The site geology consists of a surficial layer of low hydraulic conductivity clays and sands to a depth of approximately 46 feet below ground surface (bgs). Below the clay and sand layer, subsurface materials grade into alluvial sands and gravels. Below the alluvial sands lies another clay layer that separates the upper sand layer from another, deeper, sand layer. The Wellington formation forms the bedrock at the site and consists of gray and green shales. Groundwater is encountered at approximately 20 to 40 feet bgs.

The geophysical investigation was carried out using the Geoprobe® Direct Image® Soil Conductivity System. This direct push technology does not require a pre-existing borehole to perform the logging process as the conductivity probe is driven directly into virgin unconsolidated formations. Additionally, no drill cuttings are generated during the logging process, which significantly reduces waste generation and potential exposure hazards. Electrical conductivity logs were calibrated by comparing them with lithologic logs from continuous core samples taken in two locations. Conductivity logs were taken from 10 borings across the study area to depths of 40 to 60 feet below ground surface. The logs indicated the consistent presence of the surficial clay layer to a depth of approximately eight to 10 feet bgs. Furthermore, a comparison of the logs indicated that the surficial clay layer had a saddle-like structure with a ridge trending northward. The investigation concluded that the surficial clay layer acted as a confining layer, and that petroleum contamination floating on the water table was being forced northward beneath this ridge by artesian pressure.

The Soil Conductivity System was found to be a cost-effective approach for characterizing the subsurface stratigraphy. Conductivity logging can provide consistent information on stratigraphy and when accurate surface elevations are obtained from each boring, a contour map can be developed for any of the lithologic units that are identified in the survey. This information can be used to identify subsurface structures that might provide migration pathways for non-aqueous phase liquids, either light or dense.

SITE INFORMATION

Identifying Information

Kansas Underground Storage Tank (UST) Site
Salina, Kansas
Investigation Date: August 1995

Background [1, 2]

Physical Description: The Kansas Underground Storage Tank (KS UST) site is located in a commercial area within the city limits of Salinas, Kansas. Located on a small parcel of land adjacent to the I-70 exit ramp, the site is surrounded by service stations, motels, and a fast food restaurant (see Figure 1). The 160,000 square foot study area for the geophysical investigation was located to the north of Diamond Drive where the Kansas Department of Health and Environment (KDHE) suspected that an unidentified source of groundwater contamination was located. The study area lies in flat terrain with little topographical relief. The Saline River lies to the north at a distance of one mile.

Site Use: The site is the location of a former Amoco service station where past spills of petroleum products had contaminated the soils and the groundwater. There are other potential sources, however, located to the north of the site, such as a former truck stop and several ditches that may have been used to dispose of petroleum products. A motel is presently located on the site.

Release/Investigation History: Groundwater contamination was discovered during a Phase II investigation conducted to support the real estate transaction that led to the construction of a motel on the site of the former service station. The geophysical investigation was conducted in 1995.

Regulatory Context: The KS UST site is managed under the Kansas Underground Storage Tank Fund, and all compliance requirements are set by that program.

SITE INFORMATION

Site Logistics/Contacts

State Lead Agency: Kansas Department of Health and Environment (KDHE)

Federal Oversight Agency: None

KDEH Project Manager:
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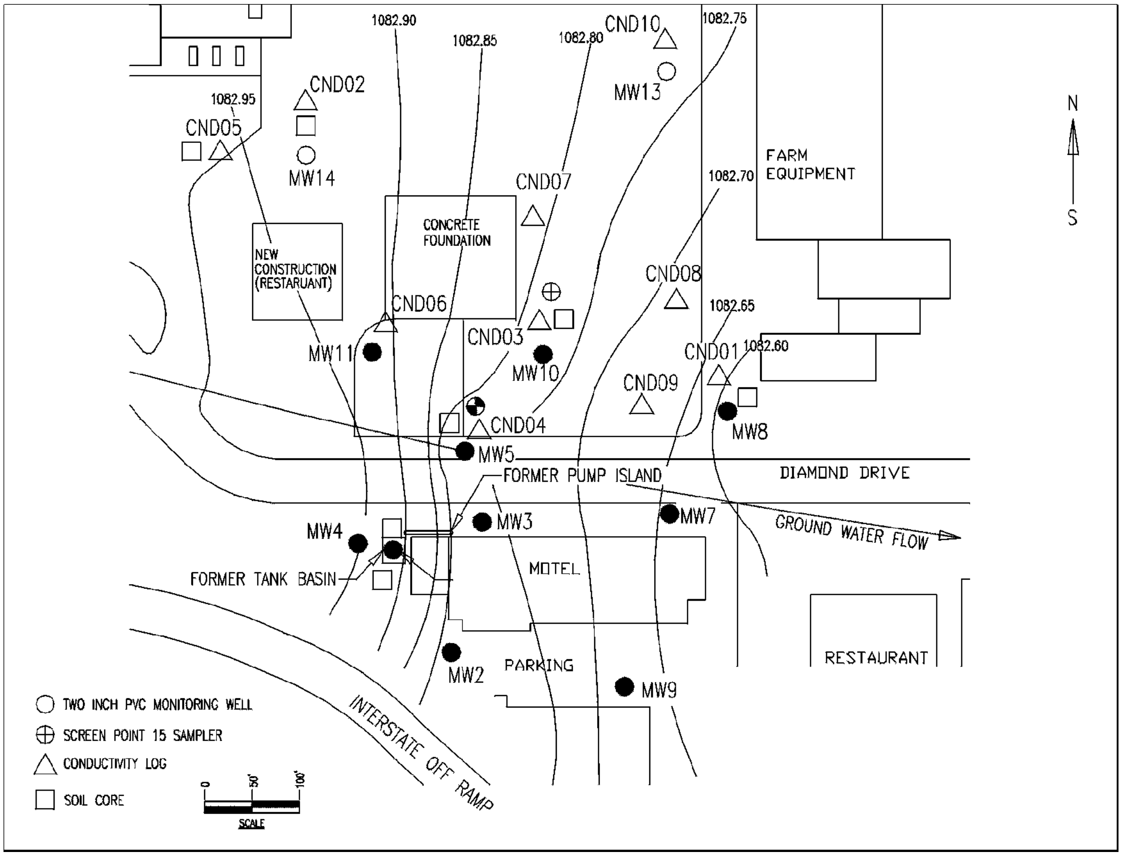

Figure 1: KS UST Study Area with Potentiometric Surface [1]

MEDIA AND CONTAMINANTS

Matrix Identification [1]

Type of Matrix Sampled and Analyzed: Subsurface clays, sands, and gravels

Site Geology/Stratigraphy [1, 2]

Surface and near-surface soils in the study area consist primarily of low hydraulic conductivity clays and sands to a depth of 46 feet below ground surface (bgs). Below this level the clays grade into alluvial sands and gravels overlying another clay layer. This clay layer is continuous throughout the study area and separates the upper sand layer from another sand layer. Bedrock is present beneath the lowest sand layer as the Wellington Formation, consisting of grey and green shales.

The formation from a depth of about 20 to 40 feet bgs grades from clayey-silts to fine sandy silts to medium-grained sands with depth. There is evidence that this upper aquifer exists under confined conditions. When wells are screened at depths of 22 to 24 feet bgs, they do not yield water, yet when screened at, or below, 28 feet bgs the static groundwater level rises to 18 feet bgs. Generalized groundwater flow is to the east and toward the Saline River at an average rate of less than one-half foot per day. A second aquifer exists in the deepest sandy layer overlying the Wellington Formation and is separated from the upper aquifer by a clay-silt layer over five feet thick.

Contaminant Characterization [2]

Primary Contaminant Groups: The principal contaminants of concern include benzene, toluene, ethylbenzene, and xylenes (BTEX). Free product contamination found in some wells indicated that the contaminants were present as light, non-aqueous phase liquids (LNAPLs).

Matrix Characteristics Affecting Characterization Cost or Performance [1,3]

The ground surface in the study area included grass- and gravel-covered areas which posed no problems for the probe. In two areas, however, the surface was concrete and holes were bored through the concrete before beginning the push in these areas.

Consistency in site lithology facilitated the conductivity survey. The site has several geologically distinct layers whose conductivity values are markedly different. Furthermore, the layers are relatively continuous throughout the study area.

Excessive soil moisture that might have interfered with conductivity readings was not a problem at any location in the study area.

GEOPHYSICAL INVESTIGATION PROCESS

Investigation Goals [3, 4]

The goal of the investigation was to identify any subsurface structures that might influence groundwater flow directions. The initial investigation found BTEX contamination on the southern side of Diamond Drive, and generalized groundwater flow to the east. When contamination was found in monitoring wells to the northwest of the suspected source area, the question was raised: were there other undiscovered source areas to the northwest, or were there groundwater flow dynamics that could result in the northerly migration of contaminants?

Geophysical Methods [1, 3, 5]

The geophysical survey was carried out using the Geoprobe® Direct Image® Soil Conductivity System, operated in a Wenner array configuration. In this configuration, an electrical current is passed through the soil and the soil conductivity is measured by four electrical contacts. The conductivity value is a function of grain size, with finer grains producing higher values and coarser grains resulting in lower values. The units of measurement for conductivity are milliSeimens per meter (mS/m). The Seimen is the inverse of the Ohm, the standard measure for electrical resistivity.

The Direct Image® system consists of a steel probe running through four stainless steel rings, as is shown in Figure 2. The SC200 probe is eight inches long and varies in diameter from one inch at the tip to 1.125 inches at the base. An electrical grade plastic insulates the rings from the steel shaft. A shielded data transmission cable is attached to the probe by a waterproof seal.

The probe is advanced using a percussion probing machine which weighs 1,680 pounds and is mounted on the back of a truck. The percussion machine delivers as much as 18,000 pounds of downward force to the drive end of the probe. The depth and rate of advancement are measured using a string pot system. When the probe is retracted, the percussion machine can exert as much as 25,000 pounds of retraction force.

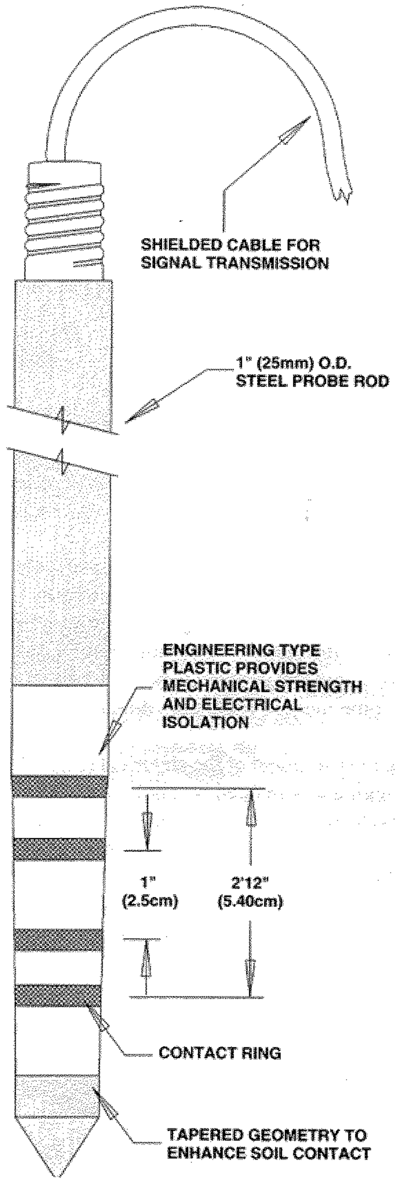

Figure 2: SC200 Electrical Conductivity Probe

GEOPHYSICAL INVESTIGATION PROCESS

The Direct Image® software, running on a PC laptop connected to the instrumentation box, provides a “real-time” display of the conductivity signal, probe depth, and rate of advancement. Individual logs can be printed in the field. Data from the logs can be easily output to a spreadsheet software, or a modeling software, such as SURFER. The Direct Image® software also includes a calibration routine for the probe that should be run before each push to ensure that the probe is operating correctly.

Technology Justification

The presence of the surficial clay layer overlying the surficial aquifer indicated the need for a geophysical technology that would not be impeded by this layer. It was necessary to penetrate this near surface clay layer and delineate the stratigraphy below the clay. The effectiveness of ground penetrating radar would have been limited by this layer and it was too close to the surface for a seismic method to be effective. Therefore, Geoprobe’s® Direct Image® Soil Conductivity System was a more effective and less expensive option to identify any subsurface structures that might influence groundwater flow directions.

GEOPHYSICAL FINDINGS

Technology Calibration [1]

A lithology log was developed from a continuous core sample taken to a depth of 40 feet below ground surface (bgs) at the northwest corner of the study area. Discrete interval samples were collected in a boring located at the northeast corner of the study area at depths of 46 to 48 feet bgs and 54 to 56 feet bgs. The deeper samples provided information on the distinct lithologic units found at those depths. Conductivity logs were taken in the same two locations. The conductivity values were correlated with the visual identification of discrete lithologic units in the core samples. The results of the correlation are shown in Table 1.

There is a unique range of conductivity values for each of the lithologic units with the exception of the units encountered between two and 32 feet bgs. In this interval, there is a silty clay layer that is somewhat coarser than the clay layers above and below it. The electrical conductivity of the silty-sandy clay layer, 70 to 140 mS/m, overlaps that of the over- and underlying clay layers which ranges from 125 to 240 mS/m. Thus, conductivity measures falling between 125 and 140 mS/m are indicative of transition intervals between the low permeability clay layers and the more permeable silty-sandy clay layer.

Below the second clay layer is a sandy layer, known as the upper aquifer whose upper surface was encountered at depths ranging from 36 to 46 feet bgs. The upper aquifer ranges in thickness from 5 to 15 feet. Conductivity values within the upper aquifer ranged from 20 to 40 mS/m. At the base of the upper aquifer is a clay layer that acts as an aquitard between the upper and lower aquifers. The aquitard was found at depths ranging from 46 to 52 feet bgs, and was found to be approximately 5 to 8 feet thick. Conductivity values in the aquitard range from 80 to 100 mS/m, making these materials similar in composition to those encountered between 13 and 32 feet bgs.

Table 1: Correlation of Conductivity Values With Discrete Lithologic Units

Conductivity Range (mS/m)	Depth Range (feet bgs)	Location of Samples	Generalized Lithologic Description
0 to 75	0 to 2	CND02	Organic rich topsoil and gravel fill
125 to >240	2 to 13	CND02	Clays, brown with some caliche development
70 to 140	13 to 32	CND02	Silty to fine sandy brown clays
125 to > 240		CND02	Clays, brown with some caliche development
20 to 40	36 to 46	CND02	Medium to coarse grained granitic sands with sparse fine gravels, water-saturated
80 to 100	46 to 52	CND10	Gray clay-silt
20 to 40	52 to 60	CND10	Medium to coarse grained granitic sands with sparse fine gravels, water-saturated

Source: [1]

Investigation Results

Conductivity logs were collected from 10 borings across the study area to depths ranging from 40 to 60 feet bgs. The locations of the borings can be seen shown in Figure 1, and the logs themselves are shown in Figures 3a and 3b. The uppermost clay layer is visible in each of the 10 logs as a rise in conductivity to values at or greater then 200 mS/m. The densest portion of this clay layer, and consequently the highest electrical conductivity value, was found consistently at a depth of approximately eight to 10 feet bgs. The consistency with which this unit is found in the logs suggests that it is continuous throughout the study area and has a low surface gradient.

The decline in conductivity values that can be seen in each of the 10 logs between 13 and 32 feet bgs can be interpreted as the gradual grading of subsurface materials from the upper clay layer into a coarser silty clay layer. At the base of this silty clay layer, the subsurface materials seem to grade once again into a tighter clay formation. This graduation can be seen in most of the logs as conductivity values rise again due to the finer grain size within the clay layer. In the logs CND01 and CND06, the clay layer is either missing, or its composition is less dense than in other portions of the study area. In the logs for CND08 and CND09, the clay layer appears to be present at shallower depths of approximately 20 to 25 feet bgs. The consistency with which this clay layer seems to be present suggests that it may act as a confining layer to the upper aquifer. This conclusion seems to be supported by the fact that when wells are screened at a depth of 22 to 24 feet bgs, they yield no water, but when screened at or below 28 feet, the static groundwater level in the casing rises to 18 feet bgs.

The sandy gravel layer that constitutes the more transmissive zone of the upper aquifer can be seen clearly in each of the 10 logs at depths ranging from 36 to 46 feet bgs. As the probe passed through these materials, there was a marked decrease in conductivity values. At the base of the upper aquifer, there is a dense layer of clay materials which can be seen in the logs as a sharp increase in conductivity values at depths ranging from 45 to 55 feet bgs. Most logs were terminated at this depth to prevent penetration of the aquitard in highly contaminated zones. The rise in conductivity values as the probe entered this layer is clearly visible, even in the shallower logs. The consistency with which this unit was encountered in the logs suggests that is laterally continuous and may act as an aquitard separating the upper and lower aquifers. The sandy gravel layer that constitutes the lower aquifer can be seen in the logs for CND01, CND02, and CND10.

These borings were the only three pushed to the full 60-foot depth because they were outside of contaminated areas and approximately bound three corners of the site. Because only three borings were advanced to this depth, the continuity of the lower aquifer cannot be determined.

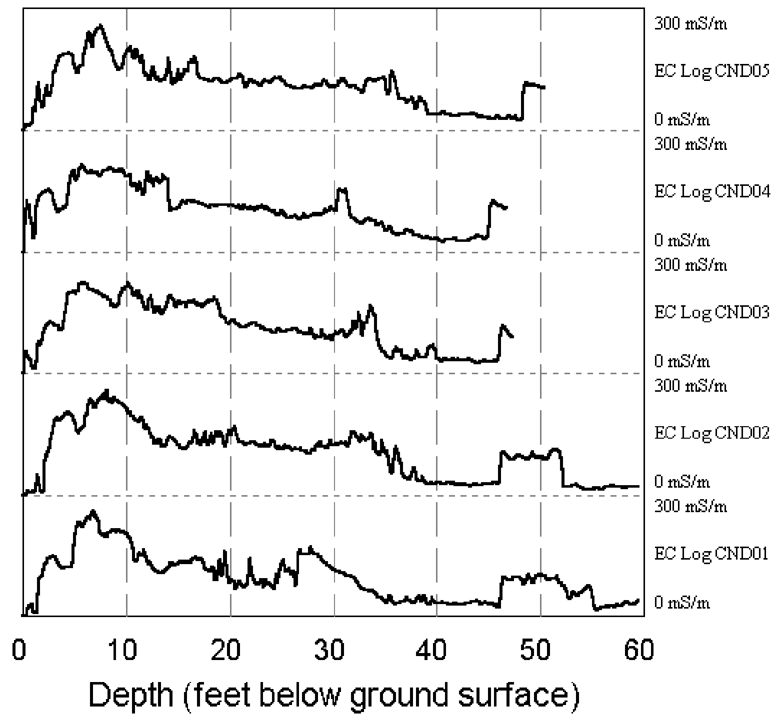

Figure 3a: Electrical Conductivity Log for CND1 - CND05 [1]

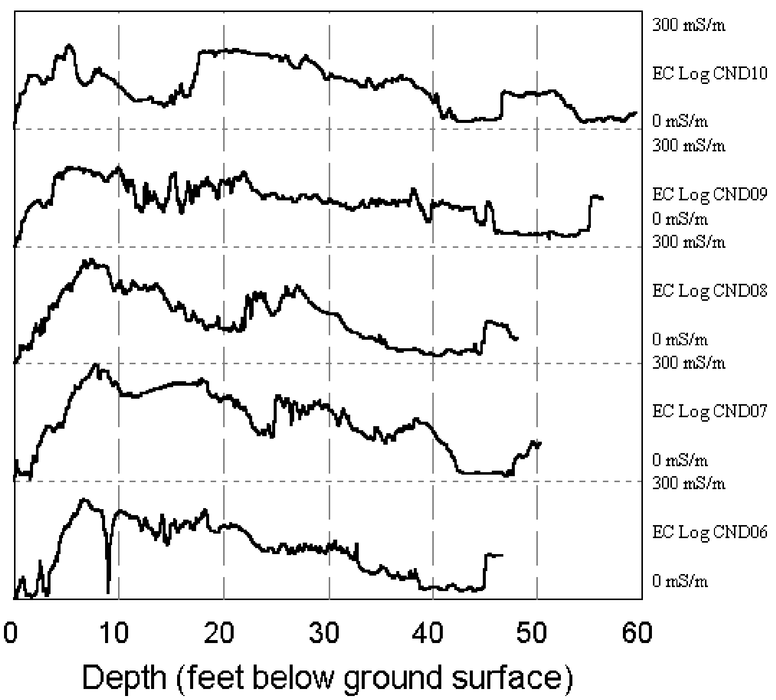

Figure 3b: Electrical Conductivity Logs for CND06 - CND10 [1]

A contour map was generated of the contact surface between the sandy layer of the upper aquifer and the overlying clay layer, and is shown in Figure 4. Surface elevations were taken at each boring location and the distance from the surface to the top of the sandy layer was calculated. Where the transition from the clay to the sand layer was more gradual and less defined, as in the logs for CND02 and CND05, the depth at which the conductivity value reached 75 mS/m was taken as the top of the sandy layer. The calculated depths to the top of the sandy layer were plotted on a site map and the elevations were contoured by hand. In Figure 4, the resulting contours show that the upper contact surface of the sandy layer has a complex saddle-like structure, with a topographic high running to the northwest through CND04 and CND06 and branching northeast toward CND03. Monitoring wells 5, 10, and 11 were highly contaminated and sporadically contained free product. Combining the information provided by this map and the finding that the overlying clay layer is continuous throughout the study area, the investigator concluded that LNAPLs within the groundwater flowing under confined conditions could migrate along the topographic high in a northwesterly direction. This would make the direction of the LNAPL migration contrary to the generalized groundwater flow to the east. The topographic low in this surface at CND09 east of the source also prevented contaminants from moving east with groundwater flow to well MW08, in which no contamination had been detected.

GEOPHYSICAL FINDINGS

Results Validation [4]

No further efforts were undertaken to validate the findings of the geophysical investigation.

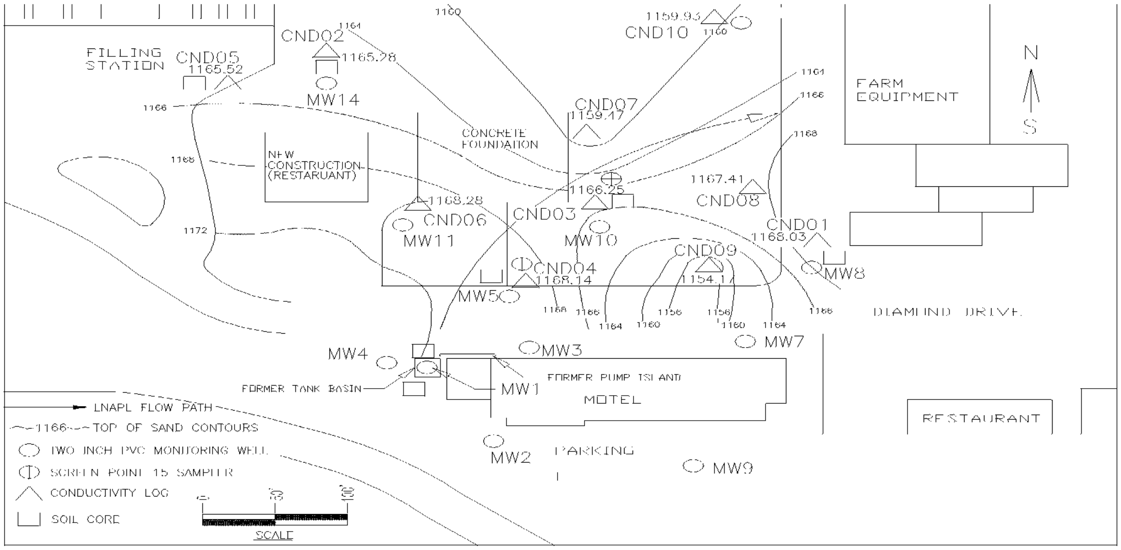

Figure 4: Contour Map of Upper Sand Layer [1]

LESSONS LEARNED

Some of the lessons learned during this investigation include:

- Electrical conductivity logging is a cost-effective approach for characterizing subsurface stratigraphy in unconsolidated materials. Alternative approaches to gathering the same information would use traditional well drilling methods, such as a hollow stem auger. The daily cost of an auger can be as high as $5,000.
- Conductivity logging can provide consistent information on stratigraphy. A review of the 10 logs produced at this site shows that the same lithologic units were identified at consistent depths across the study area. In part, the consistency was due to the similarity of the materials in the various units across the study area.
- When accurate surface elevations are obtained for each boring, a contour map can be developed for any of the lithologic units that were identified in the survey. This information can be used to identify subsurface structure that might provide migration pathways for non-aqueous phase liquids, either light or dense.

- Two soil boring logs typically are sufficient to produce an unambiguous correlation between the conductivity results and the observed lithologies. In very heterogeneous formations, additional location/depth targeted samples may be needed.

REFERENCES

1. McCall, Wesley. *Electrical Conductivity Logging to Determine Control of Hydrocarbon Flow Paths in Alluvial Sediments.* Geoprobe Systems. December 1995.

2. Geocore Services, Inc. *Quarterly Monitoring Report for KDHE UST Trust Fund Site*. March 11, 1998.

3. Personal Communications with Scott Lange, KDHE. August 18, 1998.

4. Personal Communications with Wesley McCall, Geoprobe Systems. September 15, 1998.

5. Fax Communication with Geoprobe Systems. September 15, 1998.

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