INVESTIGATION OF VOLATILE

ORGANIC COMPOUNDS IN GROUNDWATER

UVALDE, TEXAS

EDWARDS UNDERGROUND WATER DISTRICT

FIELD ACTIVITIES FROM

JANUARY 1984 THROUGH APRIL 1988

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INTRODUCTION

The Edwards Underground Water District (EUWD) has been involved in an investigation to determine the source of volatile organic compounds (VOCS) in the Edwards aquifer in the Uvalde, Texas area (fig. 1). Existing Edwards aquifer wells were used to trace VOC contamination up the hydraulic gradient in a west-northwest direction from the point of initial discovery to an area where highly contaminated wells exist. Wells further up the hydraulic gradient and in a distinct area around the contaminated area are free of VOC contamination. A monitor well drilling and sampling program was employed to better define the source area. Surface and subsurface geophysical techniques were used to reinforce monitor well data and further delineate a source area.

HISTORY OF INVOLVEMENT

Special Volatile Organics Study

From September 1983 through February 1984 the U.S. Geological Survey (USGS) collected water samples from selected wells to provide baseline data on volatile organic compounds (VOC) in the Uvalde area. The samples were collected under a cooperative contract with the EUWD. Most samples were collected from public supply wells, however, some samples were collected from private wells.

Results of Special Volatile Organics Study

In February 1984 five wells were sampled for VOCs in the Uvalde area (see Appendix B for details of all sampling events). The only VOC found was tetrachloroethylene (PCE) at a level of 6.4 micrograms per liter (ug/l) in a municipal well located at the Uvalde County airport (Garner Field). This VOC contaminated groundwater sample prompted further investigation.

To verify contamination in the vicinity of the municipal airport two sampling events were conducted in April and August, 1984. A total of eight wells were sampled including the airport well. Of the eight wells four showed PCE contamination.

Four wells drawing water from the Edwards aquifer were polluted with the same compound. This was sufficient evidence to rule out contamination by well construction materials or laboratory error. At this point it was reasonable to assume the volatile organic compound tetrachloroethylene (PCE) existed in the Edwards aquifer in the vicinity of the municipal airport.

Investigative Strategy

Upon confirmation of groundwater contamination, an initial strategy was developed to define the areal extent of the PCE groundwater contamination. Identification of the contaminant source(s) and removal of the source(s) to prevent further contamination of the Edwards aquifer system were the ultimate goals of developing this investigative strategy.

Defining The Areal Extent of Contamination

In February 1985 approximately forty-five wells within a 1.5 to 2.0 mile radius of the airport were inventoried for well construction parameters. Groundwater flow direction, stratigraphy and structural information were obtained from these newly inventoried wells.

City of Uvalde officials assisted EUWD in contacting businesses and other institutions in the vicinity of the airport to determine potential users of PCE. At the time, no known users of PCE were found.

In March 1985 a groundwater sampling event was conducted in the vicinity of the airport. Thirteen Edwards aquifer wells were sampled, only one additional well showed PCE contamination. This additional contaminated well contained the highest level of PCE of any well previously sampled. This information shifted the emphasis of the study to the northwest, from the airport area, to a light industrial area near the intersection of HWY 90 and Taylor Slough (fig. 2).

Light Industrial Area Near Hwy 90 and Taylor Slough

Historical Information

Historical information about the property west of Taylor Slough and south of Hwy 90 indicates the property was occupied by Gensco Inc. (a new and used pipe reclaimer/dealer) from about 1960 until about 1966. Uvalde Equip. Co. (a farm machinery dealership) also occupied the property from about 1960 to present. The Gensco portion of the property was sold to Uvalde Equip. Co, Lumbermart (a retail hardware/lumber outlet) and Texas Industial Services (an industrial laundry facility) in 1966.

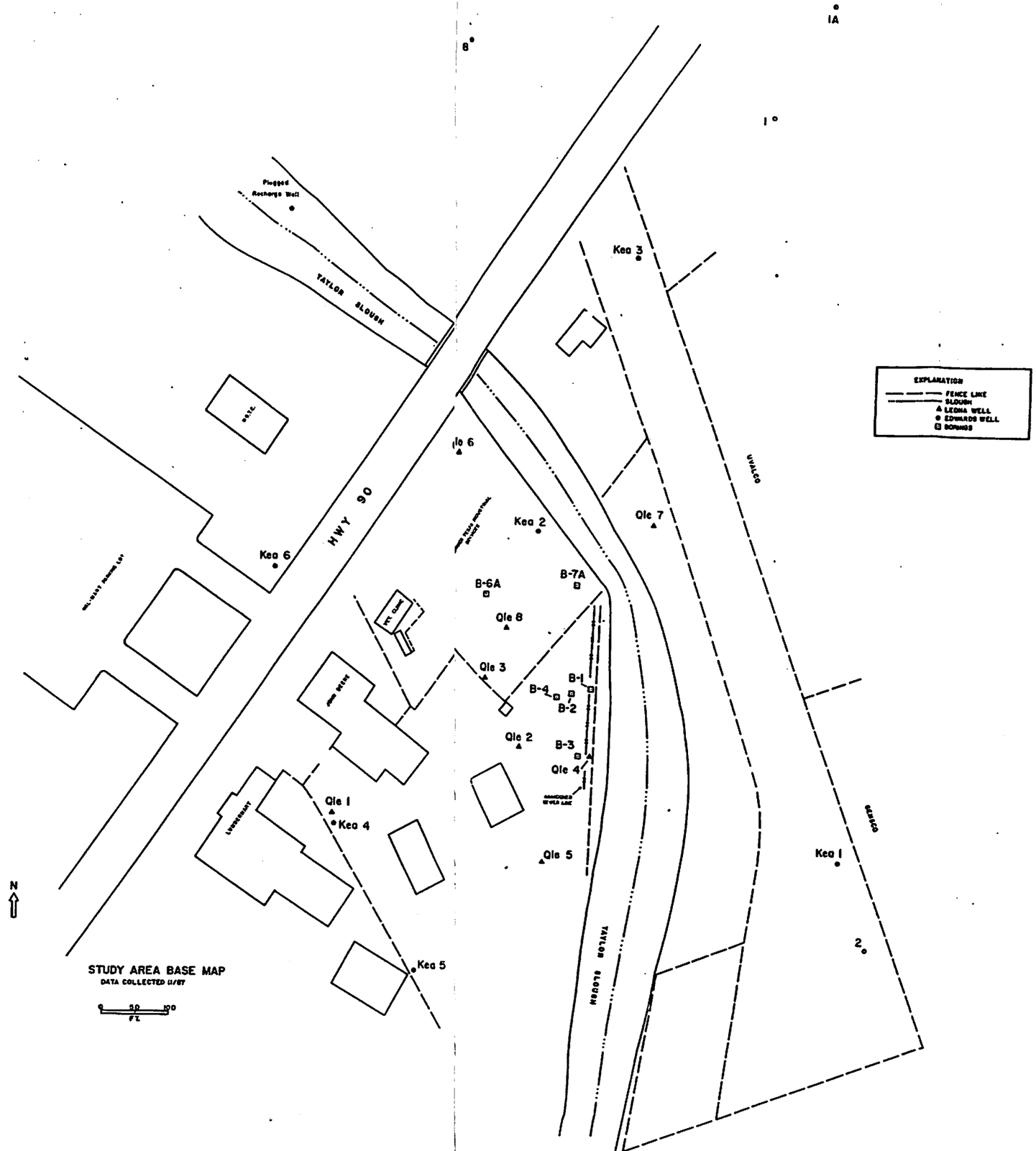

IA
8
1
Plugged Recharge Well
TAYLOR SLOUGH
Kea 3
EXPLANATION
FENCE LINE
SLOUGH
LEONA WELL
EDWARDS WELL
BORINGS
Ile 6
HWY 90
UVALDE
Kea 2
Qle 7
Kea 6
B-6A
B-7A
Qle 8
Qle 3
B-1
B-4
B-2
Qle 2
B-3
Qle 4
Qle 1
Kea 4
Qle 5
Kea 1
Kea 5
TAYLOR SLOUGH
N
STUDY AREA BASE MAP
DATA COLLECTED 11/87
0 50 100
FT

FIGURE 2

Lumbermart is operating at this location at the present time. The portion of the property which borders Hwy. 90 and Taylor Slough was occupied by Texas Industrial Service (TIS) from April 1966 until the plant was destroyed by fire in August 1979.

Properties immediately north of Hwy. 90 in the Taylor Slough area include Winter Garden International (a farm implement dealership) on the west side of the drainage. An assortment of small business operations, vacant lots and houses are located on the east side of the drainage.

The area on the east side of Taylor Slough and south of Hwy. 90 was occupied by Gensco Inc. from 1966 to 1987. This area is also occupied by a retail hardware and pipe supply company and a plumbing contractor.

Former T.I.S. Property (Hwy 90 and Taylor Slough)

After the Texas Industrial Services (TIS) laundry facility was destroyed by fire in August 1979 the property was obtained by the city of Uvalde in a trade with TIS for a new building site west of the municipal airport. The city of Uvalde subsequently sold the former TIS property to Uvalde Equipment Co. which currently uses the lot for machinery storage.

While removing the industrial laundry building slab,

Uvalde Equipment Co. encountered a concrete sump tank approximately 6 feet by 6 feet by 10 feet. The sump was covered with fill material, but not removed. While EUWD and City of Uvalde personnel were contacting local businesses about PCE use the location of the sump was reported by Uvalde Equipment Co. to the EUWD. The sump was located and its contents were sampled on June 20, 1985 by EUWD and City of Uvalde personnel; the sump was reburied after sampling. On July 16, additional samples were obtained from the sump, the sump and its contents were then removed and taken to the city landfill on the south side of Uvalde. Sludge samples taken from the sump showed concentrations of 1-2 dichloroethylene (DCE) up to 208 milligrams/kilogram (mg/kg).

Recharge Wells

Other historical information about the area near HWY 90 and Taylor Slough revealed two recharge wells located in Taylor Slough about 700 feet north of the former industrial laundry property. The wells were drilled into the Edwards aquifer by the County of Uvalde in the mid 1950's. The two wells served to recharge surface water into the Edwards aquifer. The EUWD sampled the recharge wells for VOCs, obtained geophysical logs, and closed the wells in April 1986. The sample results indicated no detectable VOCs.

Sampling of Existing Water Wells near HWY 90 and Taylor Slough

A sampling event on August 6 and 7, 1985 identified three additional PCE contaminated Edwards aquifer wells in the vicinity of the light industrial area. Additionally, three uncontaminated Edwards aquifer wells were located up the hydraulic gradient from the industrial area. The negative results (indicating no detectable VOC contamination) of these three up-gradient wells was the first indication the industrial area could be located over the up-gradient extent of the PCE contaminated groundwater.

In October 1985 a sampling event was planned to obtain additional information on the areal extent of the contamination around the perimeter of the industrial area. Six previously unsampled Edwards wells were sampled; of these six, four were found to be contaminated with PCE.

Data obtained from existing wells in the industrial area provided a more detailed Edwards aquifer water level map which indicated a southeasterly flow direction (see Appendix C, Water Level Maps).

By November 1985 eleven Edwards aquifer wells were identified as being contaminated with PCE. Five wells located up the hydraulic gradient from the industrial area showed no PCE contamination. Therefore, it appeared the industrial area should

be investigated in detail to determine if a source(s) of PCE groundwater contamination existed in the area.

Problems Using Existing Wells

Up to this point in the investigation only existing Edwards wells were used to define the areal extent of groundwater contamination in the Uvalde, Texas area. Obvious problems of limited information about the details of well construction exist. However, in this situation the initial use of existing wells instead of monitoring wells has proven reasonable for the following reasons:

1. With the exception of the immediate potential source area there are no overlying saturated geologic units that could contribute contaminated water.

2. Using driller's logs and well owner information on total depth of wells and casing depths, it was reasonable to assume that certain existing wells were completed into the Edwards Group.

3. Borehole geophysical logs on any open wells served to back-up assumptions made in number 2.

Texas Water Commission Action

The Texas Water Commission (TWC), the regulatory authority in the area, received all information collected by the EUWD on the Uvalde groundwater contamination problem. On December 10, 1985 the TWC District 8 field office sent letters inquiring of waste disposal practices to Gensco Inc. and Texas Industrial Services (TIS). TWC asked TIS to implement a soil testing program to determine if PCE contaminated soils were located on the former TIS property located at HWY 90 and Taylor Slough. TWC recommended that Gensco Inc. initiate a groundwater assessment program in conjunction with a soil testing program as related to oil contaminated soils. Both Gensco and TIS hired private consulting firms to address TWC concerns. Gensco and TIS received reports from their respective consultants stating that data did not implicate either TIS or Gensco as causing the PCE groundwater contamination in the area.

Results of the actions taken by TIS and Gensco were not known by the EUWD until October 8, 1986. The total elapsed time from notification of Gensco and TIS by TWC until the results were received by the EUWD covered a ten month period. Limited investigative efforts were conducted by the EUWD during this time. Two sampling events were conducted (May 1986 and September 1986) to monitor levels of PCE in previously identified contaminated wells.

CURRENT INVESTIGATION

Reports generated by consulting firms hired by Gensco Inc. and TIS addressing Texas Water Commision (TWC) waste disposal inquiry letters stated that insufficient information existed to implicate either Gensco or TIS. The EUWD developed an agreement with the TWC to continue its investigation based upon the fact that PCE contamination continued to exist in the groundwater.

Investigative Approach

The EUWD felt enough information existed to assume the light industrial area at Hwy. 90 and Taylor Slough contained at least one source of PCE groundwater contamination.

An objective approach was designed by EUWD to provide additional details on the horizontal and vertical extent of contaminated groundwater in the study area. Initial plans were made to drill three Edwards aquifer monitor wells in order to dissect the industrial area from north to south and begin a step by step process to define the source(s) of PCE contamination in the Edwards aquifer. Two wells were sited on the narrow strip of land located between Taylor Slough and Gensco Inc./Uvalco Inc.

western fence (see Figure 2, study area base map). The third well was sited along the west bank of Taylor Slough.

Site Conditions

The current study area, as depicted by figure 2, slopes gently to the south with an approximate grade of 1%. The north to south trending Taylor Slough is the dominant topographic feature as well as the major drainage course. The slough channel is approximately 10-15 feet deep.

The area contains several open lots with most buildings and machinery parking located in the western extent. Much of the area has been cleared of vegetation. Most vegetation occurs along fence lines and the banks of the Taylor Slough.

Site Geology

Three geologic units are of interest in the study area; the Leona Formation, the Del Rio Formation and the Edwards Group. Appendix D contains a stratigraphic column and geologic cross sections of the current study area.

The Leona Formation (Qle) is a Quaternary alluvial deposit consisting of fine calcareous silt grading down into coarse gravel. The Leona Formation exists at the surface over

the entire study area. A minor aquifer in the current study area, the Leona Formation ranges from about ten to 35 feet in thickness. Maximum saturated thickness occurs in depositional lows in the Leona Formation during times of greater than average rainfall. A maximum saturated thickness of about seven feet has been observed in the Leona Formation in the study area.

Underlying the Leona Formation is the erosional surface of the Del Rio Formation (Kdr). The Del Rio Formation is a Cretaceous Age calcareous clay unit abundant in marine mega-fossils. Observed thicknesses of the eroded Del Rio Formation ranged from zero to about thirty-five feet in the study area. Approximately 90 feet of Del Rio clay was originally deposited in the area as shown by geophysical logs of a well 0.2 miles northwest of the study area. Post-depositional faulting and erosion have caused the Del Rio clay to be discontinuous in the study area. The Del Rio clay produces no water.

Underlying the Del Rio Formation is the Edwards Group which is the major aquifer in the study area and in the region. The Edwards Group is a Cretaceous Age limestone and is divided into three formations in the Uvalde area. The Uvalde area is within the Maverick Basin sequence of the Edwards Group depositional model (Rose 1972). Edwards Group wells in and around the study area are usually completed into the Salmon Peak Formation (Ksa) which is the upper most formation of the Edwards Group. A maximum thickness of 380 feet has been reported for the

Salmon Peak Formation. The Salmon Peak Formation is mostly a dense, massive lime-mudstone with the upper 75 feet being a more permeable grainstone (MaClay & Small, 1984). The Edwards Group is highly faulted and fractured in the study area and produces moderate to high amounts of very good quality water. The Edwards Group will be referred to as "Edwards" in this report and represented by the symbol Kea.

Monitor Well Installation

A total of sixteen monitor wells have been installed by the EUWD in the current study area. The sixteen wells consist of six Edwards aquifer monitor wells, drilled to depths of 160 to 180 feet, and ten Leona wells drilled to depths of 25 to 35 feet. Steel locking well caps were placed on all Leona and Edwards monitor wells. See figure 2 for monitor well locations in the study area.

Monitor well numbering is by the order in which the wells were drilled with a prefix denoting the formation into which the well was completed. For example Kea #1 is the first Edwards aquifer monitor well installed, Qle #6 is the sixth Leona aquifer monitor well installed, etc.

Edwards Group Monitor Wells

Edwards Aquifer Monitor Well Set #1 (Kea 1,2,3)

The Edwards Group is known to be highly faulted and fractured in the study area, therefore, an increased component of conduit flow is suspected. Surface geophysical techniques were reviewed in an attempt to find a method which would serve to identify subsurface conduits and facilitate more effective monitoring of the Edwards aquifer. A microgravity survey was used to aid in site selection for the first three Edwards monitor wells. Numerous cultural features (metal fences, buried utilities, power lines, etc.) in the current study area made microgravity a reasonable technique considering the environment of the study area. See Appendix E for a brief discussion and results of the microgravity survey.

Air rotary drilling techniques were used to drill into the top of the Edwards. Six inch ID new steel casing was set and pressure cemented into the Edwards to seal off any water from the Leona Formation. After the proper cement drying time, approximately 100 additional feet of Edwards was drilled out (see Appendix F, for well construction details). The wells were finished by open hole completion. Drilling equipment was pressure washed off site with hot soapy water and rinsed with clean water before drilling each hole. City of Uvalde water was

used for the wash process. All casing was washed in the same manner. The casing was new steel which had oxidized to a state of being rusty in appearance.

After drilling to total depth, each well was purged by air lifting at its maximum output for two hours. After drilling equipment was removed each well was sampled for VOCs using a decontaminated stainless steel bailer. Submersible electric pumps were then set in the three wells at 120 feet. The submersible electric pumps and their PVC production pipes were washed, rinsed and sampled for VOC contamination prior to being placed in the Edwards monitor wells. No VOC contamination was detected from the pumps. Subsequent samples for VOCs were obtained from the three wells using the submersible pumps (see Appendix G, Sampling Protocol).

Results of Edwards Aquifer Monitor Well Set #1

All three Edwards wells showed various levels of VOC contamination under the different pumping regimes (see table 1).

TABLE 1

Water Quantity/Quality Results of Edwards Monitor Well Set #1

Well	Date	Pumping Method	Est. GPM	VOC Conc.
Kea 1	1-22-87	2 hr. purge w/rig	400	23.0 ug/l TCE
Kea 2	1-27-87	2 hr. purge w/rig	450	220.0 ug/l PCE
Kea 3	1-27-87	2 hr. purge w/rig	50	27.0 ug/l PCE
Kea 1	3-25-87	submersible pump	12	110.0 ug/l PCE
Kea 2	3-25-87	submersible pump	12	1.6 ug/l PCE
Kea 3	3-25-87	submersible pump	12	55.0 ug/l PCE

Contamination in all three Edwards aquifer wells and data on the general hydraulic gradient in the Edwards indicated an area contaminated with PCE west of the first three Edwards monitor wells. Increased levels of contamination in Kea #2, when purged near its maximum capacity, is a possible indication the well is near high concentrations of contaminated water.

The current study area, as delineated on the site base map (fig. 2), was chosen in order to concentrate investigative

efforts west of Edwards monitor wells Kea 1, 2 and 3. Operations in the eastern portion of the industrial area have not been extensively investigated by the EUWD.

Edwards Aquifer Monitor Well Set #2 (Kea 4,5,6)

Before a second set of Edwards monitor wells were drilled, an additional well inventory was conducted northwest, up the hydraulic gradient, of the study area. Five existing Edwards wells were sampled as a result of this new well inventory in an attempt to determine if contamination existed up-gradient from the industrial area. All of these wells showed no detectable VOC contamination. Thirteen previously identified contaminated private wells and monitor wells were also sampled at this time (March 1987).

Another investigative step which occurred between the drilling of Edwards monitor well set #1 and set #2 which had an effect on the choice of the location of set #2 was the coring of two holes on the former TIS lot. Borings labeled B-6 and B-7 (fig. 2) were cored at specific intervals using a four inch rock core in an attempt to find VOC contamination in formations overlying the Edwards. The borings encountered Edwards limestone at 38 feet in B-6 and 36 feet in B-7. When these borings encountered the Edwards they immediately encountered water which is atypical of Edwards wells in the current study area. Other

Edwards wells drilled in the current study area encountered a dense, recrystallized horizon at the top of the Edwards which ranges from ten to thirty feet thick, is essentially impermeable and contains no water. Water from B-6 and B-7, from the top few feet of the Edwards, was sampled with a bailer and found to contain relatively high levels of VOCs. PCE concentrations were 380 ug/l in B-6 and 190 ug/l in B-7. Three core samples were sent to a laboratory for a VOC scan (EPA method 624), all three samples showed no VOC contamination. The borings were closed by filling the Edwards portion of the hole with crushed gravel and the remainder of the hole with cement grout.

Since the sampling of groundwater up the hydraulic gradient in March 1987 did not indicate any VOC contaminated wells and VOC contaminated groundwater was found in B-6 and B-7 in the Edwards, it was reasonable to assume a source of VOC contamination existed in the western portion of the industrial area. Three more Edwards monitor wells were planned for the western extent of the industrial area, Edwards monitor well set #2 (Kea 4, 5 and 6). These three additional Edwards monitor wells were constructed in the same manner as Edwards monitor wells Kea #1, 2 and 3. See Figure 2 for well locations and the Appendix F for well construction details. Drilling equipment and casing were cleaned as described in Edwards monitor well set #1.

During the drilling of Kea # 4 and #5, water samples were obtained from the base of the Leona Formation. VOC

contamination was found to be present in these samples. Water samples obtained from the Edwards, after purging the wells with the drilling rig, indicated no VOC contamination. All subsequent sample events have shown Edwards monitor well set #2 (Kea #4, 5 and 6) to be free from VOC contamination. Samples drawn from Kea #4, 5 and 6 were taken with a stainless steel bailer. Dedicated submersible pumps were not placed in these wells. One sample set obtained with a temporarily installed submersible pump from Kea #6 in January 1988 showed no VOC contamination.

Results of Edwards Aquifer Monitor Well Set # 2

Sample results from wells Kea #4, 5 and 6 indicate no VOC contamination in the Edwards at those wells. Relatively high amounts of VOC contamination in B-6, B-7 and Kea #2 (if Kea #2 is stress pumped) indicate the up-gradient extent of contamination in the Edwards is located between B-6 and Kea #4, 5 and 6. At this point investigative efforts shifted from the Edwards to the overlying Leona Formation in search of a VOC contamination source(s).

Leona Formation Monitor Wells

Ten Leona Formation monitor wells have been installed in

the study area by the EUWD (fig. 2). These ten wells were installed to assist in determining the areal extent of contamination in the Leona Formation. Well numbers Qle 1 thru Qle 8 were constructed by air rotary drilling techniques. Drilling equipment and casing were cleaned as described in Edwards Group monitor well set #1. Leona Formation monitor wells were drilled through the Leona Formation and approximately 3 to 5 feet into the Del Rio clay. Four inch ID steel casing was then set in each well to total depth with the bottom ten to fifteen feet of the casing slotted. A rubber cement boot was placed on the casing ten feet below the surface to facilitate the placement of a concrete surface seal. Steel locking well caps were placed on all Leona and Edwards monitor wells. Qle #1 thru #8 were not gravel packed or developed in any way. Sample results from Qle #1 thru #8 have been consistent in VOC concentrations throughout their sampling history (see Appendix A, VOC Sample Results). Qle #9 and #10 (depicted as B-1 and B-2 respectively on study area base map) differ from Qle #1 thru #8 in their well construction. Qle #9 and #10 contain two inch ID PVC casing with the bottom twenty feet being manufactured PVC screen. These wells were sand packed and have a powdered bentonite seal under a surface cement slab. Qle #9 and #10 were installed February 26, 1988 during a soil sampling event. As of May 5, 1988 Qle #9 and #10 have not contained water for sampling (see Appendix F, Well Construction, for details on Qle #1 thru #10).

Leona Formation Monitor Well Set #1 (Qle #1,2)

Tetrachloroethylene (PCE) was encountered in water near the base of the Leona Formation while drilling Edwards monitor wells Kea #4 and #5. PCE concentrations were 25 ug/l and 50 ug/l respectively. Qle #1 and Qle #2 were installed on May 14, 1987 to begin defining the extent of VOC contamination in the Leona Formation. Qle #1 was placed beside Kea #4 such that both the Edwards aquifer and the Leona aquifer could be monitored at one location. Qle #2 was placed about 325 feet east-north-east of Qle #1 in the proximity of past industrial activities (fig. 2).

Results of Leona Formation Monitor Well Set #1

Water samples were obtained from Qle #1 and Qle #2 using a decontaminated one liter stainless steel bailer. The wells were purged using a 6.5 gallon decontaminated bailer. The large bailer was washed off-site with hot soapy water and rinsed with clean city water between wells. The one liter sampling bailer was washed in the same manner, then rinsed with deionized water, rinsed with methyl alcohol and rinsed again with deionized water. Quality assurance samples of the final rinse waters from both bailers were taken periodically and indicated no VOCs present after the cleaning process.

Sample results showed lower levels of PCE present in Qle

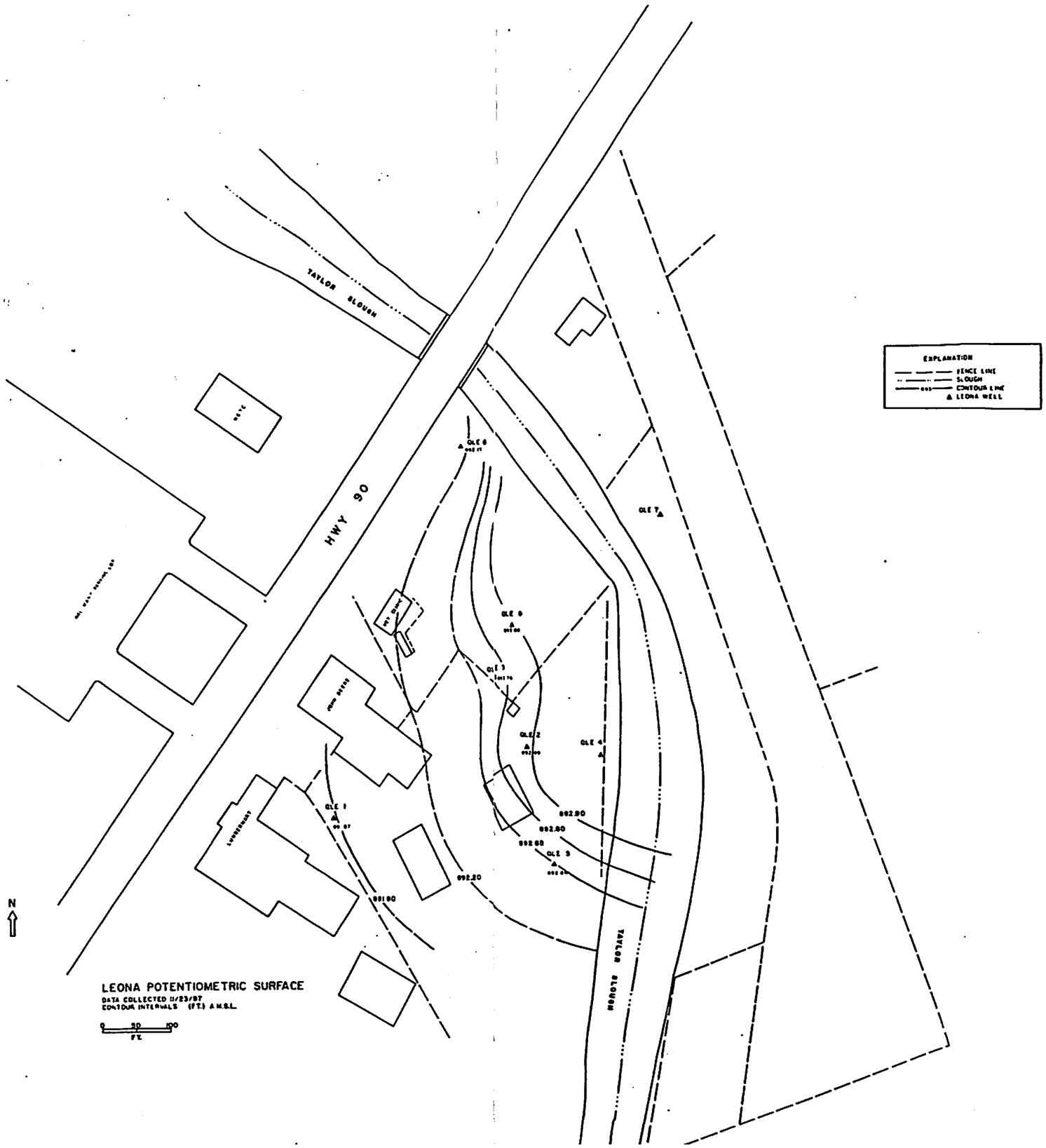
#1 (23 ug/l) and relatively high concentrations in Qle #2 (1300 ug/l). Qle #2 indicated and continues to indicate the highest concentrations of PCE in groundwater in the study area.

Leona Formation Monitor Well Set #2 (Qle #3,4,5)

High levels of PCE in Qle #2 indicated Qle #2 may be near a source of contamination. Three additional Leona Formation monitor wells (Qle #3, 4 and 5) were constructed and sampled in the same manner as Leona Formation monitor well set #1. These three monitor wells were placed in specific locations to provide additional data around Qle #2 (fig. 2).

Results of Leona Formation Monitor Well Set #2

Using the five Leona Formation monitor wells as data points, a water level gradient and a PCE concentration gradient were obtained. Ground-water flow is generally southwest (fig. 3). The PCE concentration gradient shows the greatest change near Qle #2 (fig. 4). On July 17, 1987 Qle #3, 4 and 5 had concentrations of 110 ug/l, 730 ug/l and 590 ug/l respectively. Qle #1 and #2 were sampled at the same time showing concentrations of 440 ug/l and 1600 ug/l respectively. Therefore, Qle #2 continued to be the most contaminated monitor well.


TAYLOR SLOUGH
HWY 90
TAYLOR SLOUGH
LUMBERYARD
OLE 1
OLE 2
OLE 3
OLE 4
OLE 5
OLE 6
OLE 7
OLE 8
OLE 9
992.20
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N
EXPLANATION
FENCE LINE
SLOUGH
CONTOUR LINE
LEONA WELL
LEONA POTENTIOMETRIC SURFACE
DATA COLLECTED 11/23/87
CONTOUR INTERVALS (FT.) A.M.S.L.
0 50 100
FT.

FIGURE 3

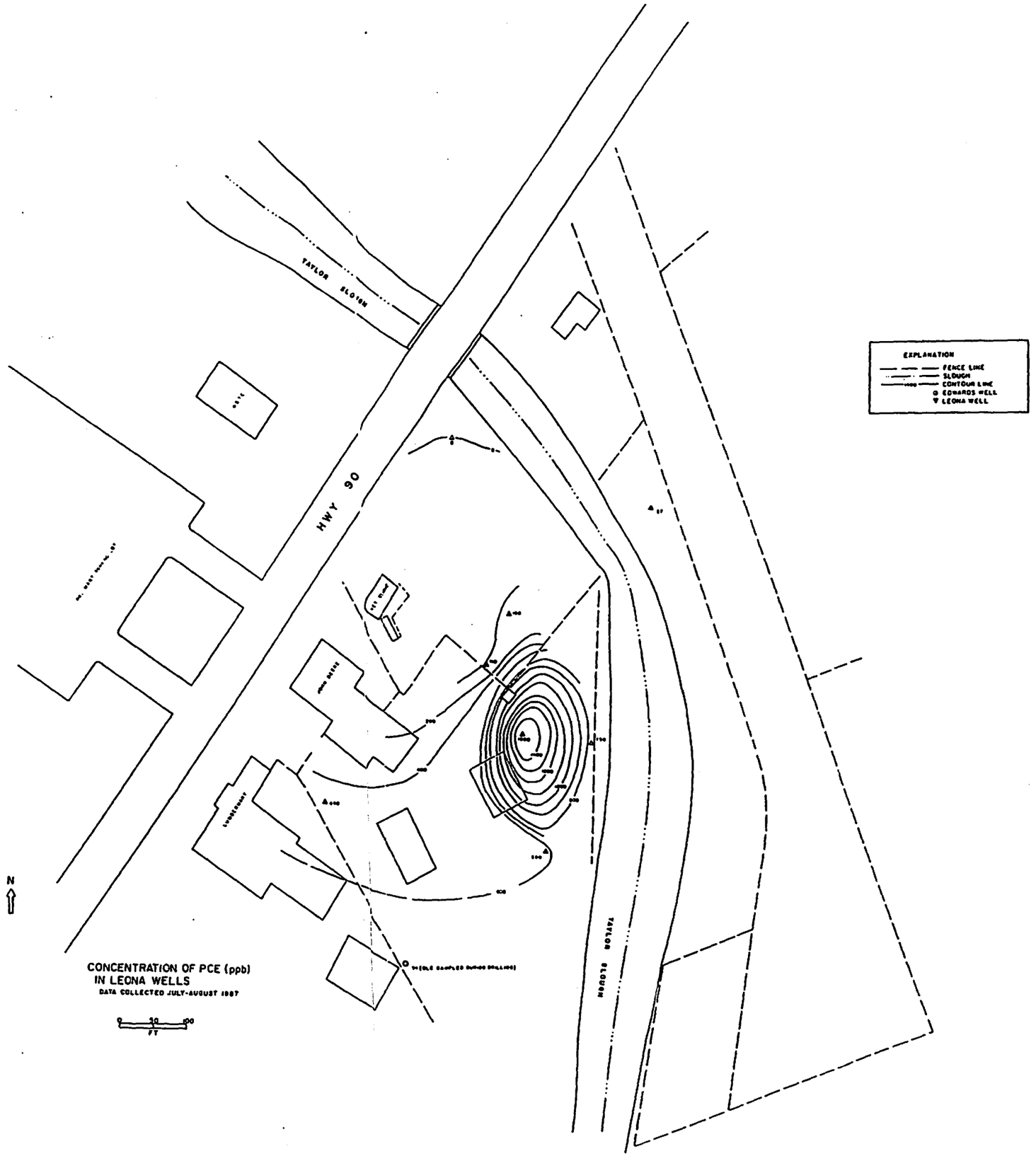

TAYLOR SLOUGH
HWY 90
N
EXPLANATION
FENCE LINE
SLOUGH
CONTOUR LINE
EDWARDS WELL
LEONA WELL
CONCENTRATION OF PCE (ppb)
IN LEONA WELLS
DATA COLLECTED JULY-AUGUST 1987
0
30
60
FT

FIGURE 4

Edwards aquifer water levels in the area were near record highs in July 1987 following a period of high rainfall in May and June of 1987. Data collected during the sampling of Leona aquifer monitor wells #1 thru #5 in July 1987 indicated the highest water levels and (with the exception of Qle #4) the highest PCE concentrations experienced in Leona monitor wells during the study. Volatile organic compounds may be mobilized from contaminated geologic materials in the Leona Formation when water levels rise. Much of the Leona Formation in the study area probably cycles between saturated and unsaturated conditions with wet and dry seasonal changes.

Leona Formation Monitor Well Set #3 (Qle #6,7,8)

Information on water level and contamination gradients obtained from previously drilled Leona Formation monitor wells was used to place the third set of Leona Formation monitor wells. Leona well set #3 (Qle #6, 7 and 8) was installed August 4, 1987 (fig. 2).

Qle #6 was placed between Qle #2 and two previously discussed recharge wells (pg. 8). The purpose of Qle #6 was to investigate the possibility of contamination originating from the ponding surface water located near the recharge wells and migrating to the suspected source area.

Qle #7 was placed up-gradient from Qle #2 to investigate the possibility of contamination migrating from other industrial areas east of Taylor Slough.

Qle #8 was placed near the former location of an underground concrete sump used by the TIS laundry operation. As mentioned in the early investigative history in this report, the sump was sampled and removed in July 1985. Sludge samples from the sump indicated concentrations of trans 1-2 dichloroethylene up to 208 mg/kg. The purpose of Qle #8 was to determine if groundwater in the area of the sump contained relatively high concentrations of VOCs. Well construction and sampling techniques for Qle #6, #7 and #8 were the same as previously described. For Qle #6, #7 and #8 locations see Figure 2.

Results of Leona Formation Monitor Well Set #3

Water level and VOC concentration gradients were refined using the three additional data points on the Leona Formation. Qle #6 water samples indicated no VOC contamination. Qle #6 has been free of VOC contamination in all subsequent sampling events.

Qle #7 initially indicated 27 ug/l of PCE. Qle #7 is unique in that it lacks Del Rio clay between the Leona Formation and the Edwards Group. The lack of Del Rio clay and the position of the Edwards indicates a significant fault exists between Qle

#7 and Kea #2 with Qle #7 being on the upthrown side (see Appendix D for geologic cross sections).

Qle #8 is the only Leona Formation monitor well to consistently show significant levels of trichloroethylene and trans 1-2 dichloroethylene in addition to tetrachloroethylene. A water sample set collected in the study area on September 25, 1987 showed VOC concentrations in Qle # 8 of 330 ug/l of trans 1-2 DCE, 21 ug/l of TCE and 160 ug/l of PCE.

Soil-Vapor Studies

The analysis of gases occupying pore spaces in the vadose zone is a method of detecting the release of volatile materials in the subsurface. The technique is most favorable for compounds which readily partition into the vapor phase. The soil-vapor and ground-water contaminant concentrations may be quantified for specific application, however, their relationship is very site specific and may be affected by temperature, depth to ground water, organic matter and soil permeability. Soil heterogeneities also affect the soil-vapor and groundwater concentration relationship. Due to the above mentioned factors, soil-vapor techniques are used in conjunction with other investigative methods (Chen, 1988).

Passive Soil-Vapor Technique

As of August 1987 eight Leona Formation monitor wells had been installed in the study area. Data collected from these wells indicated a probable source of PCE near Qle #2 and provided geologic and hydrologic information on the Leona Formation in the study area. However, more information was needed regarding the areal extent of the PCE contamination in order to define a specific source. A literature review showed a high rate of success in similar types of investigations using various types of soil-vapor analysis.

A passive soil-vapor detection technique was used by District staff in September 1987 to provide additional detail on the areal extent of PCE contamination in the study area. Ninety eight 3M model 3500 charcoal disk organic vapor monitors were placed three feet below the surface using upside-down, one gallon tin cans as manifolds. New cans were used, each being rinsed with deionized water and methyl alcohol prior to use. Each can had a wire through its base and a vapor monitor disk was then clipped to the wire allowing it to hang freely within. The apparatus was placed in the ground, covered and left for one week. At the end of the designated time, the monitors were removed and sent to a laboratory for analysis by gas chromatography. The monitors were analyzed for PCE only. Control samples and duplicate samples were used for quality assurance as suggested by H. Kerrfoot, 1987.

Results of Passive Soil-Vapor Survey

The results of the passive soil-vapor survey (fig. 5) showed an area of relatively high PCE concentrations in the vapor phase. The 20 ppb contour on Figure 5 was arbitrarily picked as generally delineating a potential source area in need of further study. These PCE vapor data had a good relative correlation with PCE concentrations in water in Leona Formation monitor wells (fig. 4).

Active or "Grab" Soil-Vapor Technique

Water samples were taken from all monitor wells in the study area on 9-24 and 9-25-87. This sample set was designed to provide data on concentrations in water near the time the passive soil-vapor data was collected. Results of these water samples showed a slight decrease in VOC concentrations in some Leona Formation monitor wells, but generally showed no significant change in the status quo (see Appendix A, Data Summary of Uvalde Volatile Organic Investigation). Data analysis and map preparation were followed by a water sampling event in late January 1988. Water samples collected in January 1988 indicated little change in Leona aquifer monitor wells, but showed a significant decrease in PCE concentrations in some Edwards aquifer monitor wells. Water quality data collected from monitor wells still closely agreed with soil-vapor data. See Appendix A for a summary of water quality results.

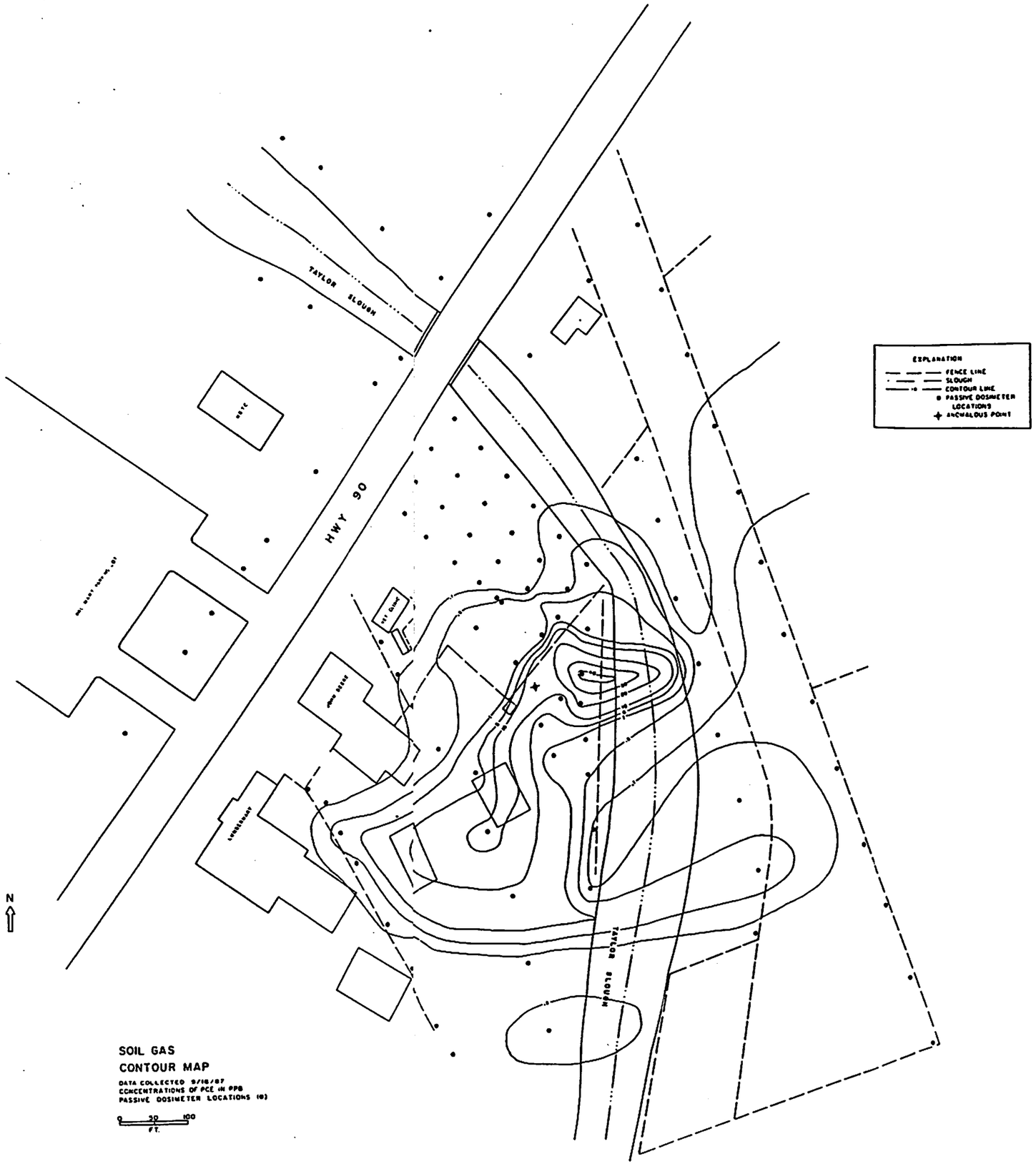

TAYLOR SLOUGH
HWY 90
TAYLOR SLOUGH
EXPLANATION
FENCE LINE
SLOUGH
10 CONTOUR LINE
PASSIVE DOSIMETER LOCATIONS
ANOMALOUS POINT
N
SOIL GAS
CONTOUR MAP
DATA COLLECTED 9/16/87
CONCENTRATIONS OF PCE IN PPB
PASSIVE DOSIMETER LOCATIONS (8)
0 50 100
FT.

FIGURE 5

A second soil-vapor survey was conducted on 2-4-88 in and around the area previously identified as having high PCE concentrations in the vapor phase. As previously described, the area was generally identified by monitor well data and more specifically by a passive soil-vapor technique. The purpose of the second soil-vapor survey was to verify the first vapor study and to provide more detail in the area of high PCE vapor concentrations.

For the second soil-vapor survey an active or "grab" sample technique was used. The method uses a probe driven into the soils which is connected to a low volume vacuum pump. A soil-vapor sample is drawn through the probe by the vacuum pump, collected, and analyzed for compounds of interest. Vapor samples were analyzed on site using portable gas chromatograph instrumentation.

The active soil-vapor study employed a portable photoionizing gas chromatograph for on site analysis. Twenty-seven soil-vapor samples were collected from twenty two sites and analyzed on site for tetrachloroethylene (PCE), trichloroethylene (TCE) and 1-2 dichloroethylene (DCE). The first three sample sites were each sampled at depths of 3, 6 and 9 feet. Subsequent sites were sampled at three feet.

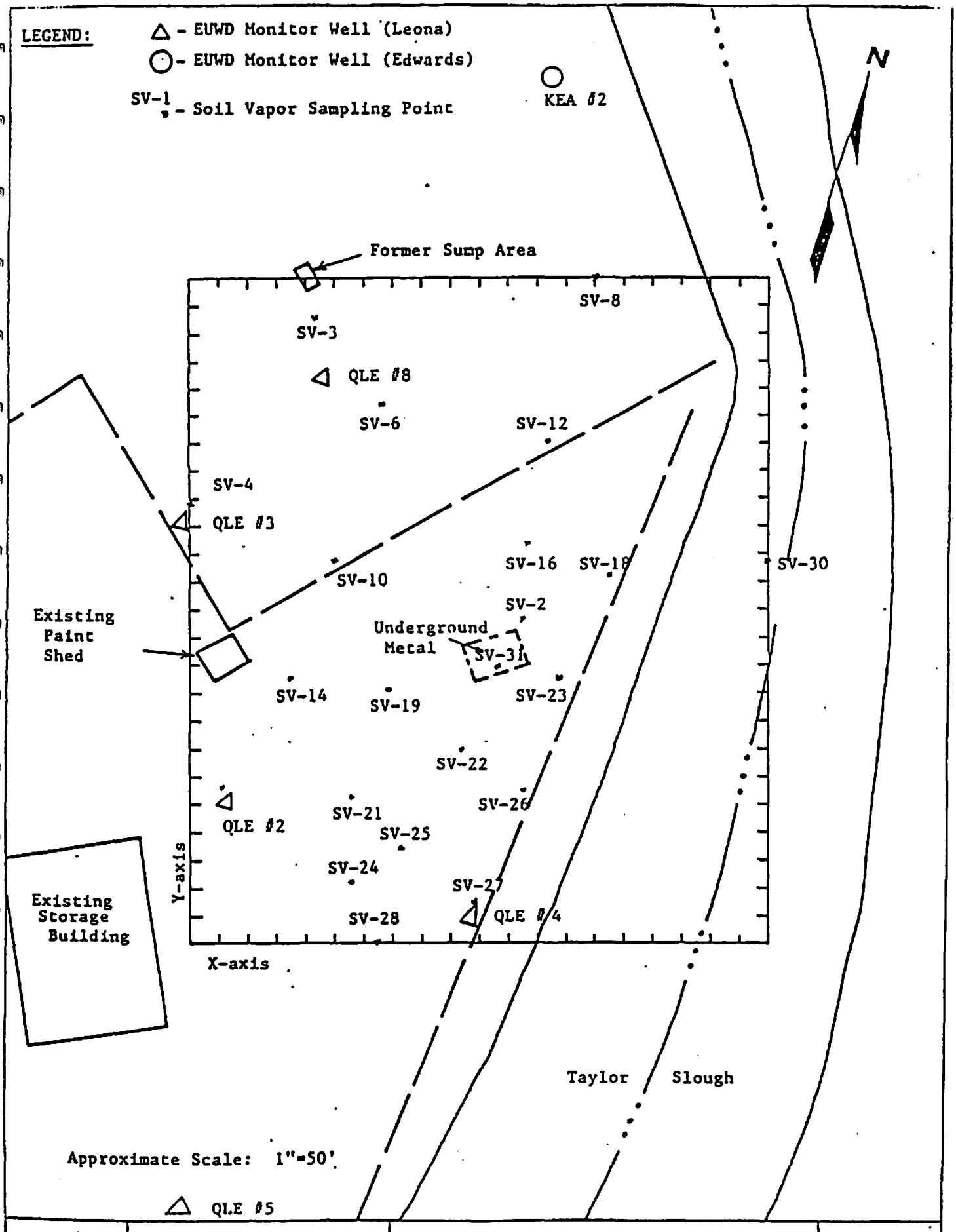
Results of the Active Soil-Vapor Survey

Concentration maps for the three compounds of interest (PCE, TCE and DCE) were constructed using the acquired data (see figures 6 thru 9). The areas of highest concentration on Figures 7 , 8 and 9 are contained within the 20 ppb contour on Figure 5. Therefore, both soil-vapor studies suggest a source of PCE soil and/or groundwater contamination may exist on the east side of the Uvalde Equipment Co. property.

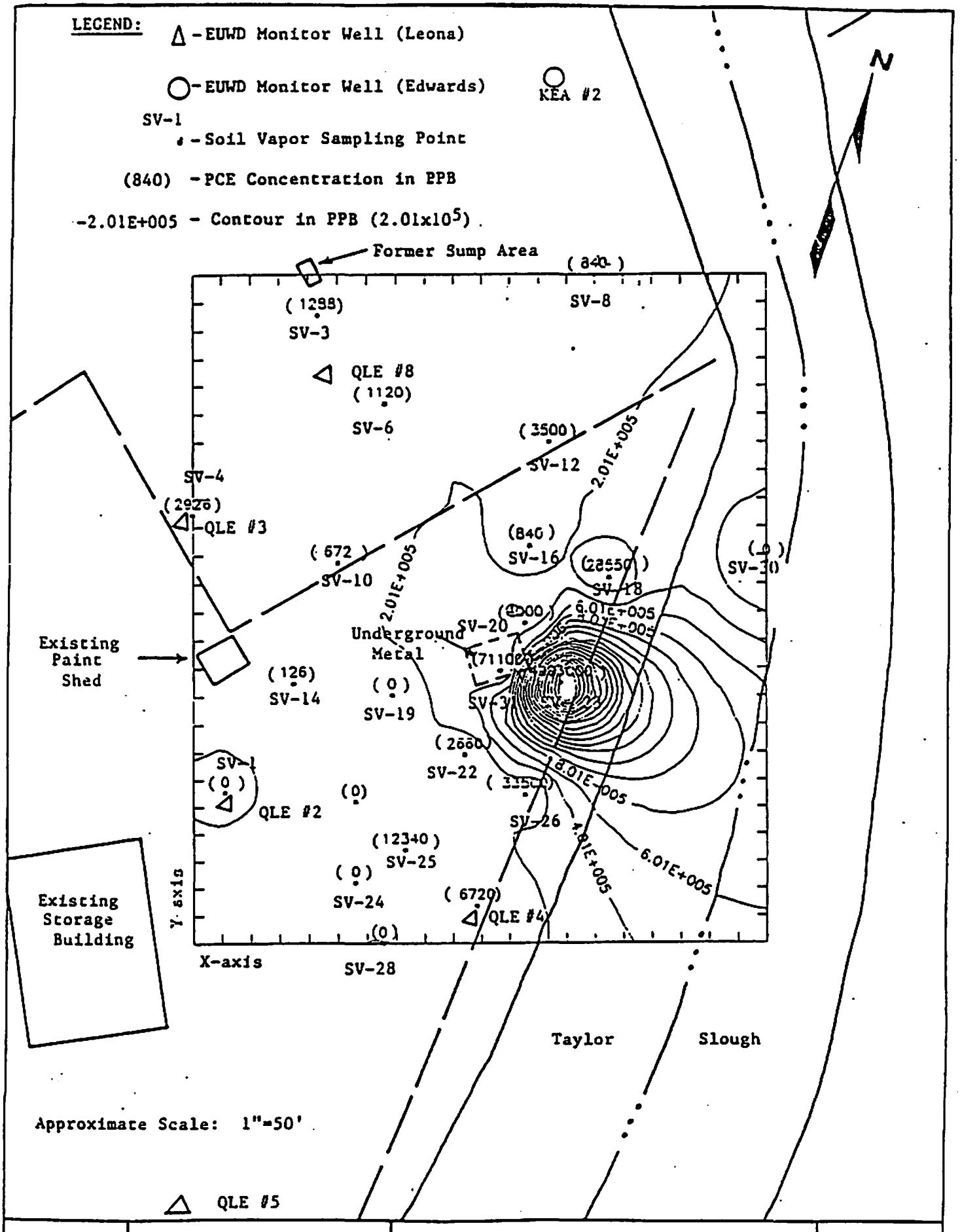
While performing the active vapor study, a brief magnetometer survey was conducted. A rectangular area roughly twelve feet by twenty feet indicated underground metal. A second magnetometer survey across the area using a portable proton precession magnetometer also indicated a magnetic anomaly in the aforementioned area. This rectangular area is labeled "underground metal" on figures 6 thru 10.

Sewer Line Survey

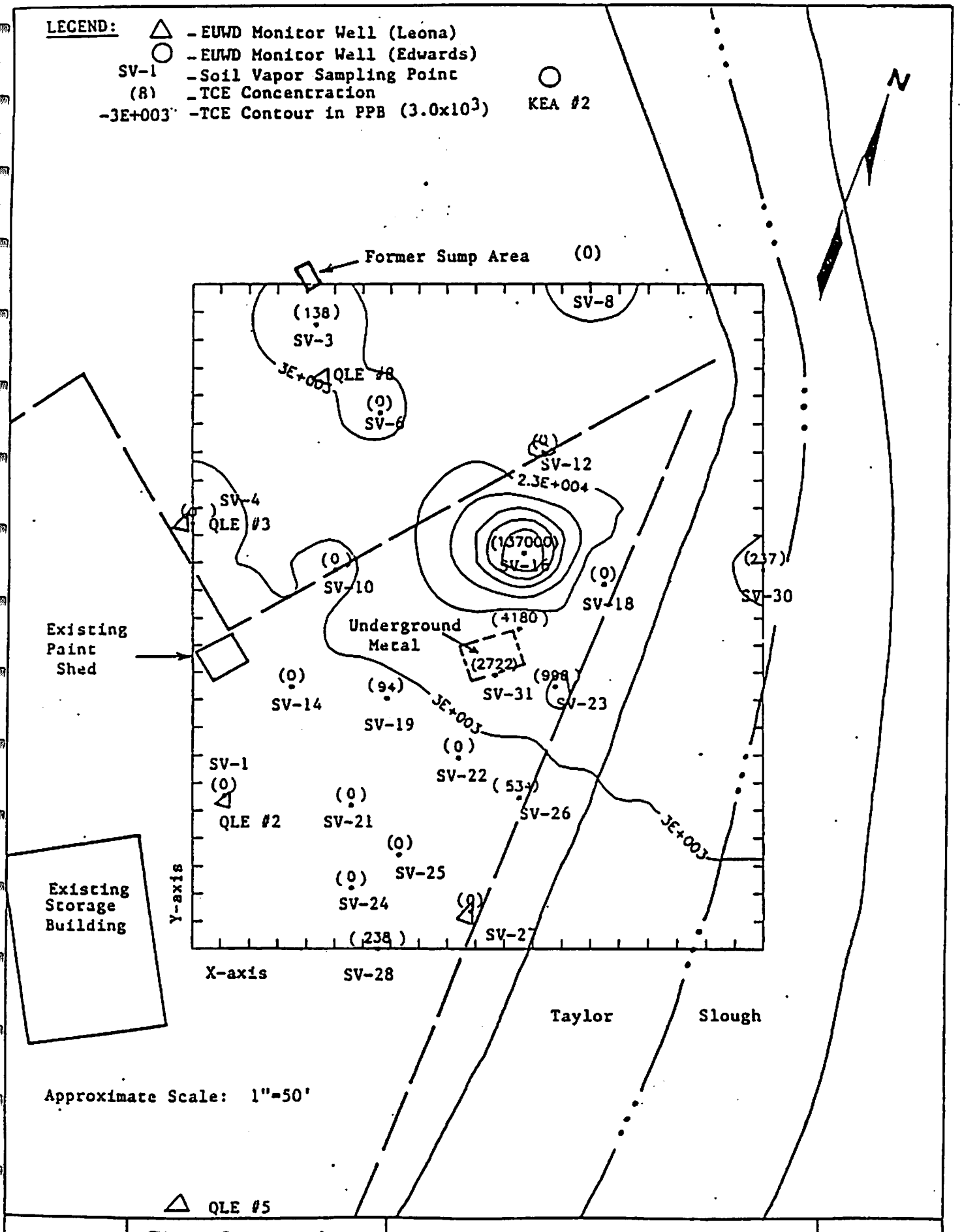
The two soil-vapor studies strongly agreed on the location of the highest concentration of PCE in the vapor phase. A "man-made" feature known to underlie the potential source area was a sanitary sewer line that exclusively served the industrial laundry.



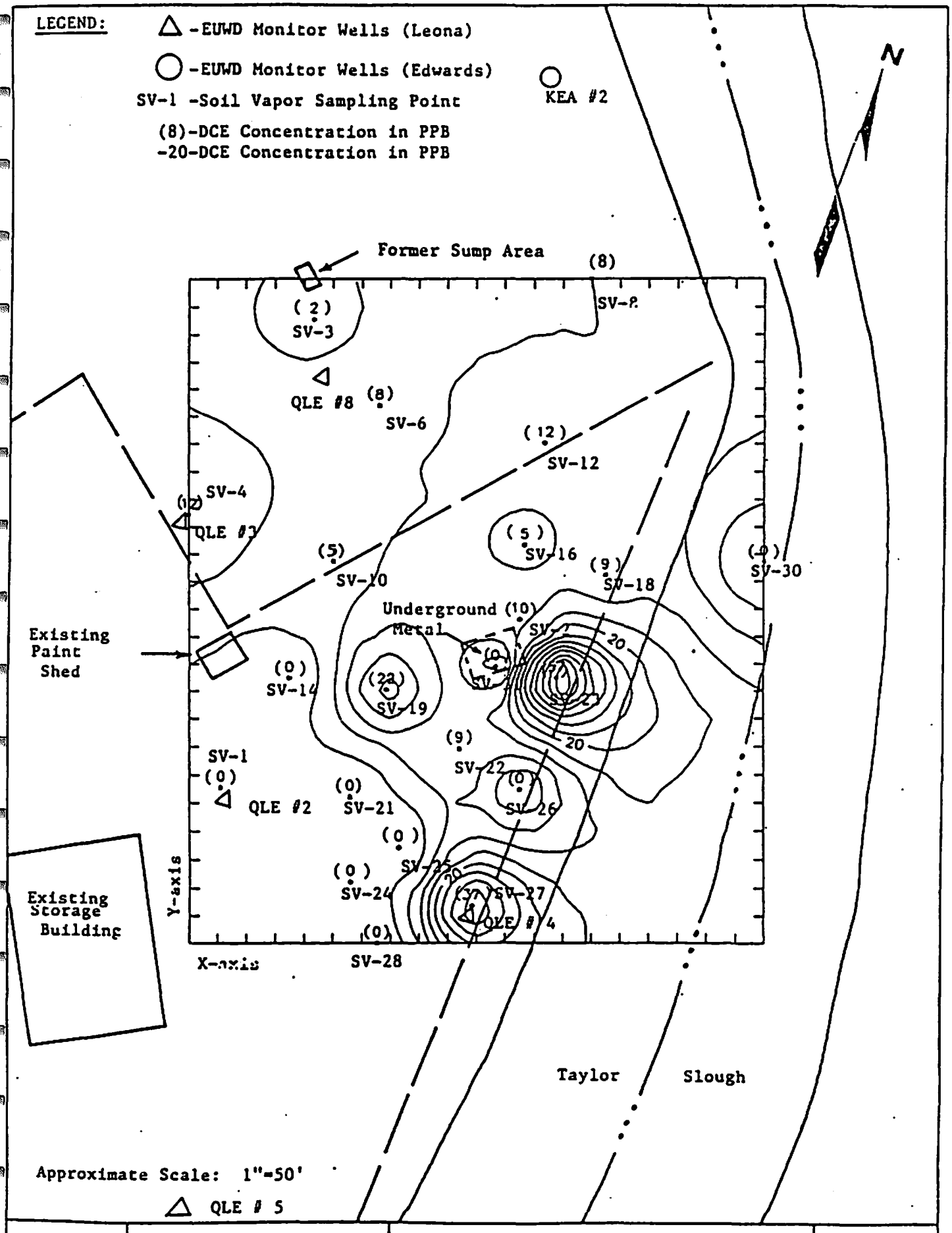
9-006-88	Chen & Associates	SOIL VAPOR SAMPLING LOCATIONS	Fig. 6



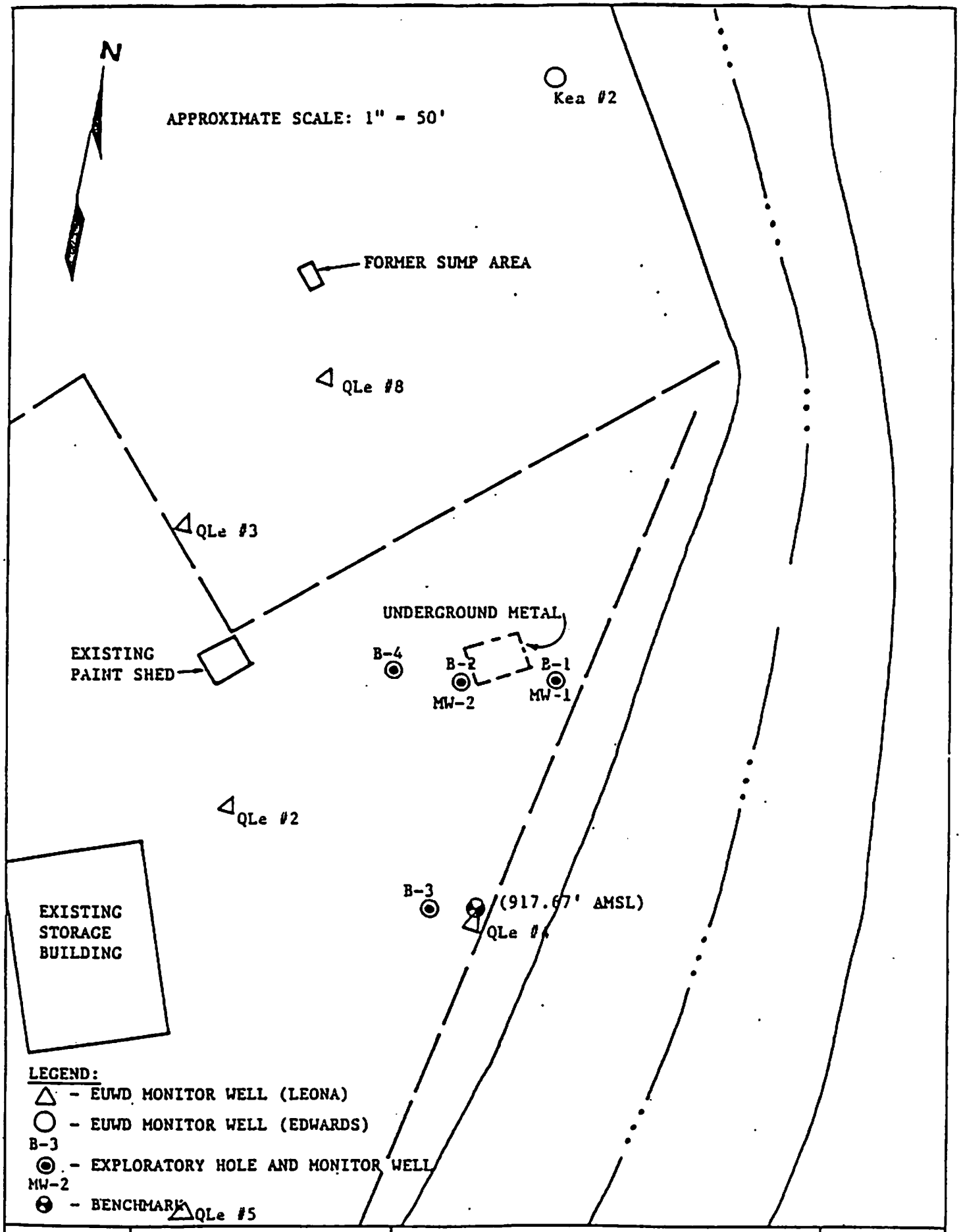
9-006-88	Chen & Associates	PCE CONCENTRATION IN PPB	Fig. 7



9-006-88	Chen & Associates	TCE CONCENTRATIONS IN PPB	Fig. 8



9-006-88	Chen & Associates	DCE CONCENTRATION IN PPB	Fig. 9



9-006-88	Chen & Associates	EXPLORATORY HOLE & MONITOR WELL LOCATIONS	Fig. 10

On 2-9-88 the sanitary sewer line was uncovered by City of Uvalde crews at a point approximately 50 feet south of Qle #4. The sewer line was encountered about six feet below the surface and consisted of eight inch ID vitrified clay pipe in approximately six foot sections with bell type connections. Flow direction in the sewer was to the south when in use. This section of sewer line was only used by TIS and has not been used since August 1979 when the industrial laundry was destroyed by fire.

The objective of digging into the sanitary sewer line was to perform a teleview survey of that portion of the line which lies directly under the identified area of highest PCE vapor phase concentrations. The televiewing would indicate any breaks or offsets in the line. When the line was initially broken open by the backhoe it was observed to be approximately two-thirds full of sediment. The sediment consisted of laminations of silt and cloth fibers and a laminated dark crustose material on the interior pipe walls. This sediment infilling would not allow a teleview camera to pass through the sewer line, therefore, a high pressure water jetting tool was required to clean out the line.

Two samples of the sediment were collected from the sewer line when it was first opened by the backhoe. A third sample was collected during the jetting process. The third sample mostly consisted of dark crustose material knocked loose by the

jetting process. A noticable solvent-like odor was emitting from the sewer line during the initial jetting process. The crustose material seemed to be the source of the solvent odor in that it emitted a noticeable odor when broken open. The three sediment samples were analyzed for PCE, TCE and DCE by EPA method 8010. Results indicated 33.7 mg/kg of PCE in the jetted sample and 5.0 mg/kg and 8.6 mg/kg of PCE in the two sediment samples collected in place from the line. Smaller amounts of TCE and DCE were also found in these samples (see Appendix A, Data Summary of VOC Samples).

After the line was cleaned of sediment it was televiewed. No breaks or large offsets were observed in the area of identified high PCE vapor phase concentrations. Several minor offsets were observed throughout the televiewed section and one highly fractured joint was observed approximately 110 feet downstream from the center of the area of high PCE vapor phase concentrations. The section of sewer line broken into for the camera survey was repaired and the excavation was backfilled by City of Uvalde work crews.

Soil Borings

The last step of the current investigative phase was the collection of four sets of soil samples from borings located in and around the previously identified area of high PCE vapor concentrations. On 2-26-88 Chen & Associates used a hollow stem auger rig and a split spoon soil sampling device to obtain soil samples at various depths. Borings 1, 2, and 4 were placed near the area of high PCE vapor concentrations. Boring #3 was placed near the highly fractured sewer pipe section identified by the sewer line camera survey. See Figure 10 for soil boring locations.

All soil samples were screened in the field for total ionizable volatile organic compounds utilizing a head spacing technique. Soil samples with higher total ionizables were sent to a lab for quantification by EPA method 8010.

Manufactured slotted PVC screen was placed in borings 1 and 2 and a sand pack placed around the screen. Borings 1 and 2 will remain as potential monitor wells and will be entered into EUWD records as Qle #9 and Qle #10 (shown on study area base map as B-1 and B-2 respectively). Borings 1 and 2 are also listed as MW-1 and MW-2 respectively on Figure 10. No water was encountered during the soil boring process and no water has yet entered these two new monitor wells. See Appendix F, Monitor Well Construction, for more information.

Results of Soil Borings

Table 2 shows the results of soil samples which were selected for laboratory analysis by the head spacing technique. Added to Table 2 are the head space technique data. Field readings show poor correlation of field data and laboratory results.

The highest PCE concentrations encountered in these soil samples are in the previously indicated area of high PCE vapor concentrations. B-3, which is the most distant soil boring from the area of highest PCE vapor concentrations, indicated the lowest PCE concentration in soils of these borings.

Of further interest was the high level of PCE in B-4 from the six foot depth. B-4 is several feet west of the area identified as having high PCE vapor phase concentrations and B-4 showed the highest PCE concentration in the soil. The reason for this may be soil heterogeneities such as some impervious layer in the area of B-4 which is less than six feet in depth. Interestingly, soil-vapor surveys indicated very low concentrations of VOC vapors in the area of B-4.

TABLE 2

VOC Concentrations in Soils
Former TIS Site, Uvalde, Texas

Sample at Depth	Compound	Lab Concentration (ppb)	Detection Limit (ppb)	Field * Total VOC (ppm)
B-1 @ 4'	Perchlorethylene	4500 ug/kg	38	91.7
B-1 @ 14'	Chloroform	35.0	3.1	124.5
	Perchlorethylene	110.0	1.9	
B-1 @ 18'	Perchlorethylene	44.2	1.8	73.5
B-2 @ 8'	Perchlorethylene	210.0	3.8	61.5
B-2 @ 14'	Perchlorethylene	200.0	3.8	115.6
B-2 @ 28'	trans 1,2 Dichloroethylene	3.9	2.5	94.0
	Perchlorethylene	26.2	1.8	
B-3 @ 12'	Perchlorethylene	10.2	1.8	6.2
B-4 @ 4'	Perchlorethylene	1100.0	7.5	24.5
B-4 @ 6'	trans 1,2 Dichloroethylene	3800	250	46.8
	Trichloroethylene	490	50	
	Perchlorethylene	16000	38	

* Field readings by a portable photoionizing vapor analyzer. Conducted on samples in the field by head space analysis.

INTERPRETATION

Edwards Aquifer Well Data

Figure 1 -shows twenty-four Edwards aquifer wells that have been identified as containing VOC contamination. Appendix A lists all wells sampled for this project, sample dates, and the VOC concentration(s) found in each sample. Sampled wells which have contained VOC contaminated water within the time frame of the study are listed first in Appendix A followed by sampled wells which have not indicated VOC contaminated water.

Of the twenty-four contaminated Edwards wells, twenty-one are previously existing wells and three are project monitor wells. The volatile organic compound detected in Edwards wells is almost exclusively PCE. PCE is detectable in Edwards aquifer wells for about two miles down-gradient from the current study area.

The hydraulic gradient in the Edwards was obtained by constructing several water level maps during the project (see Appendix C, Water Level Maps). Ground-water flow is generally east-southeast across the study area toward the airport; and, given the distribution of PCE, apparently turns northeast.

Hydraulic gradients in the Edwards aquifer in the current study area (fig. 2) shifted from an easterly direction

during lower water levels to a southerly direction during higher water levels. This may offer an explanation for the relatively high concentrations of PCE in wells northeast of the current study area. Possibly, during water levels lower than those experienced during the study, the hydraulic gradient shifts from east-southeast to east-northeast. Fault barriers may restrict flow in such a manner that only under lower water level conditions does Edwards groundwater flow northeast from the identified area of high PCE concentrations in groundwater and in the vapor phase. This is a theory only and merits further investigation. Also, the hydraulic gradient in the current study area may be affected by the pumping of municipal wells, the closest of which is the municipal well located at the airport approximately one mile southeast of the study area.

The question of how PCE contamination entered the Edwards aquifer from the source area is of interest. The highest concentrations of PCE in groundwater are found in monitor wells completed into the Leona Formation only. The furthest up-gradient Edwards monitor well that contains PCE is Kea 2, therefore, it is reasonable to believe that somewhere near Kea 2 a hydraulic connection exists between the Edwards aquifer and the Leona aquifer. Such a connection could be in the form of fault planes cutting through the Del Rio clay and then covered by the Leona Formation. At least one such fault is known to exist as shown by monitor well geophysical logs (see Appendix D, Geologic Cross Sections etc). The referenced fault trends northwest-

southeast and is located just east of Kea 2 with Kea 2 being on the down-thrown side. The absence of Del Rio clay on the up-thrown side of the fault indicates displacement of at least forty feet. If PCE contaminated water in the Leona Formation encountered the fault plane, the dense PCE solvent (specific gravity of 1.6) would have the potential to migrate down into the Edwards aquifer.

Another possible method for hydraulic connection between the Edwards and Leona aquifers is along a discontinuous erosional Del Rio clay surface. Observed Del Rio clay thicknesses on the down-thrown side of the above referenced fault range from 14 to 35 feet. Erosional channels of the Leona Formation may exist where all Del Rio clay is eroded away placing PCE contaminated Leona water directly on Edwards limestone. No such channels, with the Del Rio clay completely missing, have been encountered in monitor well drilling west of the above referenced fault. A surface geophysical technique such as the seismic method could possibly be employed to identify such channel features in the erosional Del Rio clay surface.

Improperly cased wells or wells without proper annular seals which penetrate both the Leona and Edwards aquifers could also provide a hydraulic connection between the two aquifers. No such wells are known to exist in the current study area near the identified high PCE concentrations.

Leona Aquifer Data

No Leona aquifer wells were known to exist in the current study area prior to this investigation. PCE contaminated water was first discovered in the Leona Formation while drilling Edwards aquifer monitor well Kea #4. Leona aquifer water was encountered while drilling Edwards aquifer monitor well Kea #1 and Kea #2 but was not analyzed due to laboratory error. Leona aquifer waters were cased and cemented off when constructing Edwards monitor wells and consequently, were not available for further sampling.

Eight Leona aquifer monitor wells were constructed in the current study area (see Appendix F, Well Construction Details). Geologic materials encounted while drilling these eight wells represented a typical fining-upward alluvial sequence. Water production was directly proportional to the gravel content of each well. Cleaner, coarser gravels near the base of the formation produced the most water. Water production was extremely variable ranging from a few gallons per day with total drawdown up to about 40 gallons per minute with minimal drawdown. Aquifer tests were not performed to precisely ascertain aquifer parameters; production values for Leona wells are estimates and are based on drilling and presample purging experiences. Leona wells arranged in order from highest to lowest production would be: Qle 3 - Qle 1 - Qle 2 - Qle 5- Qle 8- Qle 4- Qle 6 - Qle 7.

Leona Formation monitor wells with higher gravel content and higher water production may be associated with paleo-channels in the Leona Formation.

Leona aquifer saturated thickness was observed to range from a few feet to a maximum of about seven feet within depositional lows during higher than average water level conditions. Installation of the first eight Leona monitor wells occurred within a few months of record rainfall and record high water levels in the Edwards aquifer.

Water level records show the Edwards and Leona aquifers maintained similar water levels when referenced to mean sea level. Leona wells with higher production values showed the closest water level correlation with Edwards wells. This water level correlation suggests a local hydraulic connection between the Leona and Edwards aquifers.

The extent of VOC contamination in the Leona aquifer down-gradient from the area of relatively high PCE concentrations in water and the vapor phase is not known.

Soil Vapor Data

Both soil vapor studies conducted on the current study area indicated a high degree of correlation. The first soil vapor study (fig. 5), the passive technique, consisted of 98 survey points throughout the current study area. The second soil vapor study (fig. 6-9), the active technique, was used to confirm the first study. An area of high PCE vapor concentrations on the east side of Uvalde Equip. Co. property was identified as a potential PCE source area.

CONCLUSIONS

The described steps of the current phase of the investigation have indicated the location of a potential source of PCE soil and/or groundwater contamination. The 20 ug/l contour on the passive technique soil-vapor map (fig. 5) is used to delineate the location of a potential source area of PCE. Groundwater sample data from monitor wells in the Edwards and Leona aquifers agree with the location of the potential source area (fig. 4 and 11). The second soil-vapor study (fig. 6-9) agrees with the location of the potential source area as delineated by previous investigative efforts.

An abandoned sewer system which served the TIS laundry operation was found to contain 1-2 dichlorethylene and

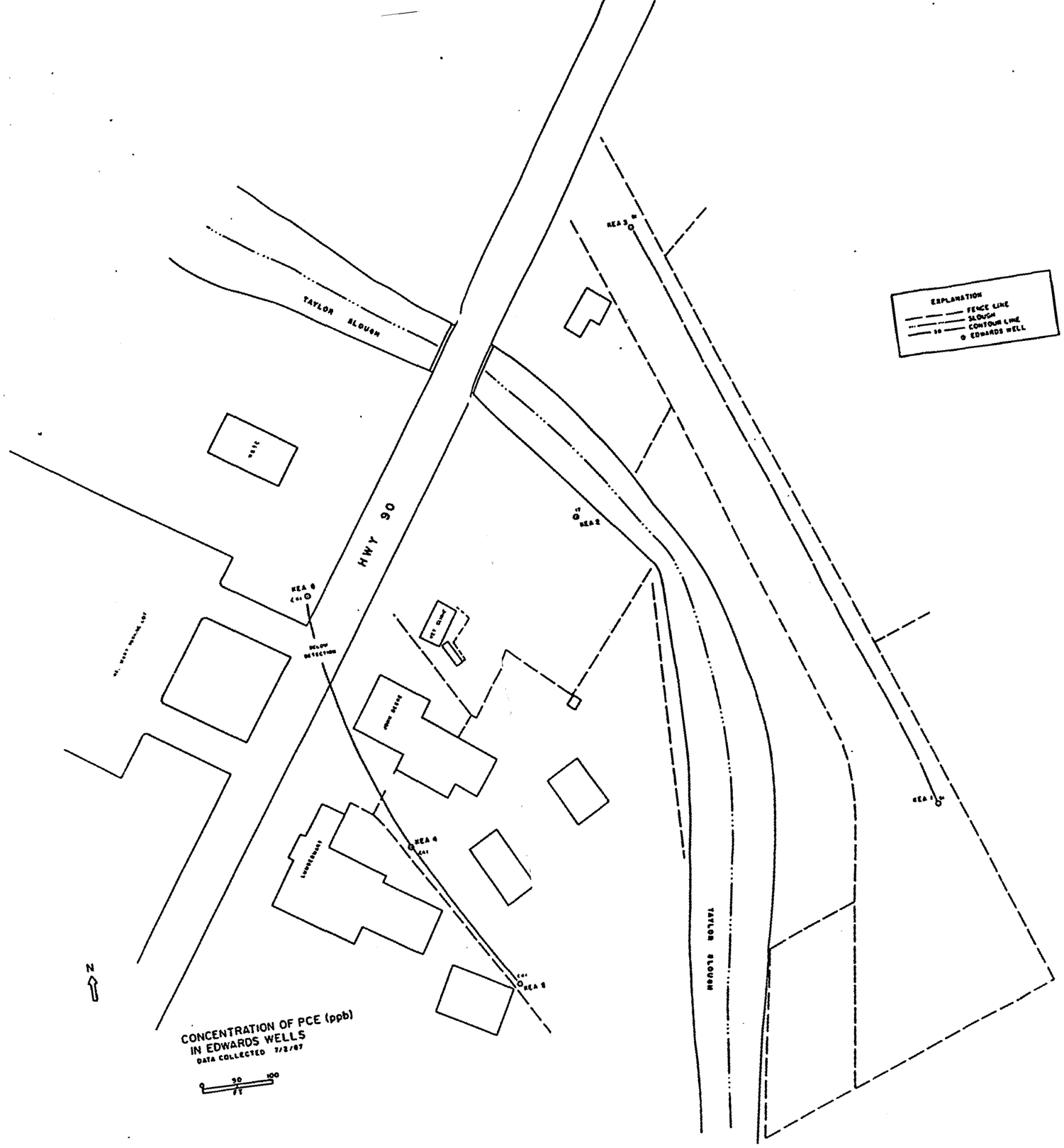

EXPLANATION
FENCE LINE
SLOUGH
CONTOUR LINE
EDWARDS WELL
TAYLOR SLOUGH
HWY 90
TAYLOR SLOUGH
N
CONCENTRATION OF PCE (ppb)
IN EDWARDS WELLS
DATA COLLECTED 7/2/87
0
50
100
FT

FIGURE 11

tetrachloroethylene. The sewer line leaving the TIS laundry operation passes under the identified area of greatest PCE vapor phase contamination. Samples of sediment from the concrete sump tank connected to the sewer line contained up to 208 mg/kg of 1-2 dichloroethylene. Samples of sediment from the abandoned sewer line contained up to 33.7 mg/kg of PCE. Historical records from the industrial laundry show PCE was used at the facility for dry cleaning purposes from 1976 until the facility was destroyed by fire in 1979.

The site occupied by the laundry facility was previously owned by Gensco Inc., therefore, the site has a history of light industrial use predating TIS by at least six years (dating back to about 1960).

RECOMMENDATIONS

The abandoned sewer line system on the Uvalde Equipment Co. property needs to be excavated to determine if VOC contaminated soils are associated with the sewer line. This excavation plan should be perceived as an additional investigative step and not remediation since a specific source is still not known. A contingency plan should be developed if contaminated soils are encountered and should be included in the excavation plan. The concentration of VOCs present which constitutes contaminated soils must be agreed upon and

appropriate instrumentation should be on site which can quickly and accurately determine VOC concentrations.

Subsurface metallic objects in the potential source area should also be investigated by excavation using the same criteria as described in the recommended sewer line excavation.

Other industrial operations in the vicinity of the identified source area should be investigated. Property east of Taylor Slough where Gensco Inc. operated from about 1967 to 1987 should be investigated by a soil-vapor study. Other sources of VOC groundwater contamination could possibly exist in the industrial area east of Taylor Slough where the EUWD has not conducted extensive investigations.

Groundwater concentrations of VOCs should be monitored for long term trends. If VOC concentrations do not decrease in groundwater after a reasonable amount of time, a remediation program may need to be implemented.

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APPENDIX A

DATA SUMMARY OF UVALDE VOLATILE ORGANIC INVESTIGATION

(by EPA Method 624 [GC/MS])

(POSITIVE WATER SAMPLES)

(SQUARE ON ACCOMPANYING MAP)

last update: 5-24-88

WELL NUMBER	DATE SAMPLED	RESULTS
1A	04-04-88	VOC NOT FOUND
	01-25-88	VOC NOT FOUND
	03-26-87	12.0 ug/l PCE
	09-03-86	49.0 ug/l PCE
	09-03-86	34.0 ug/l TCE
	05-21-86	27.0 ug/l PCE
	05-21-86	32.7 ug/l PCE
	10-04-85	52.8 ug/l PCE
1	04-04-88	4.6 ug/l PCE
	03-26-87	30.0 ug/l PCE
	08-06-85	62.0 ug/l PCE
2	04-04-88	15.0 ug/l PCE
	09-03-86	12.0 ug/l PCE
	09-03-86	7.4 ug/l TCE
	05-21-86	19.0 ug/l PCE
	08-06-85	21.0 ug/l PCE
3	04-04-88	VOC NOT FOUND
	07-02-87	15.0 ug/l PCE
	03-23-87	39.0 ug/l PCE
	09-04-86	49.0 ug/l PCE
	05-22-86	43.9 ug/l PCE
	05-22-86	36.0 ug/l PCE
	10-04-85	14.4 ug/l PCE
	08-07-85	29.0 ug/l PCE
	03-13-85	29.0 ug/l PCE
4 Uvalde City **(#51-104)	04-04-88	2.5 ug/l PCE
	04-04-88	VOC NOT FOUND
	01-26-88	VOC NOT FOUND
	07-09-87	13.0 ug/l PCE
	03-24-87	10.0 ug/l PCE
	09-04-86	7.5 ug/l PCE
	05-22-86	7.7 ug/l PCE
	08-07-85	5.9 ug/l PCE
	03-11-85	3.0 ug/l PCE
	08-23-84	<3.0 ug/l PCE
	04-05-84	9.0 ug/l PCE
	02-28-84	6.4 ug/l PCE

5		04-05-88	5.3 ug/l PCE
		08-07-85	5.7 ug/l PCE
		03-11-85	3.0 ug/l PCE
		08-23-84	9.4 ug/l PCE
		04-05-84	13.4 ug/l PCE
6		04-05-88	VOC NOT FOUND
		04-05-88	4.8 ug/l PCE
		03-24-87	7.4 ug/l PCE
		05-22-86	9.6 ug/l PCE
		08-06-85	8.6 ug/l PCE
		03-11-85	12.0 ug/l PCE
		08-23-84	10.0 ug/l PCE
7		04-05-88	5.2 ug/l DCE
		03-12-85	6.3 ug/l PCE
		08-22-84	5.3 ug/l PCE
8		04-04-88	VOC NOT FOUND
		09-03-86	6.0 ug/l PCE
		05-21-86	10.1 ug/l PCE
		05-21-86	5.5 ug/l PCE
		10-04-85	26.0 ug/l PCE
9		04-04-88	3.3 ug/l PCE
		04-04-88	VOC NOT FOUND
		05-09-87	29.0 ug/l PCE
		03-24-87	48.0 ug/l PCE
		09-04-86	>120.0 ug/l PCE
		05-21-86	112.0 ug/l PCE
		05-21-86	79.0 ug/l PCE
		10-04-85	127.0 ug/l PCE
10		08-28-86	49.0 ug/l PCE
11	Kea MONIT WELL #1	04-04-88	18.0 ug/l PCE
		04-04-88	8.9 ug/l PCE
		01-25-88	VOC NOT FOUND
		09-25-87	61.0 ug/l PCE*
		07-02-87	51.0 ug/l PCE
		03-25-87	110.0 ug/l PCE
		01-22-87	23.0 ug/l TCE
12	Kea MONIT WELL#2	04-04-88	13.0 ug/l PCE
		04-04-88	7.4 ug/l PCE
		01-22-88	VOC NOT FOUND
		09-24-87	VOC NOT FOUND*
		07-02-87	17.0 ug/l PCE
		07-02-87	15.0 ug/l Toluene
		05-12-87	4.5 ug/l TCE
		03-25-87	1.6 ug/l PCE
		01-27-87	220.0 ug/l PCE

13	Kea MONIT WELL#3	04-04-88	70.0 ug/l PCE
		04-04-88	36.0 ug/l PCE
		01-25-88	83.0 ug/l PCE
		09-25-87	80.0 ug/l PCE*
		07-02-87	51.0 ug/l PCE
		03-25-87	55.0 ug/l PCE
		01-27-87	27.0 ug/l PCE
27	Kea MONIT WELL#5	04-04-88	5.0 ug/l PCE
		04-04-88	VOC NOT FOUND
		01-22-88	VOC NOT FOUND
		09-24-87	VOC NOT FOUND*
		07-01-87	VOC NOT FOUND
		05-01-87	VOC NOT FOUND
14	B-6A	02-11-87	380.0 ug/l PCE
			8.9 ug/l TCE
			82.0 ug/l DCE
15	B-7A	02-11-87	190.0 ug/l PCE
16		04-05-88	18.0 ug/l PCE
		03-23-87	29.0 ug/l PCE
17		04-05-88	32.0 ug/l PCE
		03-24-87	0.6 ug/l PCE
		08-07-85	1.7 ug/l PCE
18		04-04-88	6.6 ug/l PCE
19		04-05-88	6.5 ug/l PCE
20		04-05-88	11.4 ug/l PCE
		03-24-87	VOC NOT FOUND
		08-06-85	VOC NOT FOUND
21		04-04-88	9.6 ug/l PCE
		06-02-86	VOC NOT FOUND
22		04-05-88	VOC NOT FOUND
		04-05-88	2.8 ug/l PCE
	UVALDE CITY (#50-203)	04-05-88	VOC NOT FOUND
		04-04-88	VOC NOT FOUND
		03-24-87	44.0 ug/l PCE
	Kea Monit Well #4 (Qle H2) @ 45')	04-28-87	25.0 ug/l PCE
	Kea Monit Well #5 (Qle H20 @ 45')	04-30-87	54.0 ug/l PCE

Qle TEST Well #1	04-05-88	17.0 ug/l DCE
		6.4 ug/l TCE
		110.0 ug/l PCE*
	01-27-88	270.0 ug/l PCE
	09-25-87	110.0 ug/l PCE
	07-17-87	440.0 ug/l PCE
	06-11-87	37.0 ug/l PCE
	05-15-87	23.0 ug/l PCE
		14.0 ug/l DCE
		2.0 ug/l TCE
Qle TEST Well #2	04-05-88	8.1 ug/l DCE
		12.0 ug/l TCE
		1,850 ug/l PCE
	01-27-88	1,300 ug/l PCE
	09-25-87	1,200 ug/l PCE*
	07-17-87	1,600 ug/l PCE
	06-12-87	1,400 ug/l PCE
		5.7 ug/l TCE
Qle TEST Well #3	04-05-88	3.2 ug/l TCE
		460 ug/l PCE
	01-27-88	52 ug/l PCE
	09-25-87	22 ug/l PCE*
	07-17-87	110 ug/l PCE
Qle TEST Well #4	04-05-88	16 ug/l DCE
		5.4 ug/l TCE
		190 ug/l PCE
	01-27-88	860 ug/l PCE
	09-25-87	460 ug/l PCE*
	07-28-87	730 ug/l PCE
Qle TEST Well #5	04-05-88	3.4 ug/l TCE
		180 ug/l PCE
	01-27-88	210 ug/l PCE*
	09-25-87	210 ug/l PCE
	07-17-87	590 ug/l PCE
Qle TEST Well #7	04-05-88	Dry, No Sample
	01-27-88	Dry, No Sample
	09-25-87	18 ug/l PCE*
	08-05-87	27 ug/l PCE

Qle TEST	04-05-88	Dry, No Sample
Well #8	01-27-88	180 ug/l DCE
		25 ug/l TCE
		100 ug/l PCE
	09-25-87	430 ug/l DCE*
		24 ug/l TCE
		160 ug/l PCE
	08-25-87	330 ug/l DCE
		21 ug/l TCE
		160 ug/l PCE
	08-06-87	150 ug/l DCE
		11 ug/l TCE
		80 ug/l PCE
GENSCO	08-25-87	34 ug/l Methylene Chloride
B-1		

DATA SUMMARY OF UVALDE VOLATILE ORGANIC INVESTIGATION

(BY EPA METHOD 624 [GC/MS])

(NEGATIVE WATER SAMPLES)

(CIRCLE ON ACCOMPANYING MAP)

WELL NUMBER	DATE SAMPLED	RESULTS
1	04-06-88	VOC NOT FOUND
	08-06-85	VOC NOT FOUND
2	05-22-86	VOC NOT FOUND
	08-06-85	VOC NOT FOUND
3	04-05-88	VOC NOT FOUND
	03-12-85	VOC NOT FOUND
4	04-04-88	VOC NOT FOUND
	03-12-85	VOC NOT FOUND
5	03-19-85	VOC NOT FOUND
6	04-07-88	VOC NOT FOUND
	03-11-85	VOC NOT FOUND
*7	03-13-85	VOC NOT FOUND
*8	03-13-85	VOC NOT FOUND
*9	03-20-85	VOC NOT FOUND
*10	03-13-85	VOC NOT FOUND
11	04-04-88	VOC NOT FOUND
	10-04-85	VOC NOT FOUND
12	04-04-88	VOC NOT FOUND
	04-04-88	VOC NOT FOUND
	05-23-86	VOC NOT FOUND
	10-04-85	VOC NOT FOUND
13	04-04-88	VOC NOT FOUND
	11-12-85	VOC NOT FOUND
14	04-10-86	VOC NOT FOUND
15	05-23-86	VOC NOT FOUND
16	06-02-86	VOC NOT FOUND
17	09-03-86	VOC NOT FOUND

18		03-23-87	VOC NOT FOUND
19		03-23-87	VOC NOT FOUND
20		03-23-87	VOC NOT FOUND
21		03-23-87	VOC NOT FOUND
23		04-04-88	VOC NOT FOUND
		04-04-88	VOC NOT FOUND
		03-26-87	VOC NOT FOUND
24		04-04-88	VOC NOT FOUND
		03-25-87	VOC NOT FOUND
25	Kea MONIT	04-04-88	VOC NOT FOUND
	Well #6	01-22-88	VOC NOT FOUND
		09-25-87	VOC NOT FOUND
		07-01-87	VOC NOT FOUND
		05-01-87	VOC NOT FOUND
26	Kea MONIT	04-04-88	VOC NOT FOUND
	Well #4	01-22-88	VOC NOT FOUND
		09-24-87	VOC NOT FOUND
		07-01-87	VOC NOT FOUND
		05-01-87	VOC NOT FOUND
28	QlE TEST	04-05-88	VOC NOT FOUND
	WEll #6	01-27-88	VOC NOT FOUND
		09-25-87	VOC NOT FOUND
		08-25-87	VOC NOT FOUND
29		04-05-84	VOC NOT FOUND
		04-05-84	VOC NOT FOUND
30		04-04-88	VOC NOT FOUND
32		04-05-88	VOC NOT FOUND
33		04-04-88	VOC NOT FOUND
34		04-04-88	VOC NOT FOUND
35		04-05-88	VOC NOT FOUND
36		04-04-88	VOC NOT FOUND

37	04-04-88	VOC NOT FOUND
38	04-04-88	VOC NOT FOUND
39	04-04-88	VOC NOT FOUND
40	04-05-88	VOC NOT FOUND
41	04-05-88	VOC NOT FOUND
42	04-04-88	VOC NOT FOUND
43	04-06-88	VOC NOT FOUND
44	04-07-88	VOC NOT FOUND
45	04-07-88	VOC NOT FOUND
46	04-07-88	VOC NOT FOUND

NON AQUEOUS SAMPLES

SAMPLE TYPE	NAME	DATE SAMPLES	RESULTS
CORE	T.I.S. B-6 (12')	2-11-87	N/D
CORE	T.I.S. B-6 (21')	2-11-87	N/D
CORE	T.I.S. B-7 (23')	2-11-87	N/D
SLUDGE	Sewer Sump	6-20-85	208 mg/kg DCE
SLUDGE	T.I.S. Sump	7-16-85	9.0 mg/kg DCE .035 mg/kg Benzene .535 mg/kg Toluene .298 mg/kg E-Benzene
SLUDGE	T.I.S. Sump	7-16-85	6.12 mg/kg DCE .033 mg/kg PCE .056 mg/kg Benzene
SLUDGE	T.I.S. Sump	7-16-88	.758 mg/kg Toluene .624 mg/kg E-Benzene
SOIL	Outside T.I.S. Sump	7-16-88	.054 mg/kg Toluene .026 mg/kg E-Benzene
OIL	Gensco Waste	6-14-85	46:4 mg/l Toluene

SLUDGE	T.I.S. Sewer Line	2-09-88	1.7 mg/kg DCE .57 mg/kg TCE 33.7 mg/kg PCE
SLUDGE	T.I.S. Sewer Line	2-09-88	.06 mg/kg TCE 5.0 mg/kg PCE
SLUDGE	T.I.S. Sewer Line	2-09-88	.09 mg/kg DCE .15 mg/kg TCE 8.6 mg/kg PCE

UVALDE EQUIP CO. (CONTENTS OF ABANDONED TANK)

TANK		DATE	RESULTS
TANK #1	(NORTH)	6-12-87	310 ug/l BENZENE 490 ug/l TOLUENE
TANK #2	(SOUTH)	6-12-87	3.7 ug/l TOLUENE

*Samples analyzed by Lab after recommended two week maximum holding time.

**Four samples were taken by the city of Uvalde from point of use (homes) served by YP69-51-104. Samples for VOA taken to RK on 4-22-86. No VOC's Found.

PCE = Tetrachloroethylene
TCE = Trichloroethylene
DCE = Trans 1-2 Dichloroethylene

TAYLOR SLOUGH

TOWN OF UVALDE

MEMORIAL HOSPITAL

SOUTHWEST TEXAS JR. COLLEGE

GARNER FIELD

90

1023

EXPLANATION

EASTERN UVALDE TEXAS VOC INVESTIGATION

STUDY AREA BASE MAP (FIG. 2)

12 CONTAMINATED EDWARDS WELL

(2) UNCONTAMINATED EDWARDS WELL

SCALE 1: 12000

0 1000 2000 3000 4000 5000 FEET

N

APPENDIX A, FIG. 1

APPENDIX B

Early Sample Events Used to Define Study Area

Sq. represents squares on figure 1. Cr. represents circles on figure 1. * indicates wells not shown on figure 1. All wells are completed in the Edwards aquifer and sampled for VOCs.

February 1984 sampling event.

Well Number and Name	VOCs Present
Sq. 4	(+)
* (City well, N. side of Uvalde)	(-)
* (City well, N. side of Uvalde)	(-)
* (S. side of Uvalde)	(-)
* (S. side of Uvalde)	(-)

April 1984 sampling event.

Sq. 4	(+)
Sq. 5	(+)
Cr. 29	(-)

August 1984 sampling event.

Sq. 4	(+)
Sq. 5	(+)
Sq. 6	(+)
Sq. 7	(+)
* (W. Side of Uvalde)	(-)
* (SW. of Municipal Airport)	(-)
* (W. of Municipal Airport)	(-)

March 1985 sampling event.

Sq. 4	(+)
Sq. 5	(+)
Sq. 6	(+)
Sq. 7	(+)
Sq. 3	(+)
Cr. 3	(-)
Cr. 4	(-)
* (NE. of Airport)	(-)
Cr. 5	(-)
* (NE. of Airport)	(-)

* (NE. of Airport)	(-)
* (NE. of Airport)	(-)
Cr. 6	(-)

August 1985 sampling event.

Sq. 2	(+)
Sq. 17	(+)
Sq. 1	(+)
Sq. 5	(+)
Sq. 4	(+)
Sq. 3	(+)
Sq. 6	(+)
Cr. 2	(-)
Cr. 1	(-)
Cr. 22	(-)

October 1985 sampling event.

Sq. 3	(+)
Sq. 1A	(+)
Sq. 9	(+)
Sq. 8	(+)
Cr. 12	(-)
Cr. 11	(-)

May 1986 sampling event.

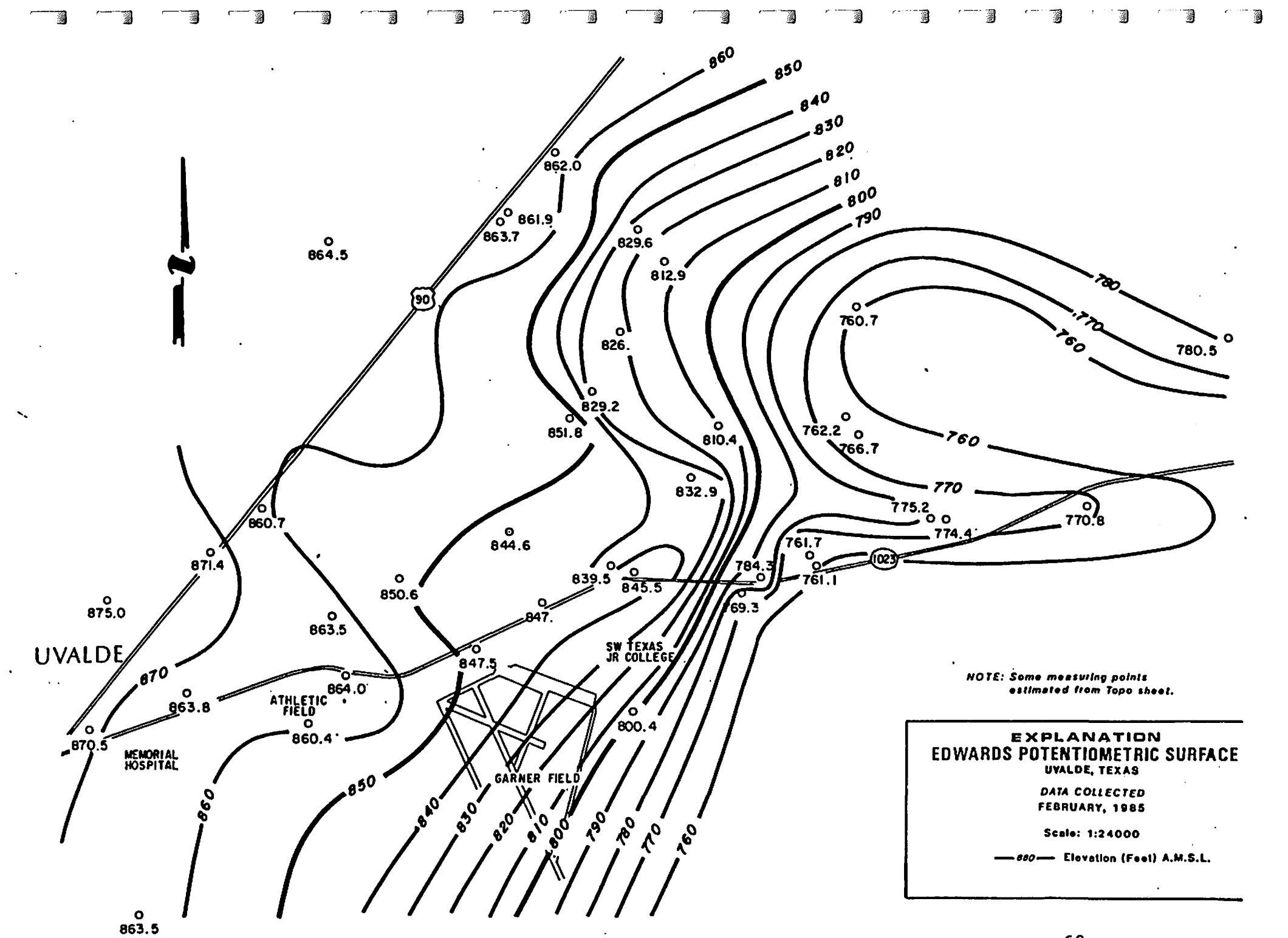
Sq. 1A	(+)
Sq. 2	(+)
Sq. 3	(+)
Sq. 4	(+)
Sq. 6	(+)
Sq. 8	(+)
Sq. 9	(+)
Cr. 2	(-)
Cr. 12	(-)
Cr. 15	(-)

September 1986 sampling event.

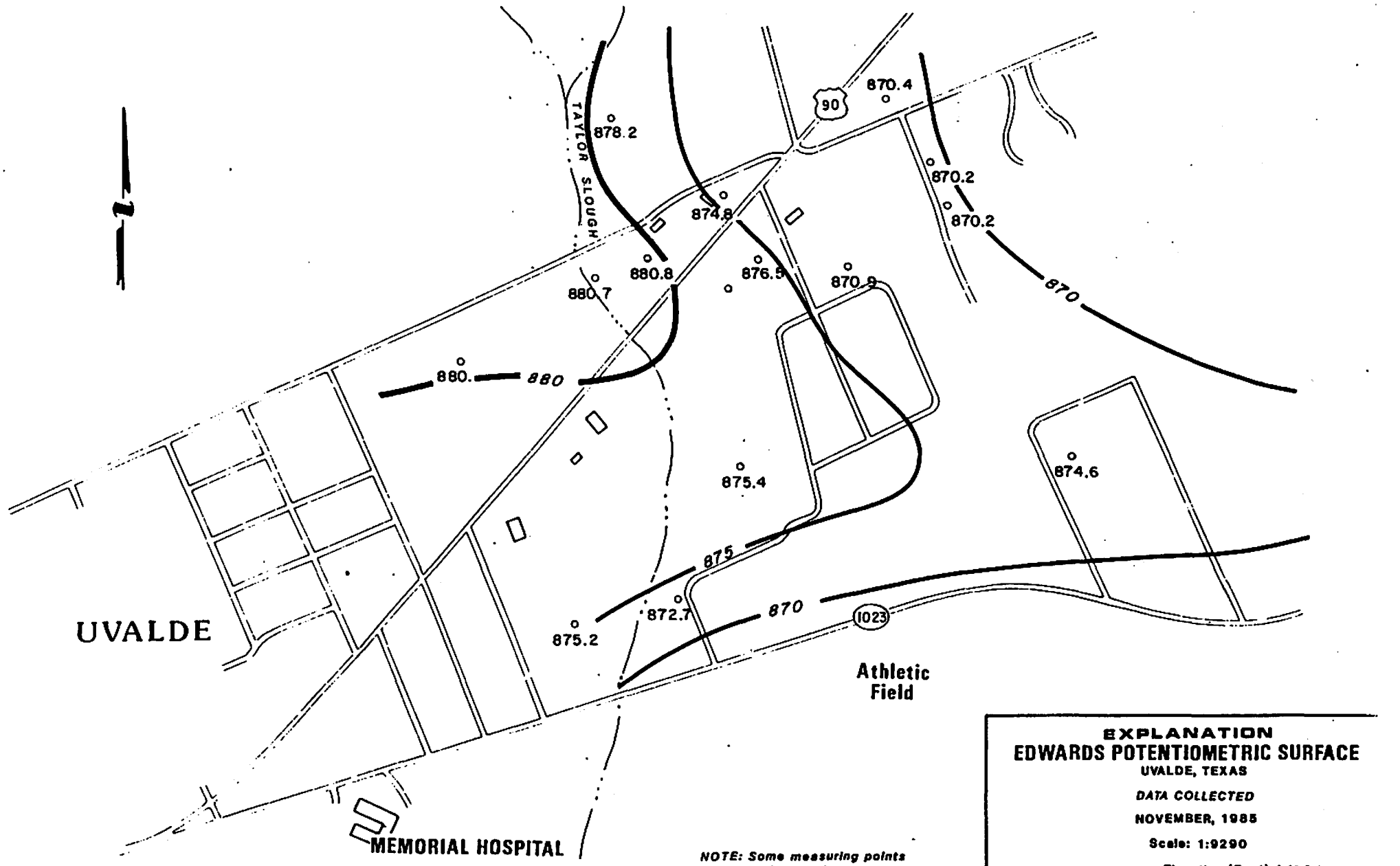
Sq. 1A	(+)
Sq. 2	(+)
Sq. 3	(+)
Sq. 4	(+)
Sq. 8	(+)
Sq. 9	(+)

March 1987 sampling event.

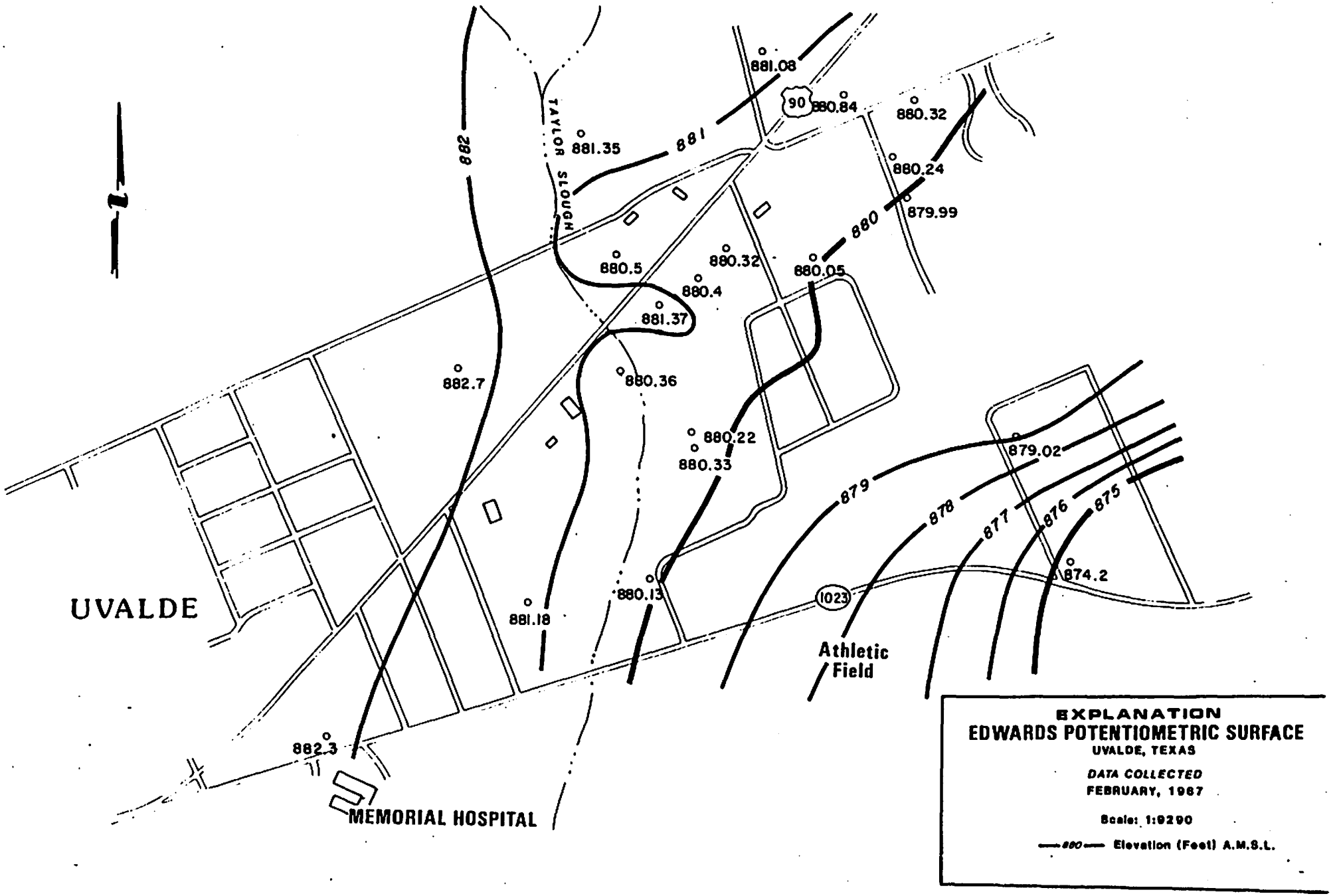
Sq. 1A	(+)
Sq. 1	(+)
Sq. 3	(+)
Sq. 4	(+)
Sq. 6	(+)
Sq. 9	(+)
Sq. 16	(+)
Sq. 17	(+)
* (City well, N. side of Uvalde)	(+)
* (private well, NW. of study area)	(-)
* (private well, NW. of study area)	(-)
* (private well, NW. of study area)	(-)
* (private well, NW. of study area)	(-)
Cr. 22	(-)
Cr. 23	(-)



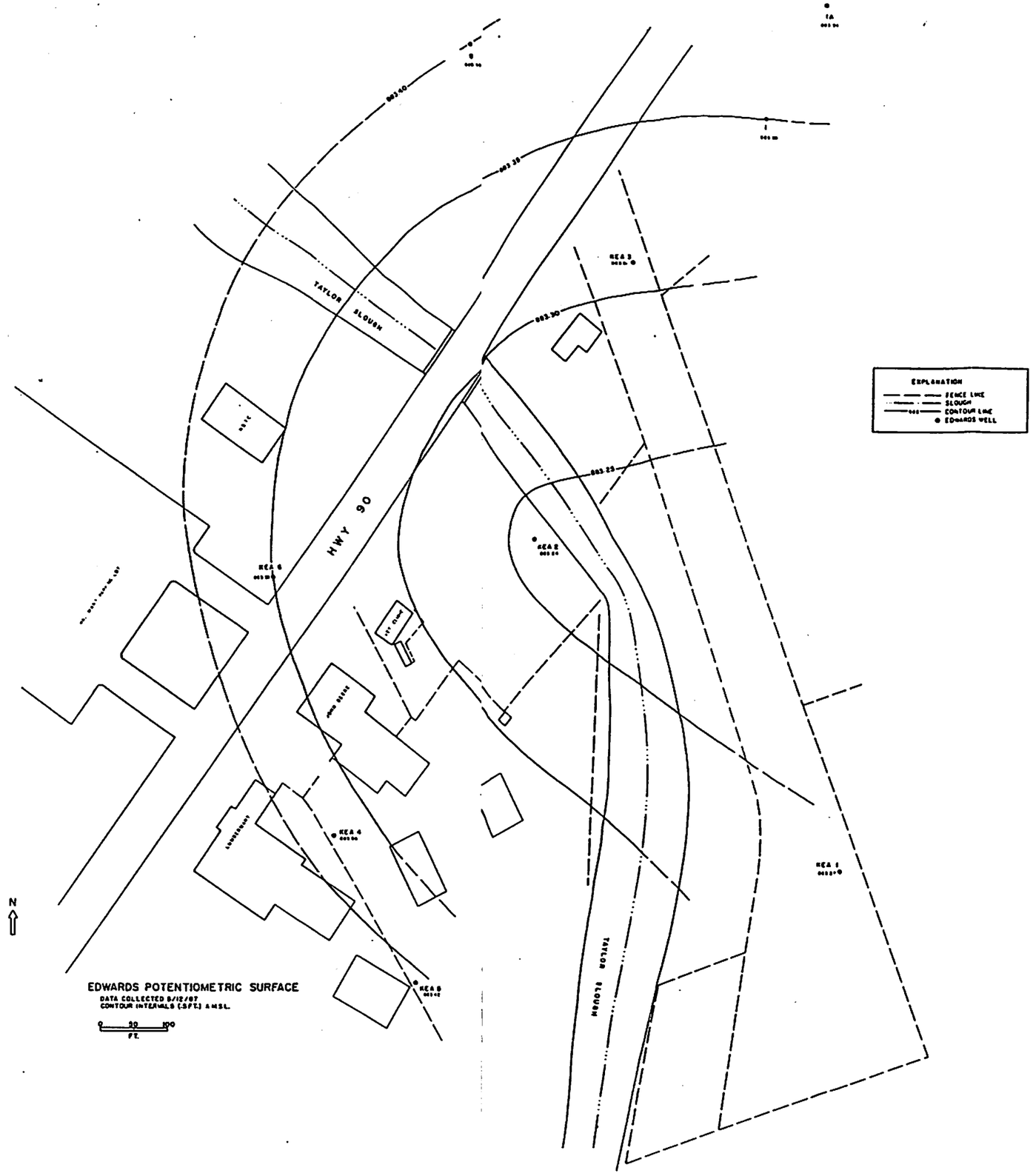
APPENDIX C, FIG. 1



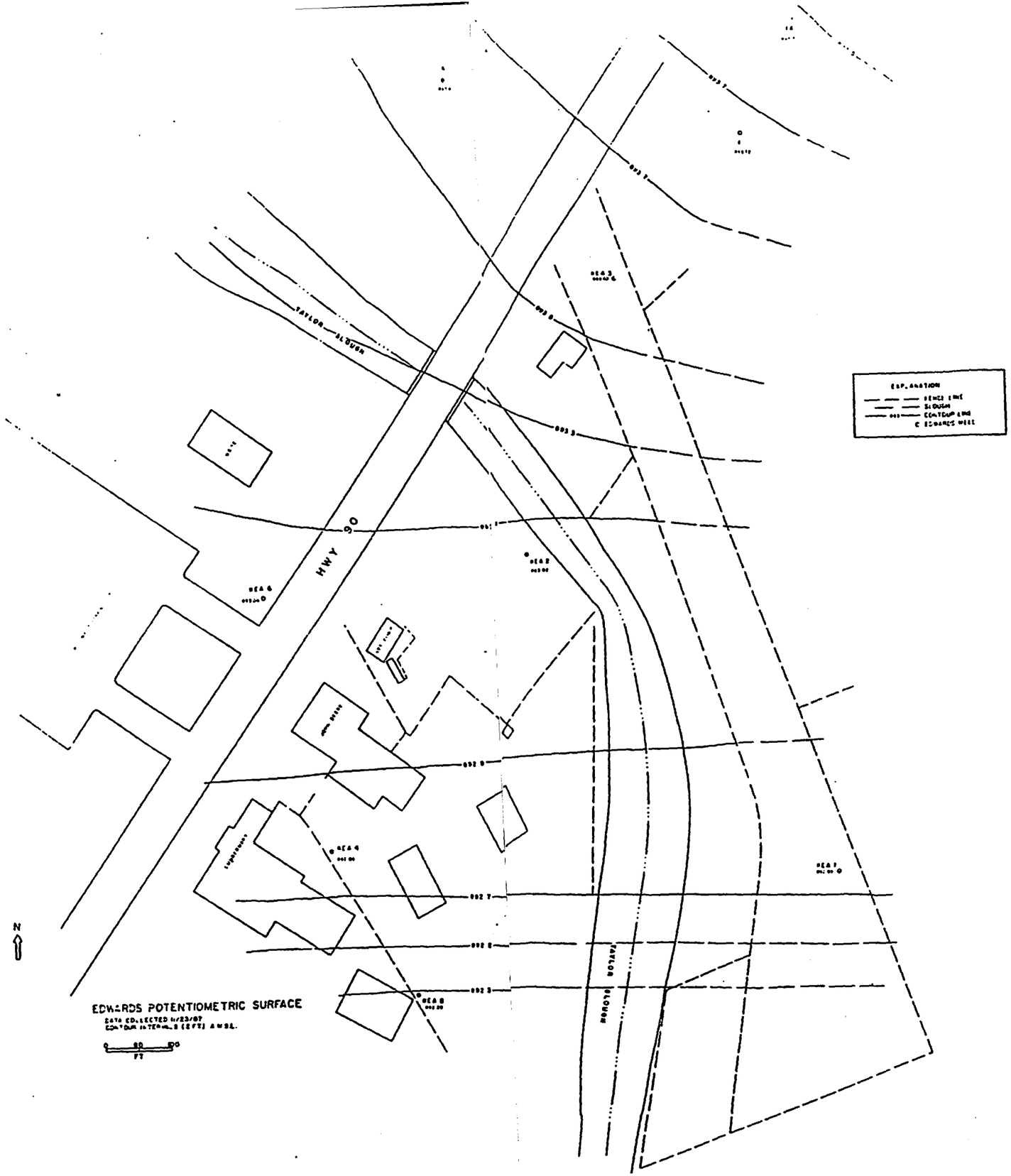
APPENDIX C, FIG. 2



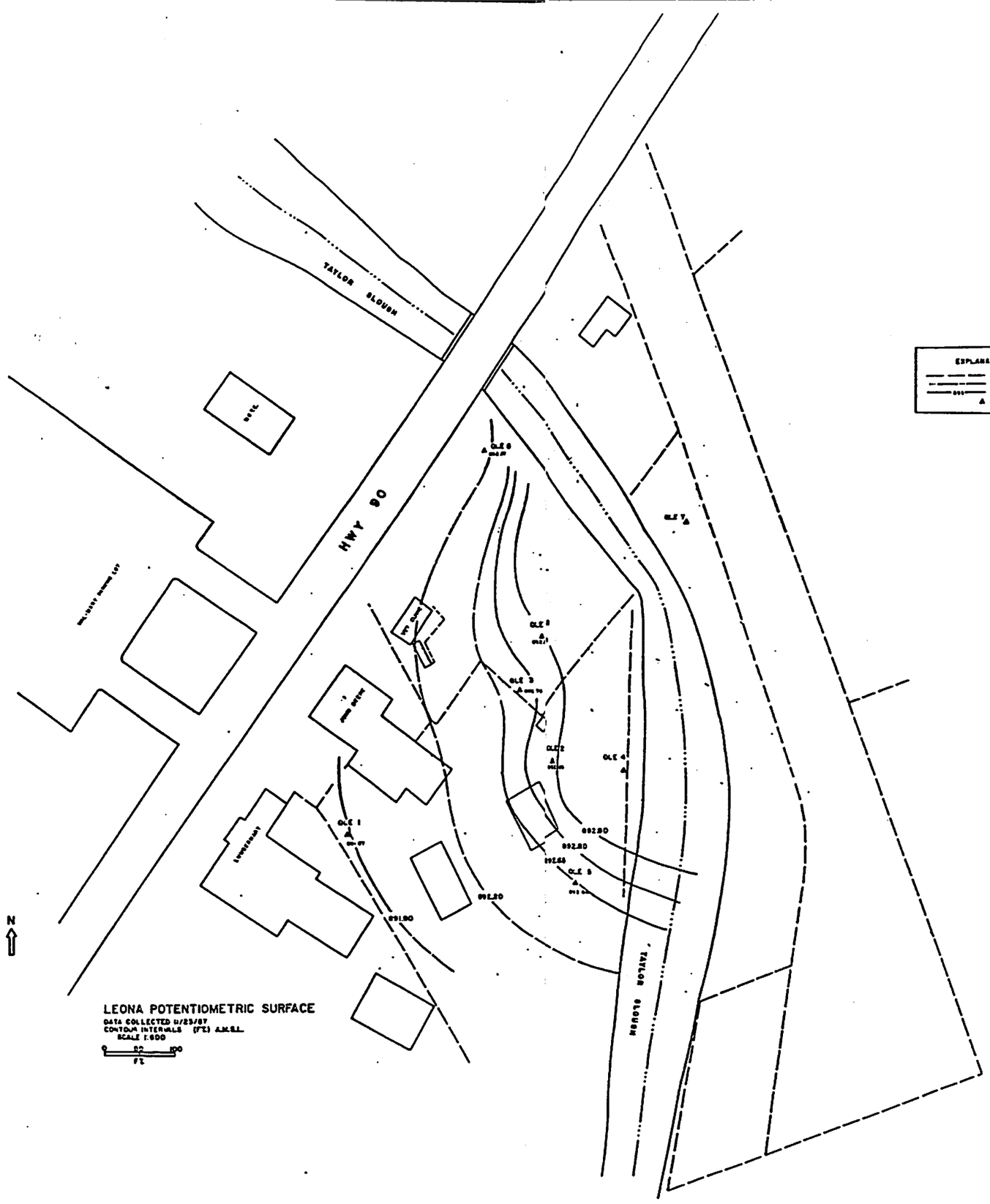
APPENDIX C, FIG. 3



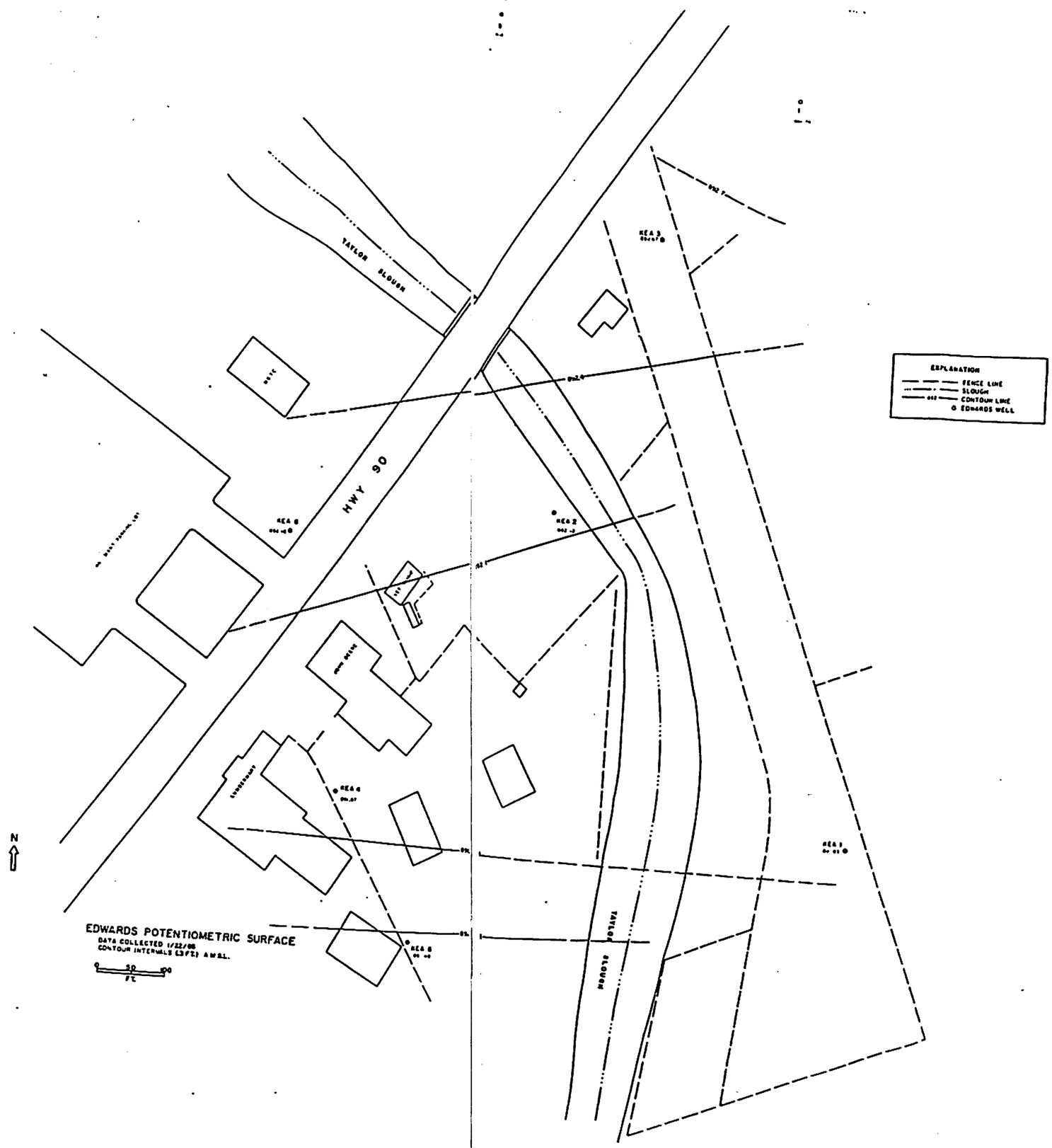
APPENDIX C, FIG. 4



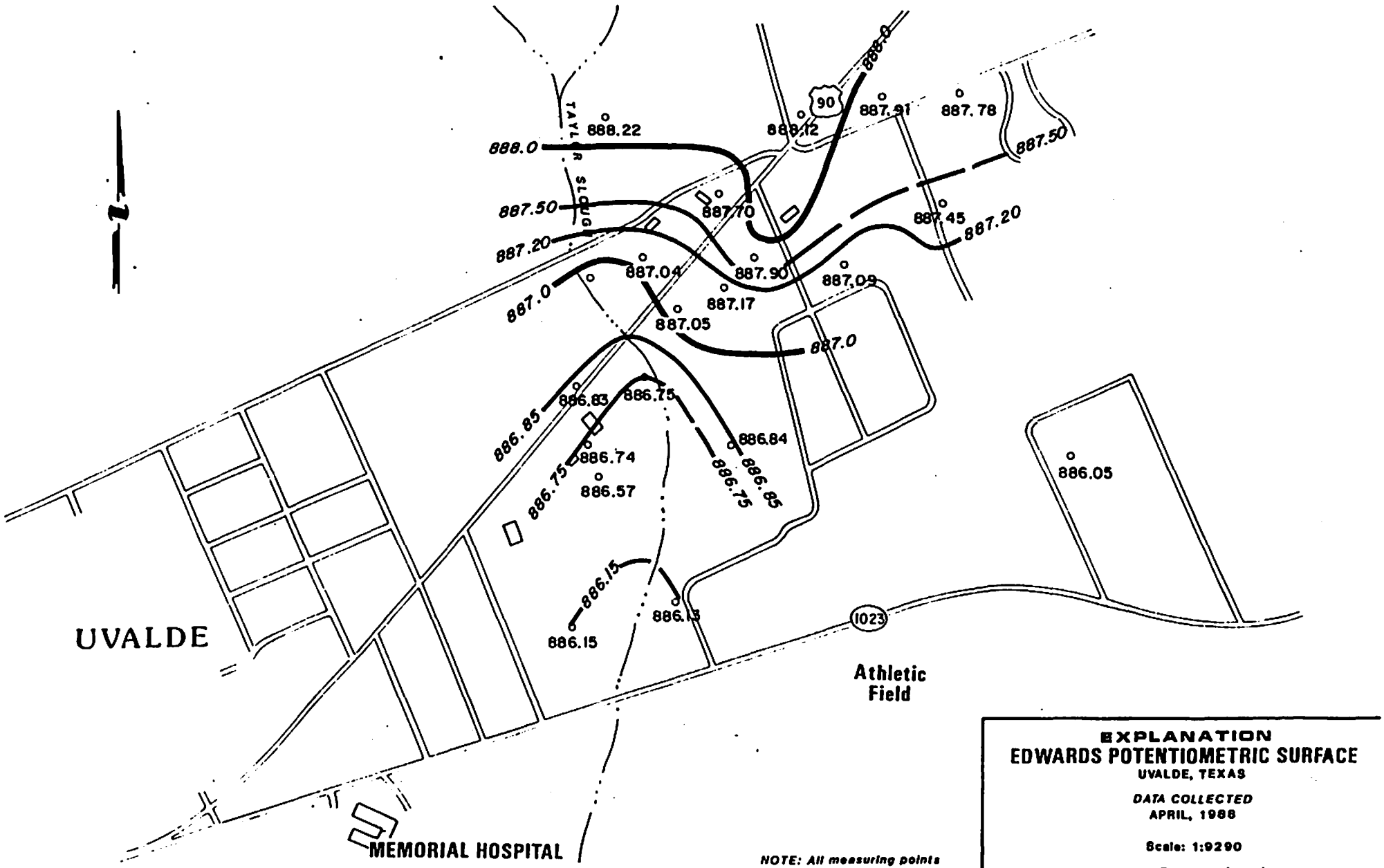
APPENDIX C, FIG. 5



APPENDIX C, FIG. 6



APPENDIX C, FIG. 7



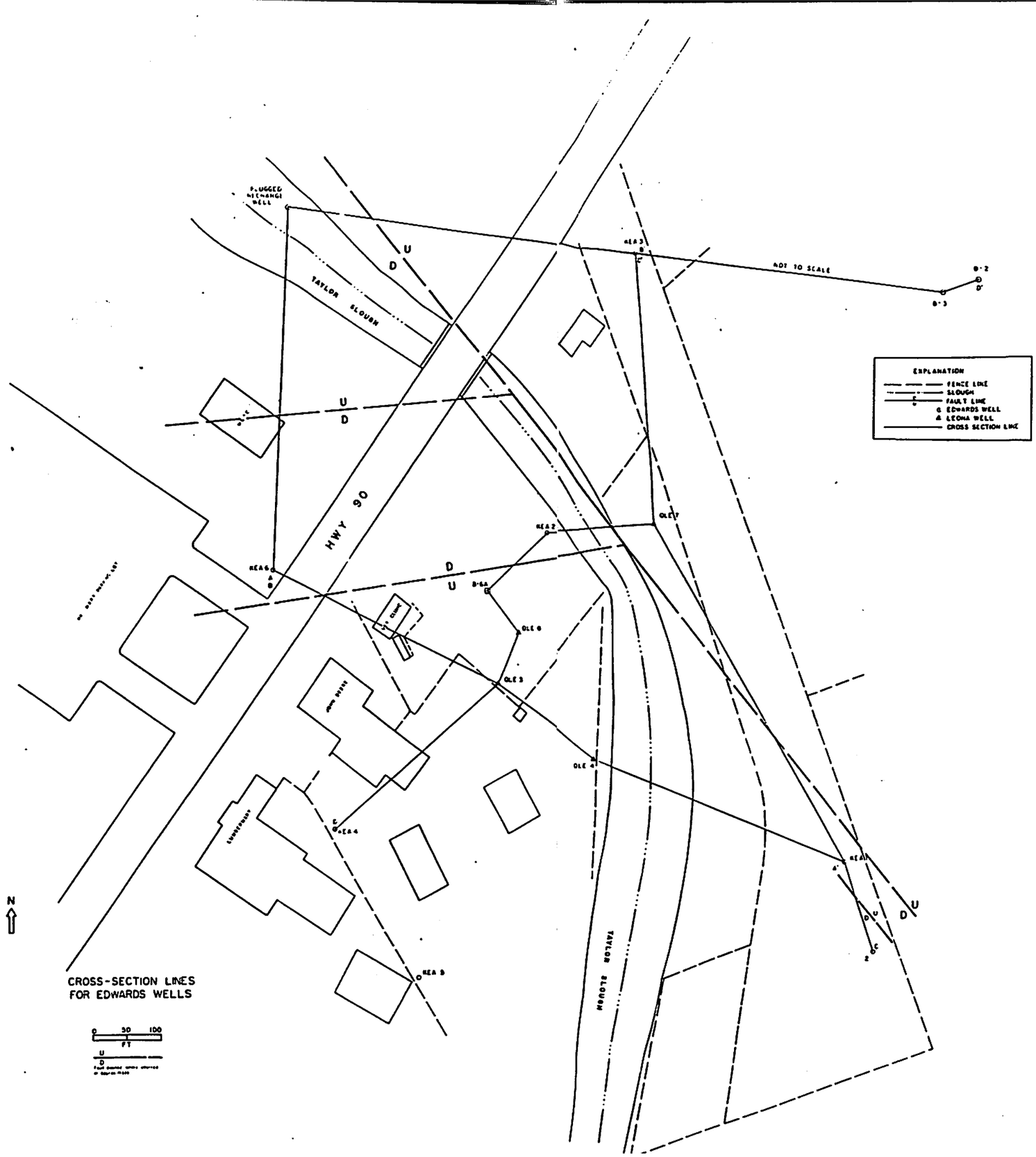
APPENDIX C, FIG. 8

Maverick basin

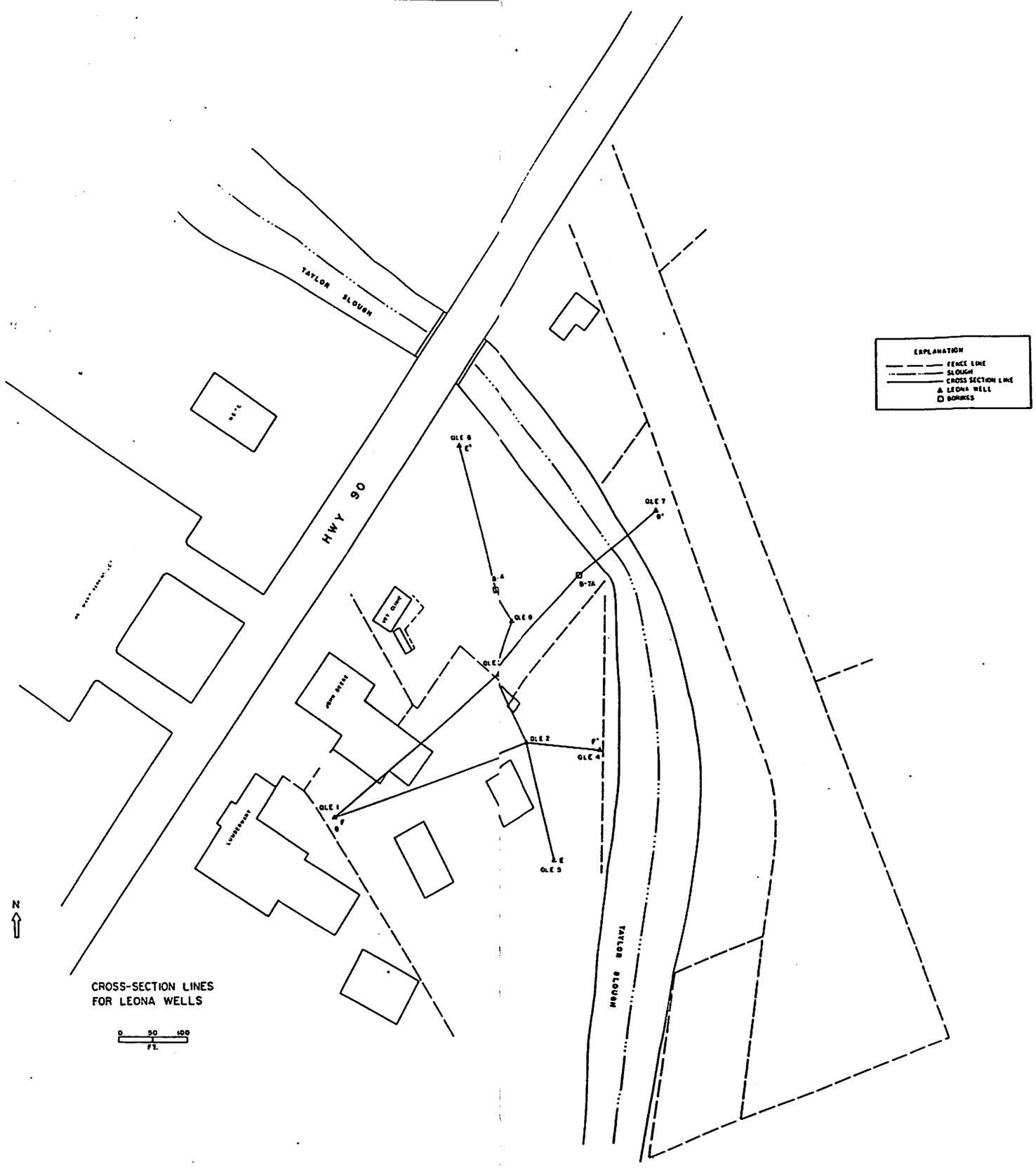
System	Provincial series	Group	Formation	Function	Member or informal unit	Function	Thickness (feet)	Lithology	Hydrostratigraphy
Quaternary			LEONA			AQ where saturated	6-80	Gravel, sand, silt, and clay. Coarser nearer the base and toward the Balcones fault Escarpment.	Alluvial fans extending from the Balcones fault Escarpment. Associated fluviatile deposits.
Cretaceous	Gulfian		Anacacho Limestone	CB			500	Limestone and marl; contains bentonite, chalky, and massive bedded.	Little permeability.
		Austin	Undivided	CB			600	Chalk and marl; chalk mostly microgranular calcite, bentonite seams, glauconitic.	Little to moderate permeability.
			Igneous rocks					Basalt.	Intrusive sills, laccoliths, and volcanic necks. Negligible permeability.
		Eagle Ford	Undivided	CB			250	Shale, siltstone, and limestone; flaggy limestone beds are interbedded with carbonaceous shale.	Little permeability.
	Comanchean	Washita	Buda Limestone	CB			100	Limestone; fine grained, bioclastic, glauconitic, hard, massive, nodular, argillaceous toward top.	Little permeability.
			Del Rio Clay	CB			120	Clay and shale; calcareous and gypsiferous, some thin beds of siltstone.	Negligible permeability.
		EDWARDS	Salmon Peak formation	AQ			380	Limestone; upper 80 feet contains reef talus grainstones and caprinid boundstones, crossbedding of grainstones; the lower 300 feet is a uniform dense carbonate mudstone.	Deep water deposits except toward the top. Upper part is moderately to very permeable. Lower part is almost impermeable except where fractured.
			McKnight	CB			150	Limestone and shale; upper 55 feet is a mudstone containing thin zones of collapse breccias; middle 24 feet is shaly, lime mudstone; lower part is limestone containing collapse breccias in upper part.	Deep basinal, euxinic deposits. Little permeability.
			West Nueces	CB			140	Limestone; upper 80 feet is largely a massive unit of miliolid and mollusc-bearing grainstone; lower 60 feet is a nodular, dense mudstone.	Upper part is moderately permeable. Lower part is almost impermeable.
		Trinity	Glen Rose	CB	Upper member		1,000-1,500	Limestone, dolomite, and marl; limestone is fine grained, hard to soft, marly; dolomite is porous and finely crystallized.	Little permeability.
					Lower member			Limestone and some marl. Massive bedded.	More permeable toward base of unit.
			Pearsall	CB			400	Sandstone, limestone, and shale.	Little permeability.
	Coahuilan		Sligo	CB			200	Limestone and some shale.	Little to moderate permeability.
			Hosston				900	Sandstone and shale.	Moderate to little permeability.
Pre-Cretaceous								Sandstone and limestone.	Little permeability.

APPENDIX D, FIG. 1

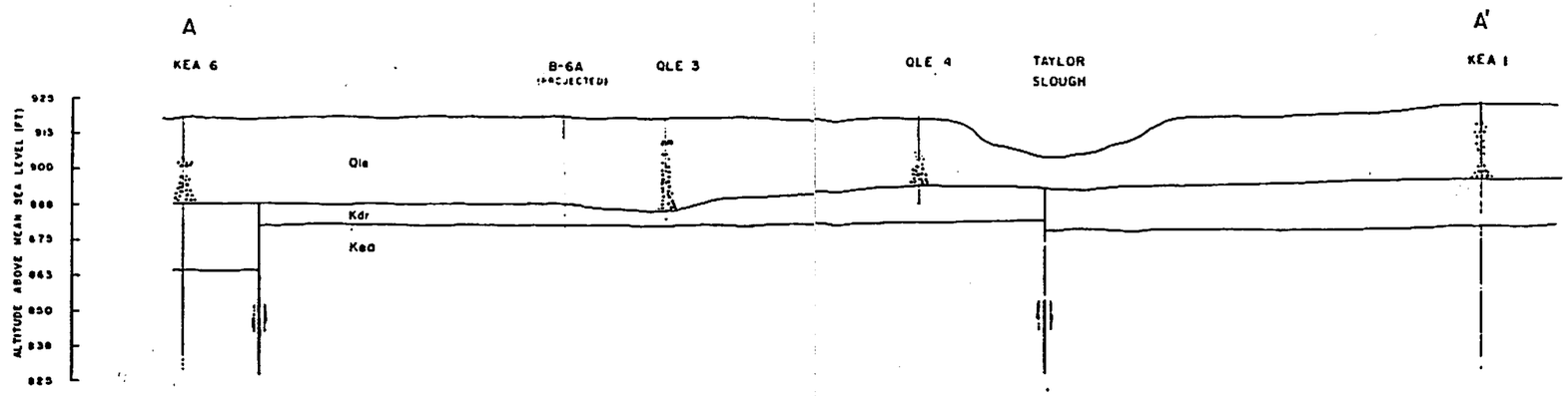
MODIFIED FROM MACLAY AND SMALL, 1984

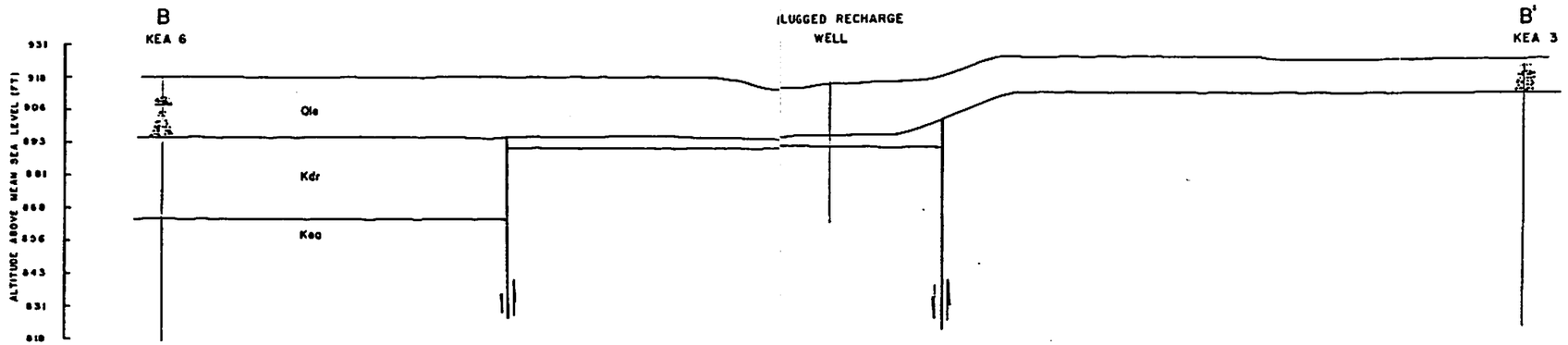


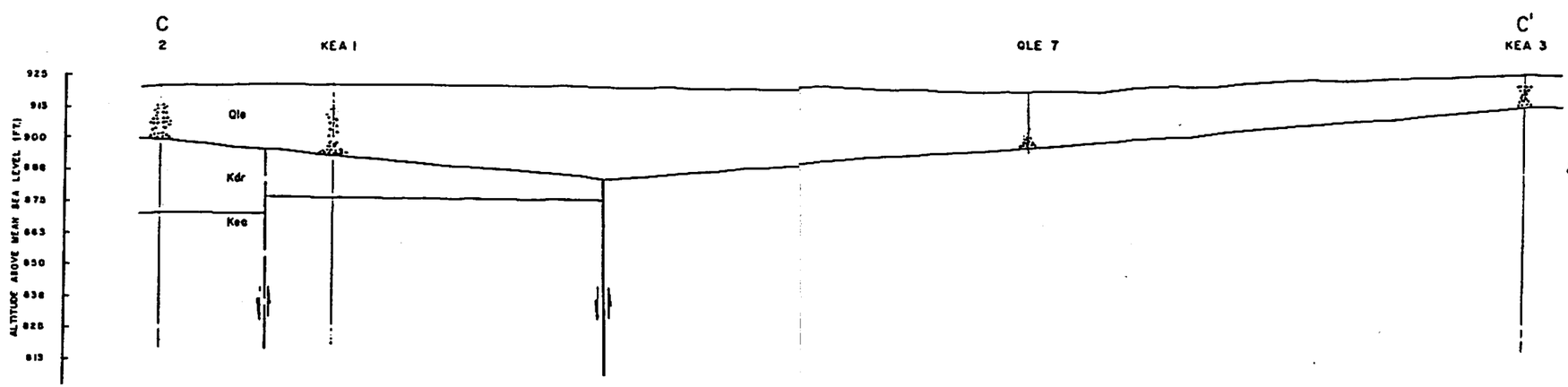
APPENDIX D, FIG. 2



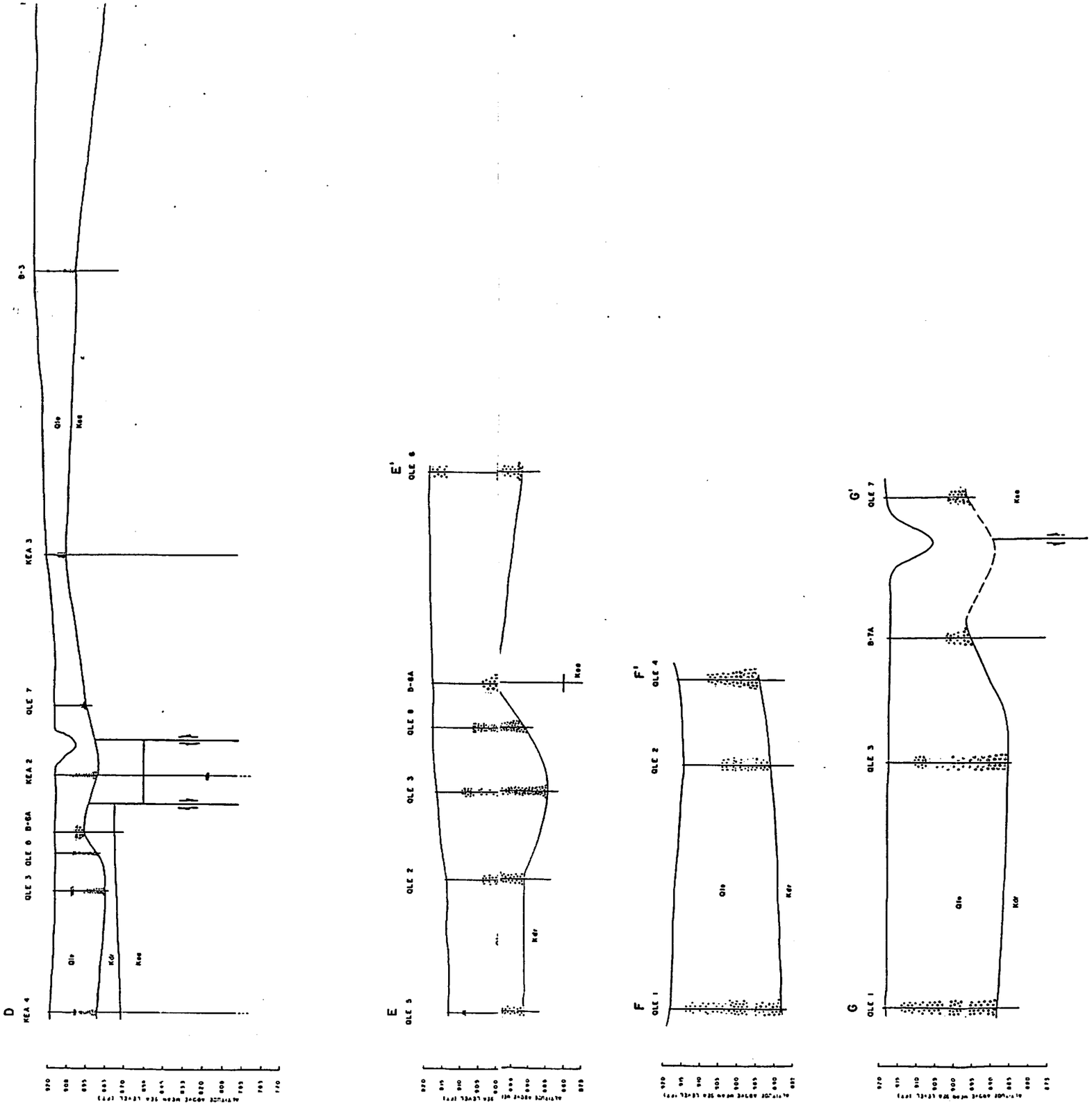
APPENDIX D, FIG. 3







APPENDIX D, FIG. 4



APPENDIX D, FIG. 4 (Cont'd)

APPENDIX E

Microgravity Survey

On January 6th and 7th 1987 a microgravity survey was conducted in the current study area using eight survey lines consisting of a total of 132 points (Appendix E, Fig. 1). A Lacoste and Romberg model D microgal gravity meter was used to take the microgravity readings.

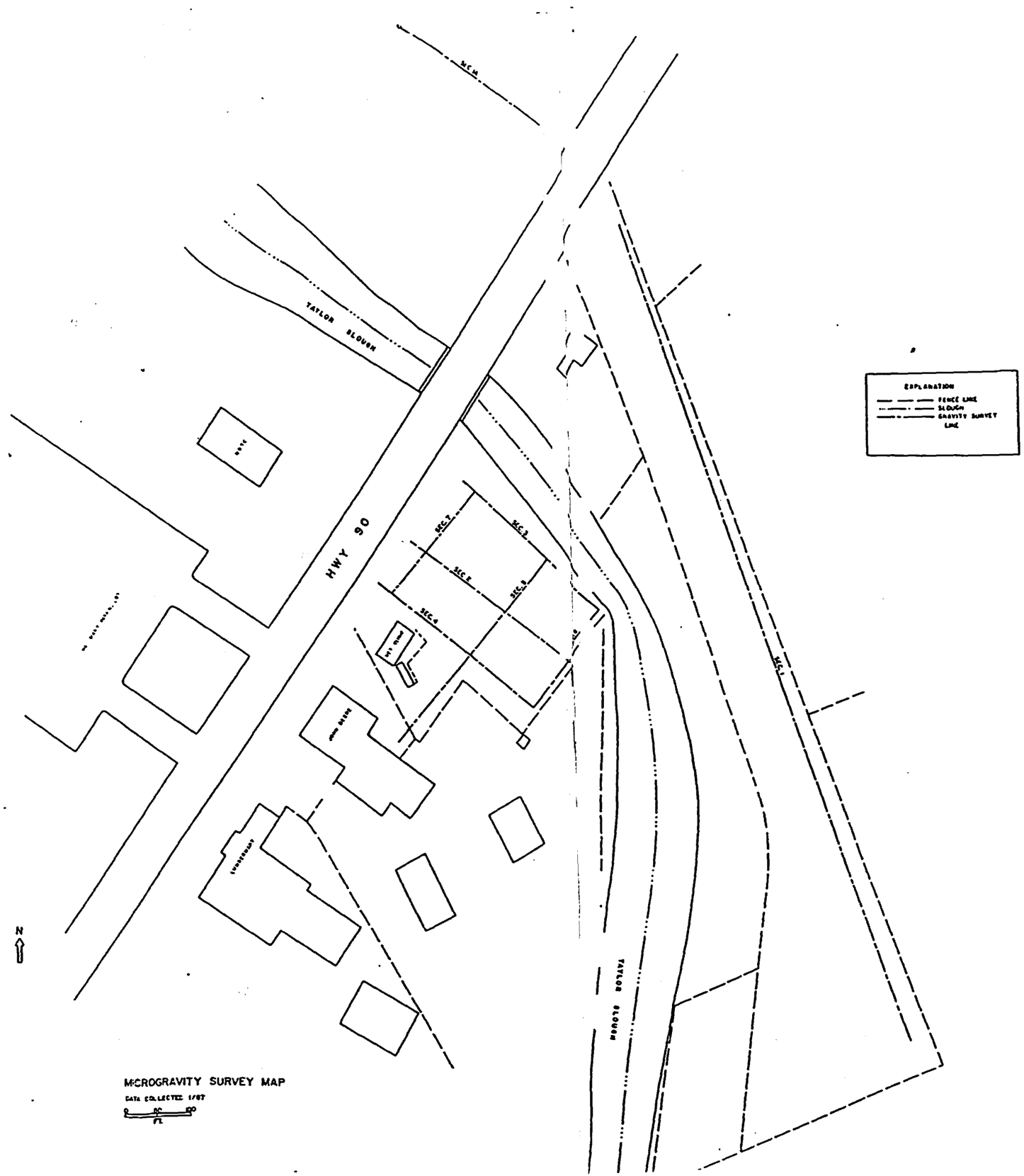
The Microgravity lines were placed and surveyed for elevation by district staff. The actual microgravity data was collected and reduced by Earth Science and Engineering of Austin, TX.. Standard gravity surveying techniques were used including the necessary corrections for latitude, free air corrections and Bouguer corrections.

Results of Microgravity Survey

Appendix E, Figure 2A-2D plots the obtained microgravity readings for the respective microgravity survey lines. Gravity readings are in negative milligals to allow for lower gravity readings to be shown as low points on the graphs.

Areas of gravity lows are interpreted as areas of missing mass. Missing mass in a carbonate aquifer would result from the limestone being subject to dissolution thus creating conduit flow paths; these conduit flow paths would be the most advantageous location for monitor well placement.

Edwards aquifer moniter wells Kea #1 and Kea #2 were placed in gravity lows and are capable of relatively greater discharges than other Edwards wells in the current study area.



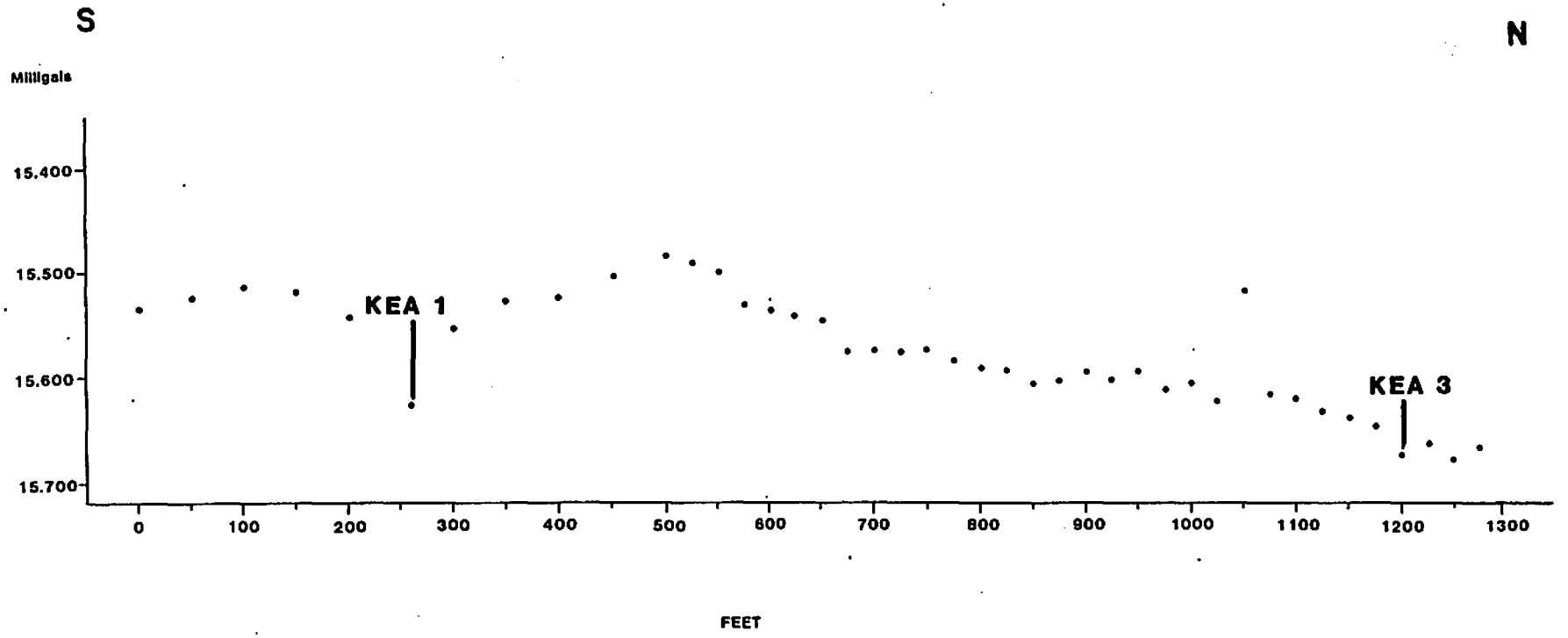
MICROGRAVITY SURVEY MAP

DATA COLLECTED 1/87

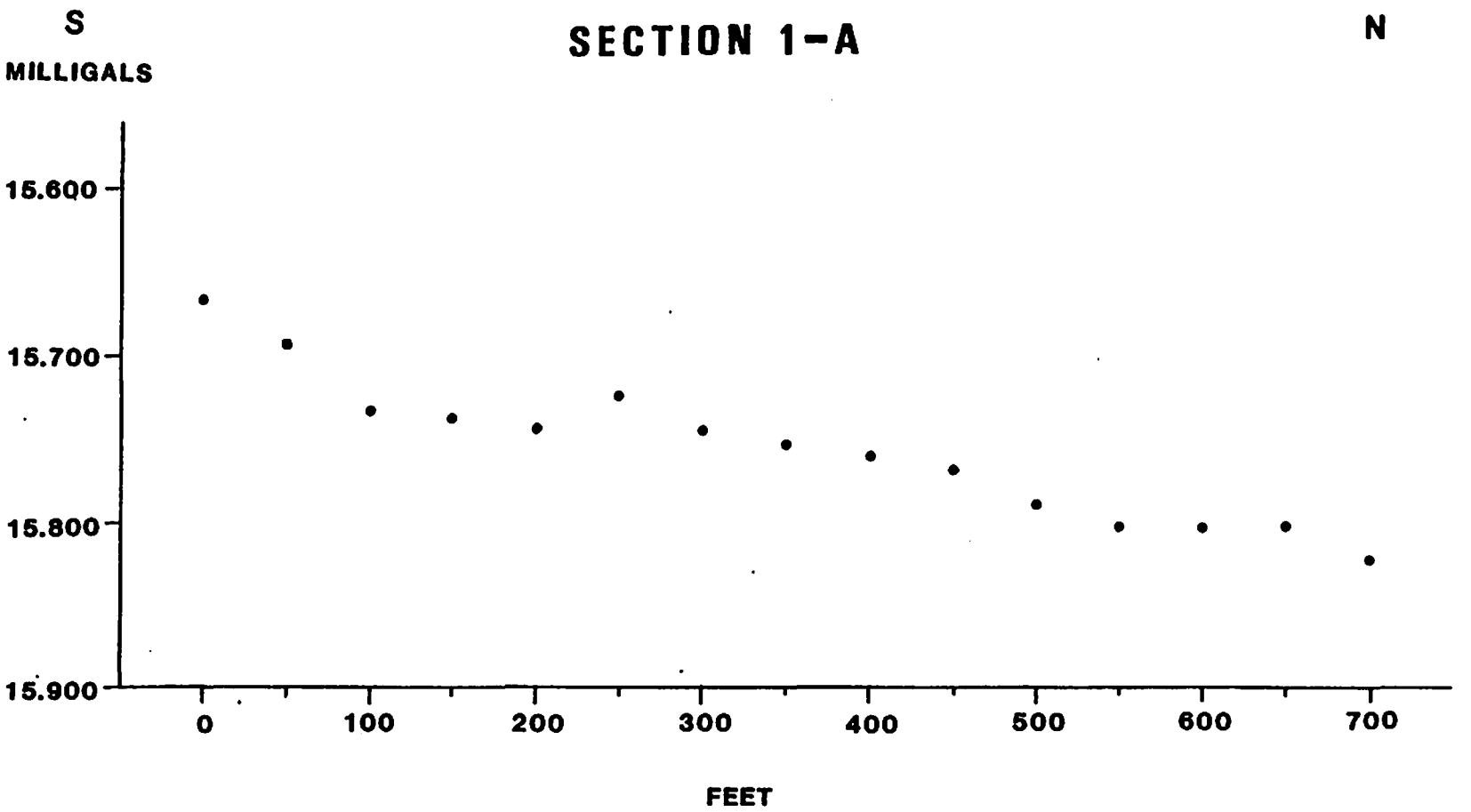
0 50 100
FT

APPENDIX E, FIG. 1

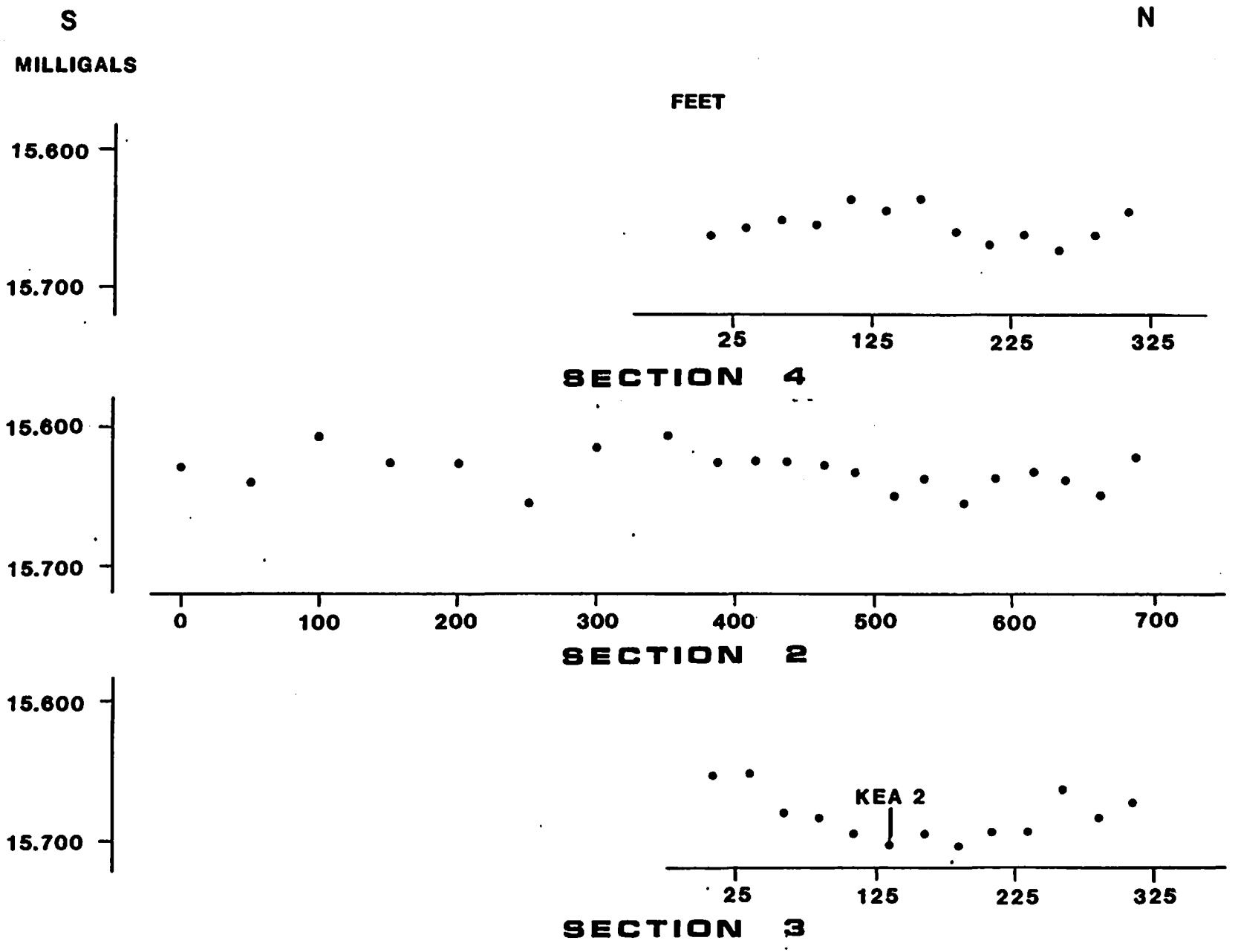
SECTION 1



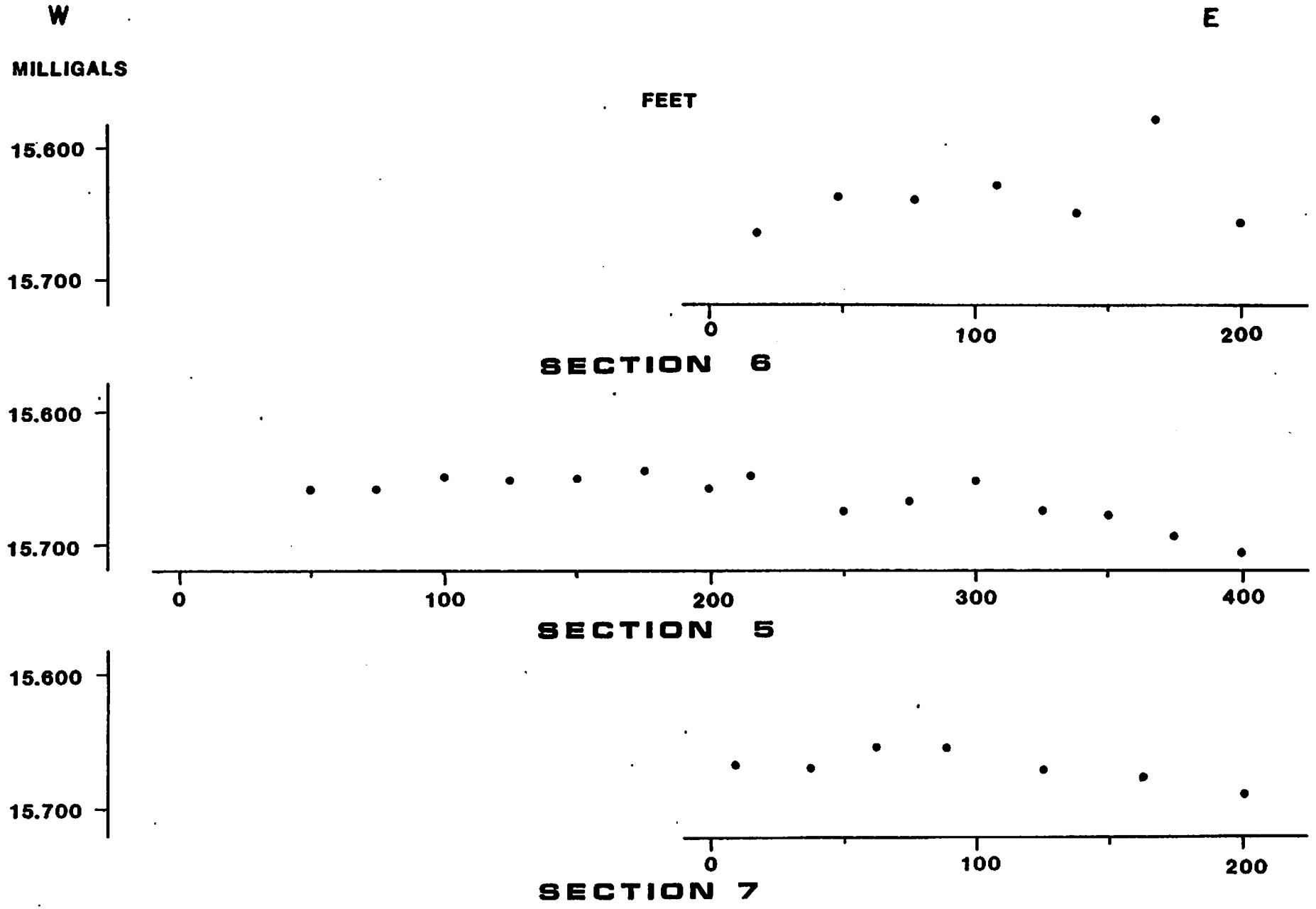
APPENDIX E, FIG. 2-A



APPENDIX E, FIG 2-B



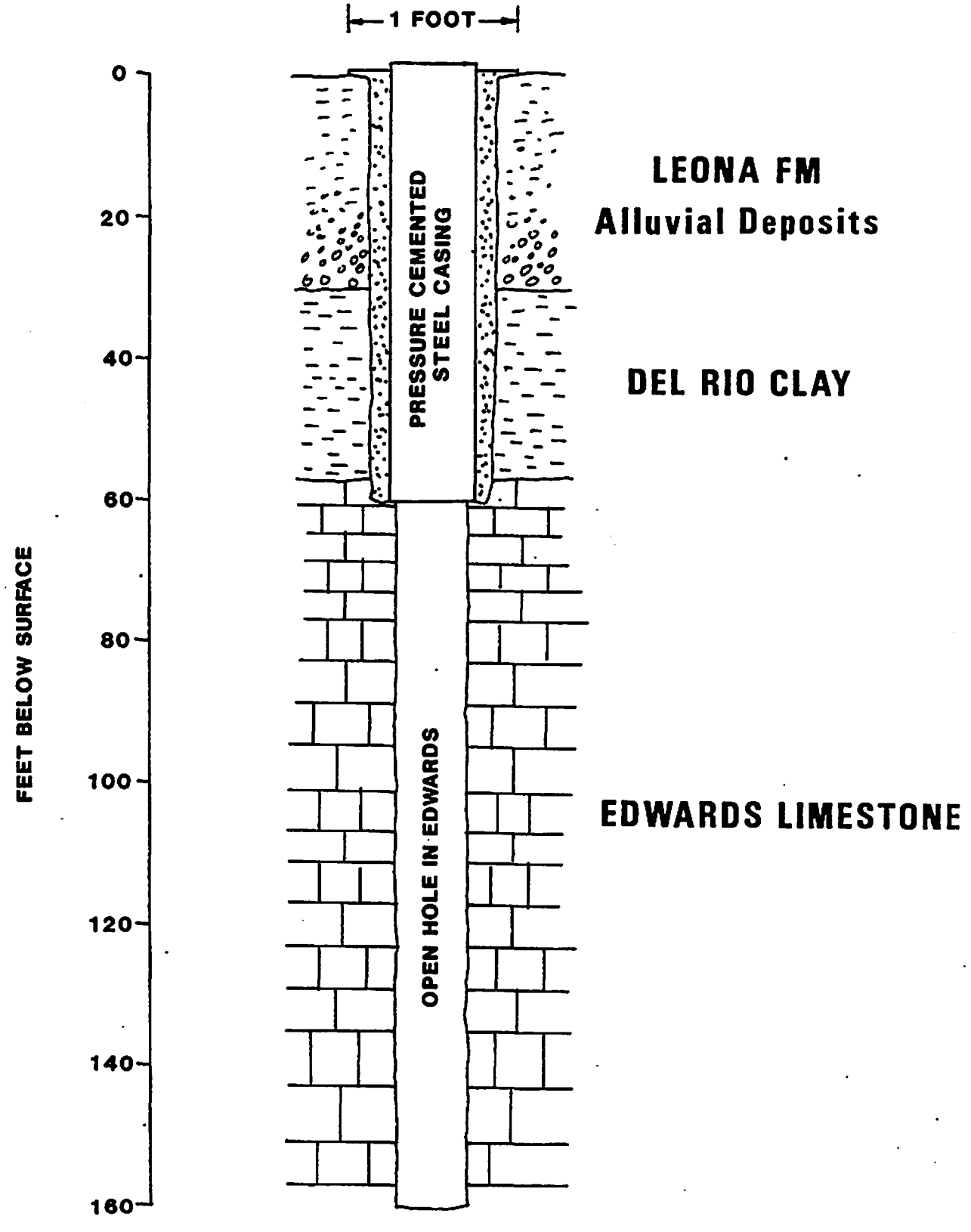
APPENDIX E, FIG 2-C



APPENDIX E, FIG. 2-D

UVALDE VOC INVESTIGATION
EDWARDS AQUIFER MONITOR WELL

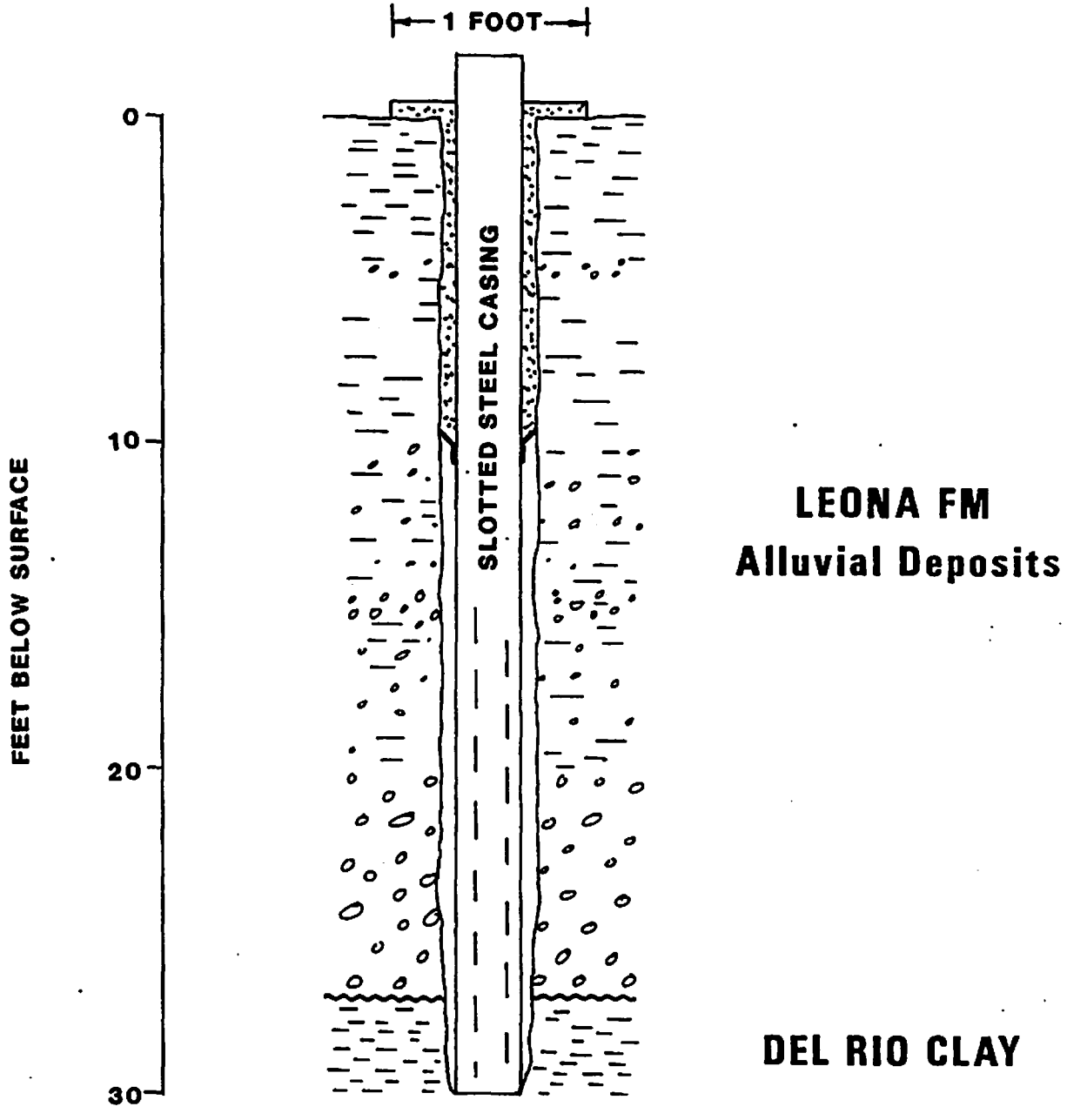
Typical Well Construction Diagram



APPENDIX F, FIG. 1

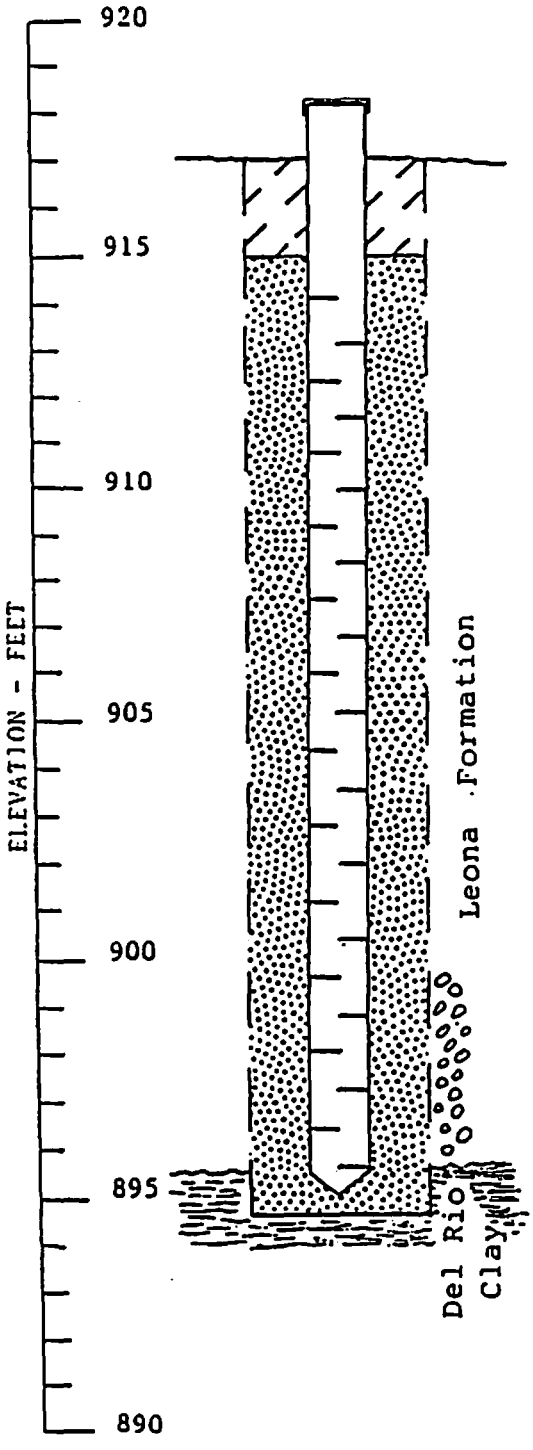
UVALDE VOC INVESTIGATION
LEONA AQUIFER MONITOR WELL

Typical Well Construction Diagram



APPENDIX F, FIG. 2

WELL CONSTRUCTION DETAILS QLE 9



MONITOR WELL DETAILS

Elevation Top of PVC 918.1 ft

Elevation of Ground Surface 917.0 ft

Depth to Top of Bentonite Seal 0.0 ft

Thickness of Bentonite Seal 2.0 ft

Depth to Top of PVC Well Screen 2.0 ft

Length of PVC Well Screen 20.0 ft

Depth to Bottom of PVC Well 22.0 ft

Depth to Bottom of Hole 22.5 ft

Ground water was not encountered at the time of drilling.

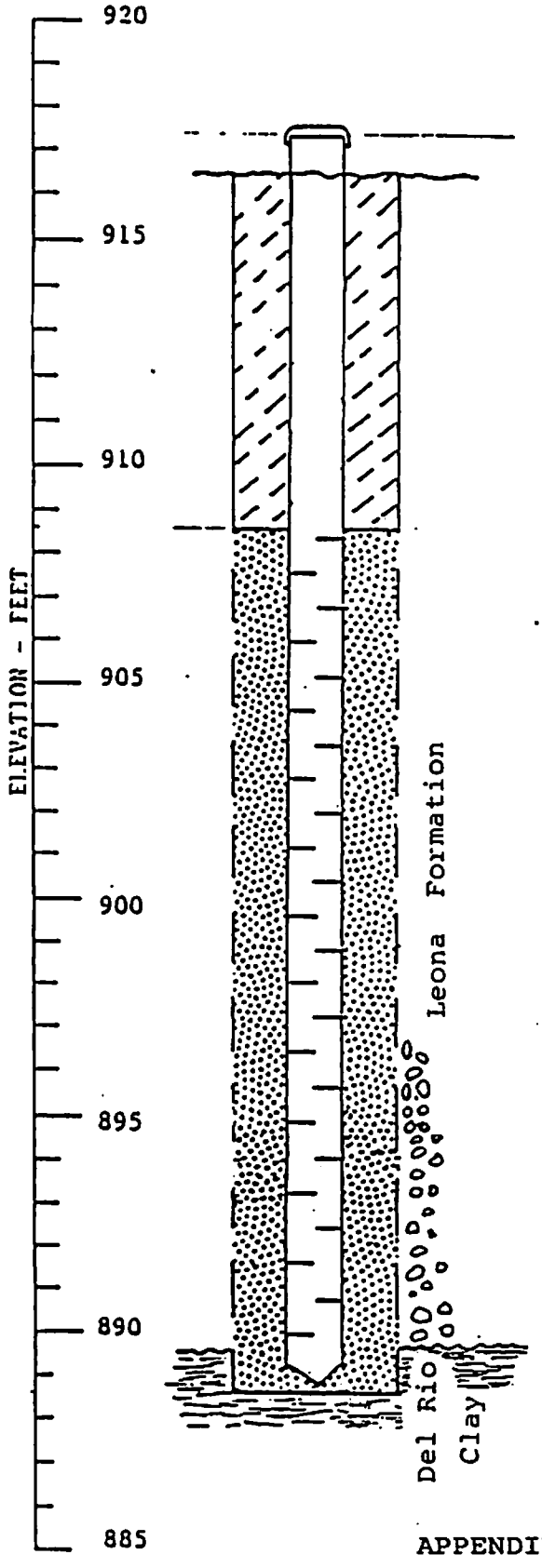
LEGEND

Bentonite Seal

20-40 Silica Sand Pack

APPENDIX F, FIG. 3

WELL CONSTRUCTION DETAILS QLE 10



MONITOR WELL DETAILS

Elevation Top of PVC Well 917.4 ft

Elevation of Ground Surface 916.5 ft

Depth to top of Bentonite Seal 0.0 ft

Thickness of Bentonite Seal 8.0 ft

Depth to Top of PVC Well Screen 8.0 ft

Length of PVC Well Screen 20.0 ft

Depth to Bottom of PVC Well 28.0 ft

Depth to Bottom of Hole 28.6 ft

Ground water was not encountered at the time of drilling.

LEGEND

Bentonite Seal

20-40 Silica Sand Pack

APPENDIX F., FIG. 4

Appendix G

Sampling Protocol

The objective of the sampling protocol was to obtain representative samples of formation waters and guard against cross-contamination by sampling equipment. Methodology of collection of samples for volatile organic compound analysis varied according to well type. Wells sampled include monitor wells installed into the Leona and Edwards formations by the Edwards Underground Water District, and other active and inactive private and public wells completed in the Edwards Aquifer.

In general, wells equipped with submersible pumps were purged until temperature, conductivity, and pH stabilized. Samples were collected into 40 ml V.O.A. vials upstream of pressure tanks from a point near the well head.

Wells not equipped with pumps were sampled with a Kemmerer stainless steel bailer. Wells were sampled just above the total depth of the well.

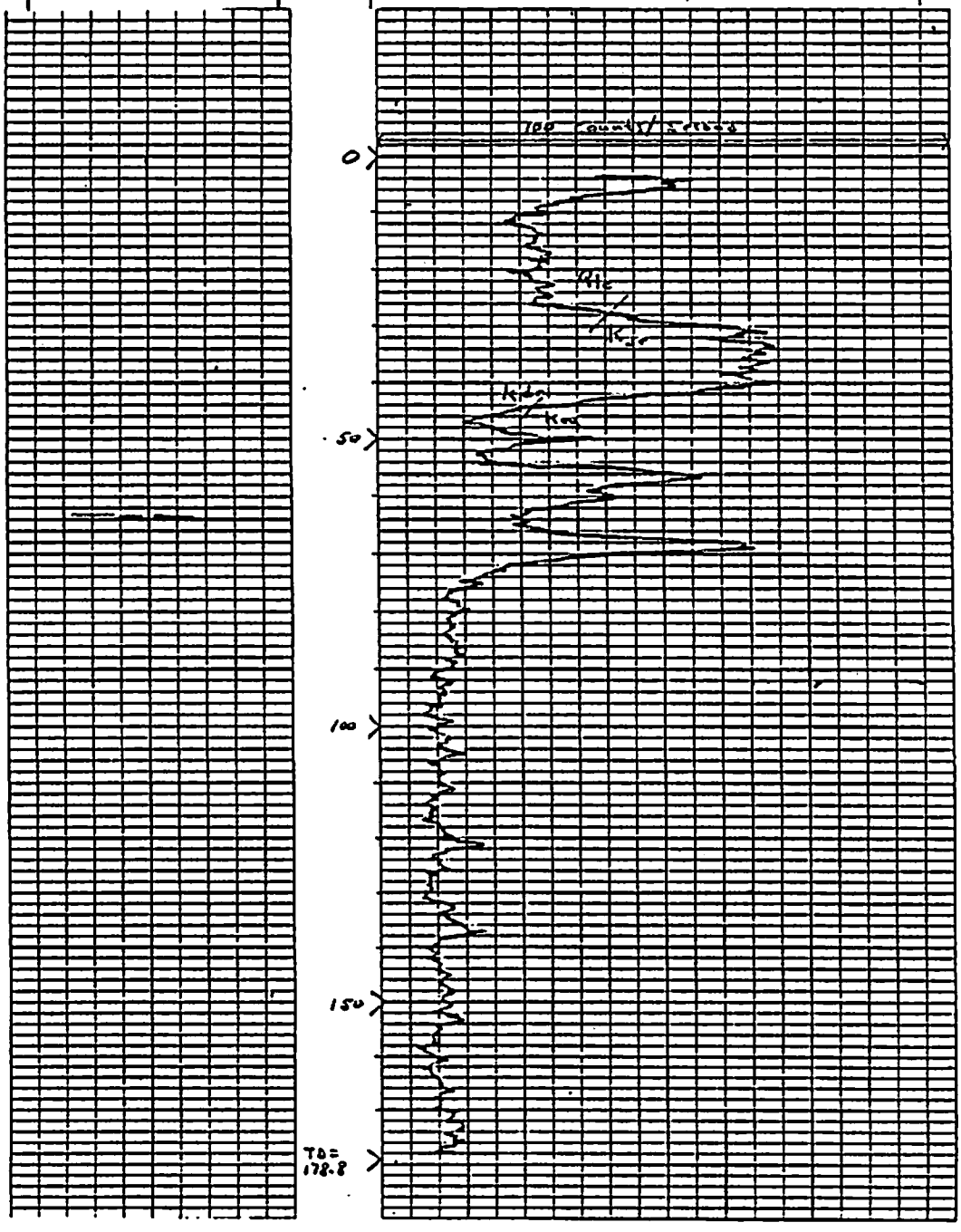
Owing to the generally low hydraulic conductivity of the Leona Formation, the Leona monitor wells were purged by bailing at least 24 hours prior to sampling events. This was accomplished by use of a large bailer mounted on a service vehicle.

In preparation of a sampling event, the Kemmerer sample bailer was washed with a high pressure, hot water wand and rinsed with distilled water. It was then rinsed with methyl alcohol and given a final distilled water rinse. Sampling equipment was decontaminated according to this procedure (excepting the high pressure wash) between each well site. Furthermore, wells were sampled in order of increasing contamination on the basis of previous results.

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMA AND CASING COLLAR LOG

DATE: 21-JAN-87
WELL NO: YP-69-50-324 WELL DEPTH: 179.00 (BELOW LSD)
LATITUDE: 29-13-15 LONGITUDE: 99-45-39 (D-M-S)
OWNER: O.V. CASEY
LOCATION: APPROX. 890 FT. SE OF HWY 90 & 250 FT. E OF SLOUGH

DRILLER: WILLIAMSON DRILLING METHOD: AIR ROTARY
CASING (1) DIA: 6.25 FROM: 0.00 TO: 64.00 (DIA = ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE (1) DIA: 8.00 FROM: 0.00 TO: 65.00
(2) DIA: 5.00 FROM: 65.00 TO: 177.00
LOG OPERATOR: HOYT LOG MP: 922.10 LOG TD: 178.00 LSD: 922.10
ELECT LOG: NO CALIPER LOG: YES (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 5.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND: 100.00/20.00 (CHART DIVISIONS)
COMMENTS: KEA 1, UVALDE VOC STUDY, WATER LEVEL M.P. = 923.54

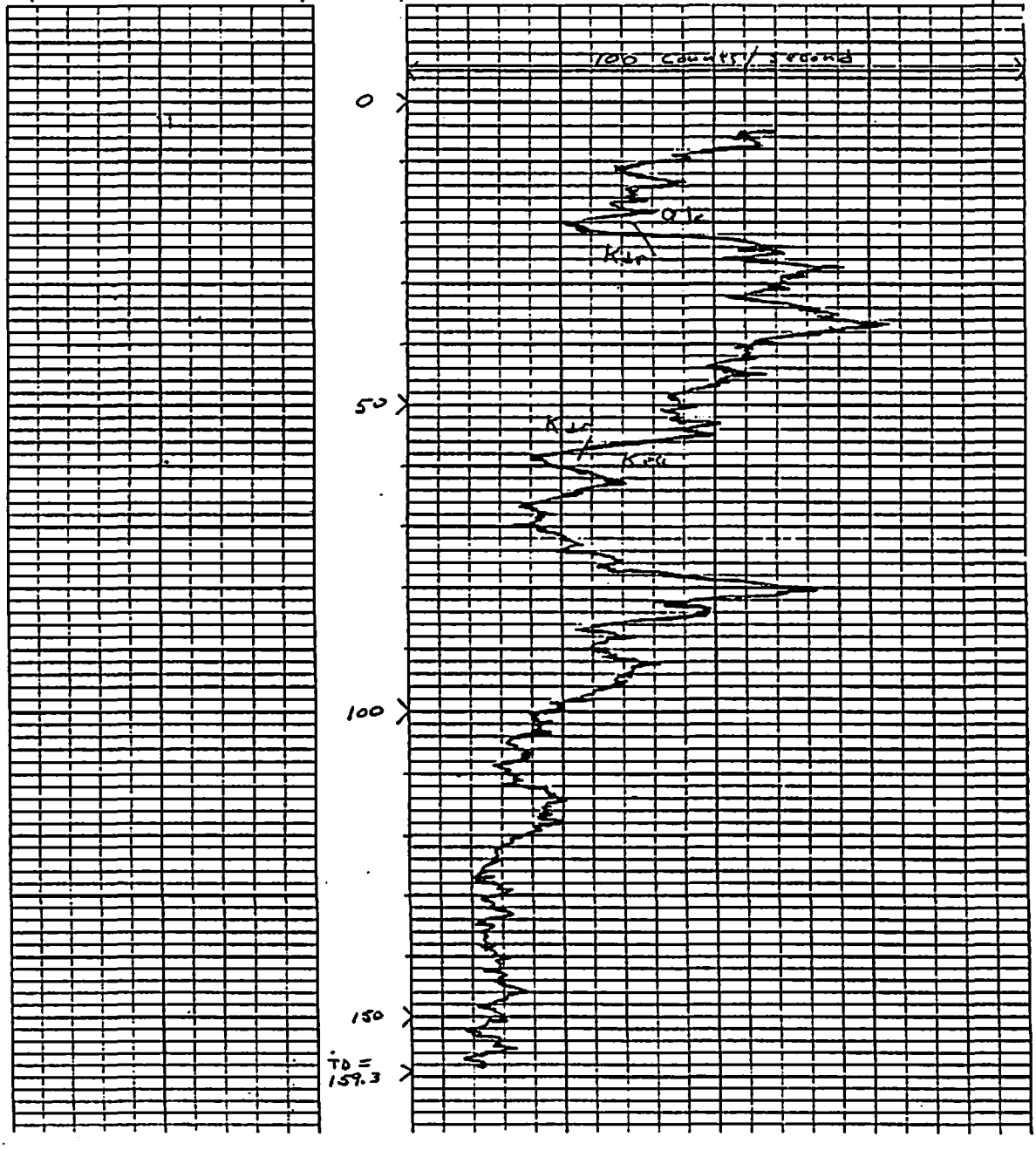


APPENDIX H, Kea 1

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 27-JAN-87
WELL NO: YP-69-50-321 WELL DEPTH: 159.50 (BELOW LSD)
LATITUDE: 29-13-18 LONGITUDE: 99-45-45 (D-M-S)
OWNER: UVALDE EQUIPMENT CO.
LOCATION: WEST BANK OF TAYLOR SLOUGH, 230 FT. SE OF HWY 90

DRILLER: WILLIAMSON DRILLING METHOD: AIR ROTARY
CASING (1) DIA: 6.25 FROM: 0.00 TO: 60.00 (DIA = ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE (1) DIA: 8.00 FROM: 0.00 TO: 61.00
(2) DIA: 5.00 FROM: 61.00 TO: 159.50
LOG OPERATOR: HOYT LOG MP:917.80 LOG TD:158.00 LSD: 917.80
ELECT LOG: NO CALIPER LOG: YES (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):0.00
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 5.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND:100.00/20.00 (CHART DIVISIONS)
COMMENTS: KEA 2, UVALDE VOC STUDY, WATER LEVEL M.P. = 919.32

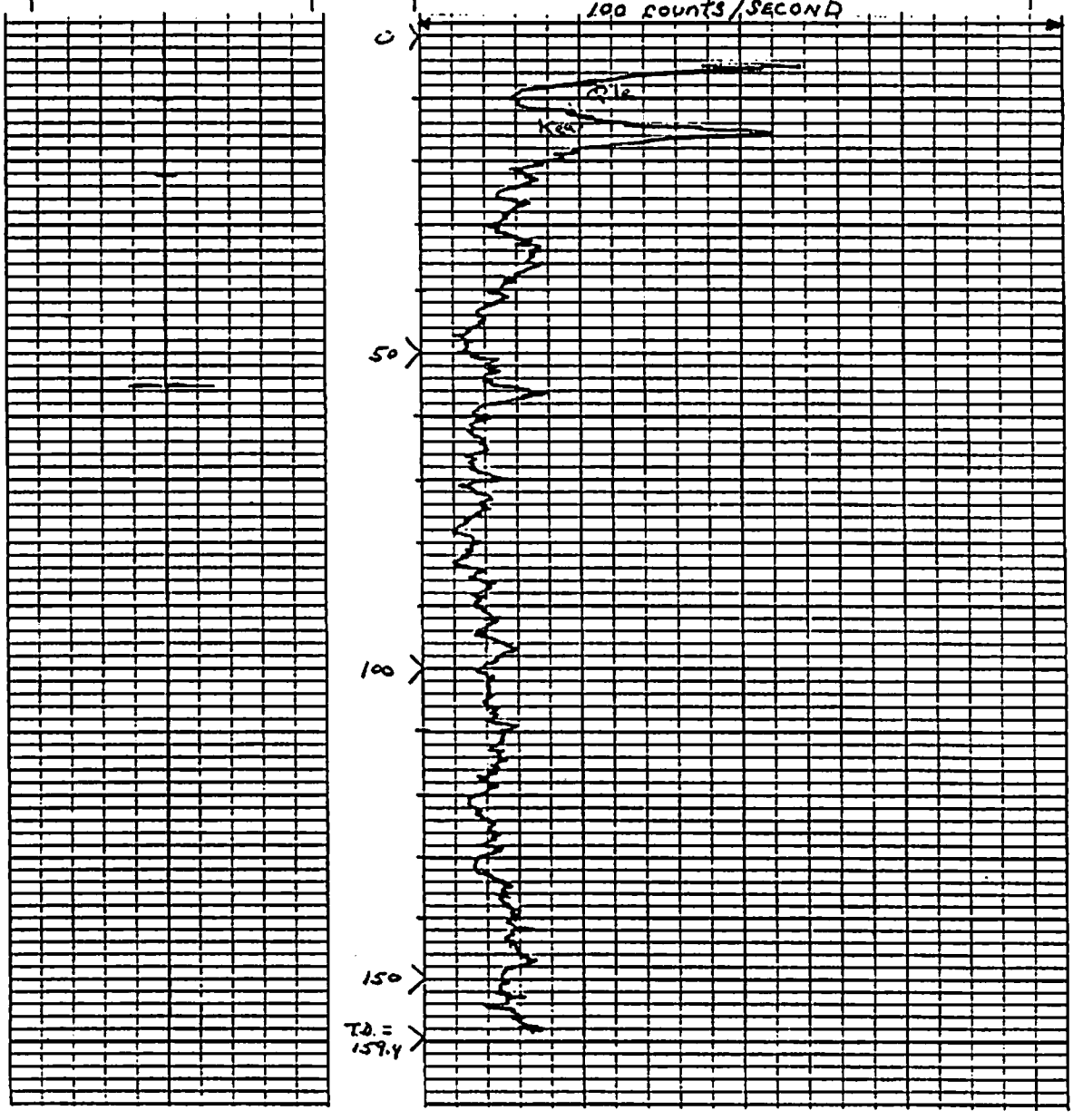


APPENDIX H, Kea 2

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 27-JAN-87
WELL NO: YP-69-50-325 WELL DEPTH: 159.50 (BELOW LSD)
LATITUDE: 29-13-22 LONGITUDE: 99-45-42 (D-M-S)
OWNER: O.V. CASEY
LOCATION: 150 FT. SE OF HWY 90, 270 FT. NE OF TAYLOR SLOUGH

DRILLER: WILLIAMSON DRILLING METHOD: AIR ROTARY
CASING (1) DIA: 6.25 FROM: 0.00 TO: 55.00 (DIA = ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE (1) DIA: 8.00 FROM: 0.00 TO: 60.00
(2) DIA: 5.00 FROM: 60.00 TO: 159.50
LOG OPERATOR: HOYT LOG MP:925.10 LOG TD:158.00 LSD: 925.10
ELECT LOG: NO CALIPER LOG: YES (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):0.00
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 5.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND:100.00/20.00 (CHART DIVISIONS)
COMMENTS: KEA 3, UVALDE VOC STUDY, WATER LEVEL M.P. = 926.53

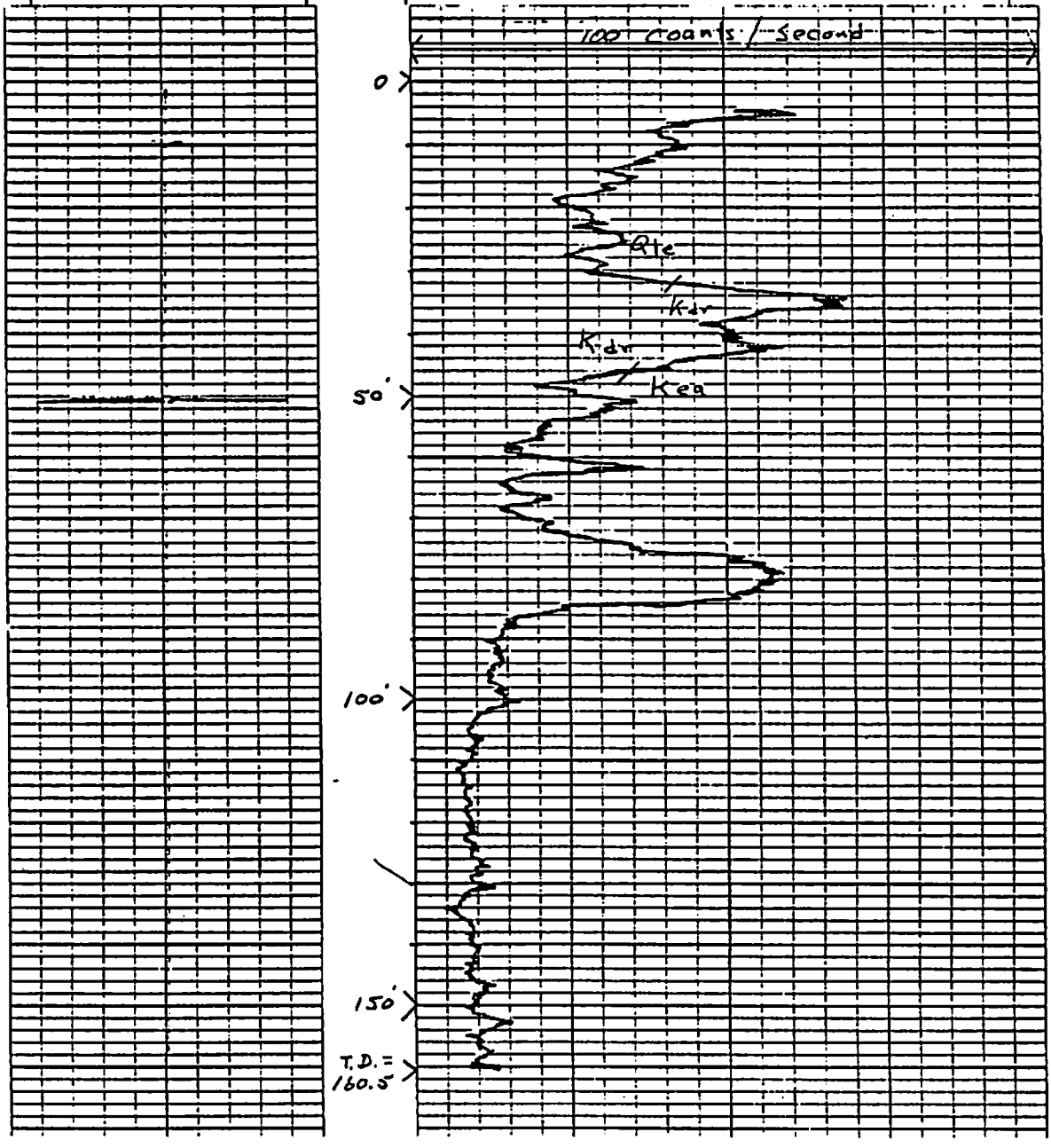


APPENDIX H, Kea 3

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 01-MAY-87
WELL NO: YP-69-50-300___ WELL DEPTH: 160.50__ (BELOW LSD)
LATITUDE: 29-13-14_____ LONGITUDE: 99-45-49_____(D-M-S)
OWNER: UVALDE EQUIPMENT CO_____
LOCATION: APP. 210 FT SE OF HWY 90 ON WEST PROPERTY LINE___

DRILLER: WILLIAMSON_____ DRILLING METHOD: AIR ROTARY
CASING (1) DIA: 5.00____ FROM: 0.00____ TO: 50.00___ (DIA = ID in INCHES)
(2) DIA: 0.00____ FROM: 0.00____ TO: 0.00___ (DEPTHS = FEET)
HOLE (1) DIA: 7.88____ FROM: 0.00____ TO: 50.00___
(2) DIA: 4.75____ FROM: 50.00___ TO: 160.50__
LOG OPERATOR: HOYT__ LOG MP:918.70__ LOG TD:160.00__ LSD: 918.70__
ELECT LOG: YES CALIPER LOG: YES (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):36.51___
LOG SPEED: 30.00_(FT / MIN) VERTICAL SCALE: 5.00__(INCHES / 100 FT)
TIME CONSTANT: 2.00__ COUNTS / SECOND:100.00/20.00_(CHART DIVISIONS)
COMMENTS: KEA 4, UVALDE VOC STUDY, WATER LEVEL M.P. = 919.87_____

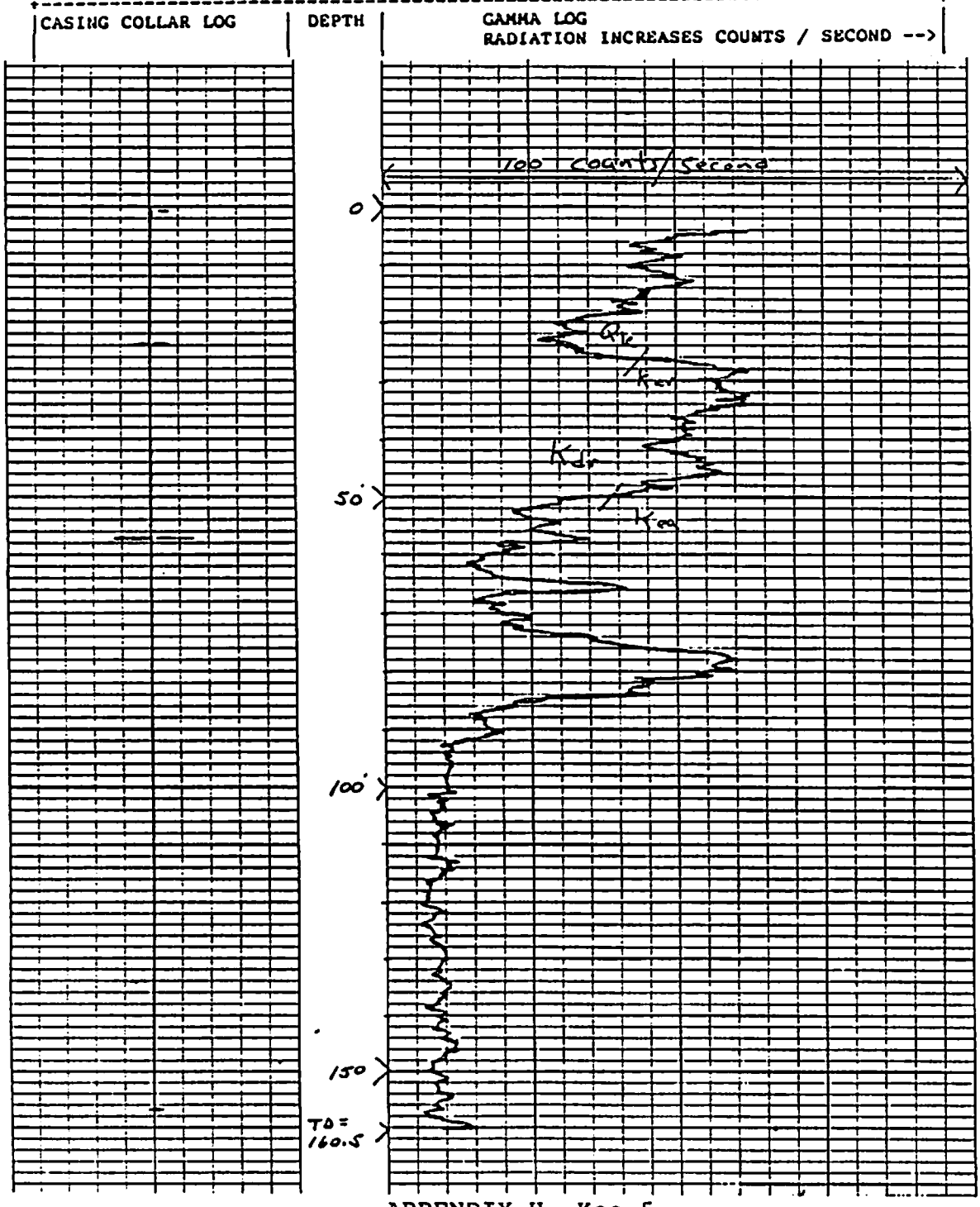


APPENDIX H, Kea 4

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 01-MAY-87
WELL NO: YP-69-50-300___ WELL DEPTH: 160.50__ (BELOW LSD)
LATITUDE: 29-13-11_____ LONGITUDE: 99-45-48_____(D-M-S)
OWNER: UVALDE EQUIPMENT CO_____
LOCATION: APP. 435 FT SE OF HWY 90 ON WEST SIDE OF PROPERTY

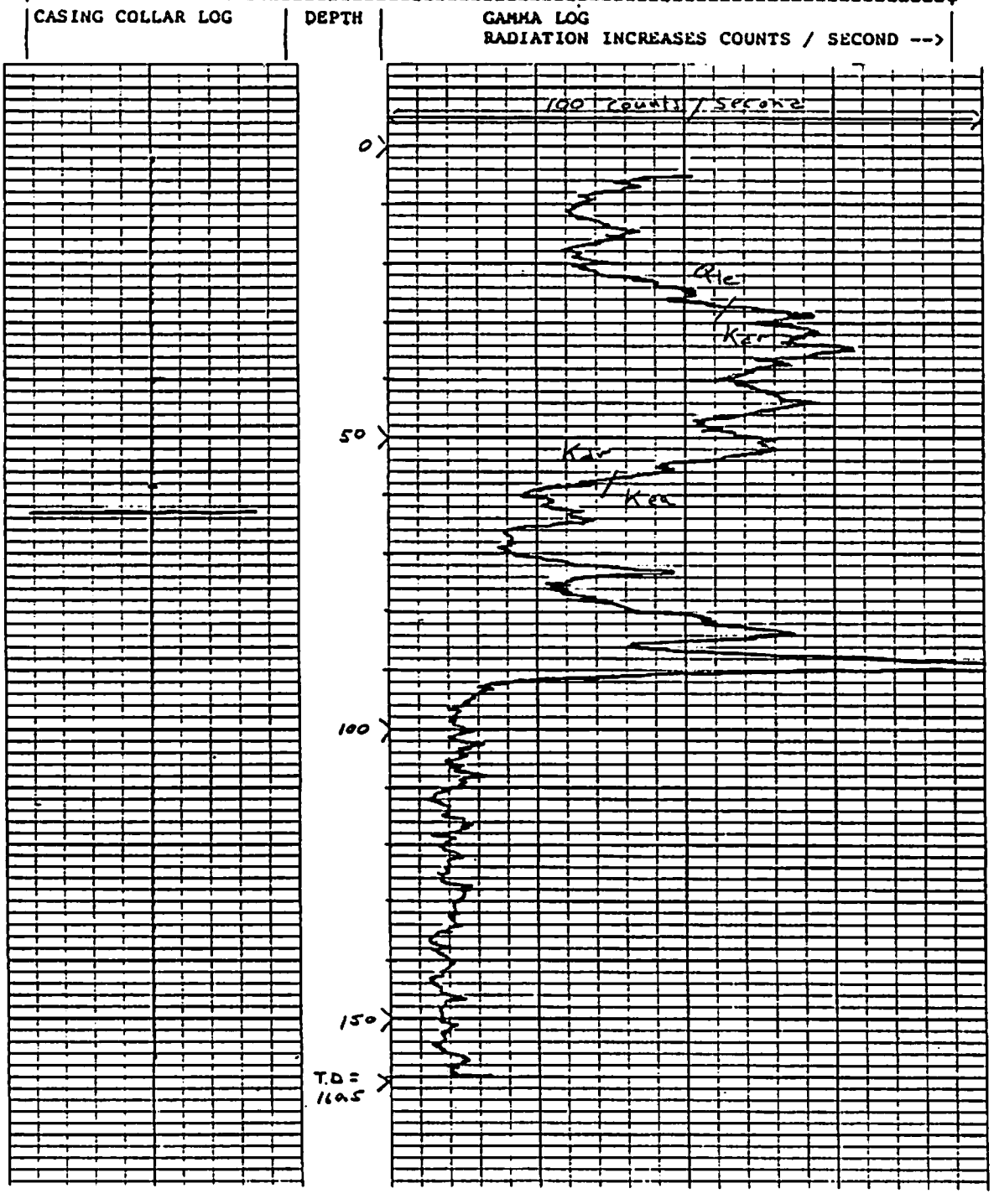
DRILLER: WILLIAMSON_____ DRILLING METHOD: AIR ROTARY
CASING (1) DIA: 5.00____ FROM: 0.00____ TO: 57.00___ (DIA = ID in INCHES)
(2) DIA: 0.00____ FROM: 0.00____ TO: 0.00____ (DEPTHS = FEET)
HOLE (1) DIA: 7.88____ FROM: 0.00____ TO: 57.00___
(2) DIA: 4.75____ FROM: 57.00___ TO: 160.50__
LOG OPERATOR: HOYT__ LOG MP:916.70__ LOG TD:159.00__ LSD: 916.70__
ELECT LOG: YES CALIPER LOG: YES (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):34.75___
LOG SPEED: 30.00_(FT / MIN) VERTICAL SCALE: 5.00__(INCHES / 100 FT)
TIME CONSTANT: 2.00__ COUNTS / SECOND:100.00/20.00_(CHART DIVISIONS)
COMMENTS: KEA 5, UVALDE VOC STUDY, WATER LEVEL M.P. = 918.17_____



EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 06-MAY-87
WELL NO: YP-69-50-300 WELL DEPTH: 160.50 (BELOW LSD)
LATITUDE: 29-13-18 LONGITUDE: 99-45-50 (D-M-S)
OWNER: TEXAS HWY DEPT.
LOCATION: 20 FT NW OF HWY 90, 37 FT NE OF WALLMART NE DRIVE

DRILLER: WILLIAMSON DRILLING METHOD: AIR ROTARY
CASING (1) DIA: 5.00 FROM: 0.00 TO: 61.00 (DIA = ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE (1) DIA: 7.88 FROM: 0.00 TO: 61.00
(2) DIA: 4.75 FROM: 61.00 TO: 160.50
LOG OPERATOR: HOYT LOG MP:919.20 LOG TD:159.00 LSD: 919.20
ELECT LOG: YES CALIPER LOG: YES (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):35.86
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 5.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND:100.00/20.00 (CHART DIVISIONS)
COMMENTS: KEA 6, UVALDE VOC STUDY, WATER LEVEL M.P. = 919.21



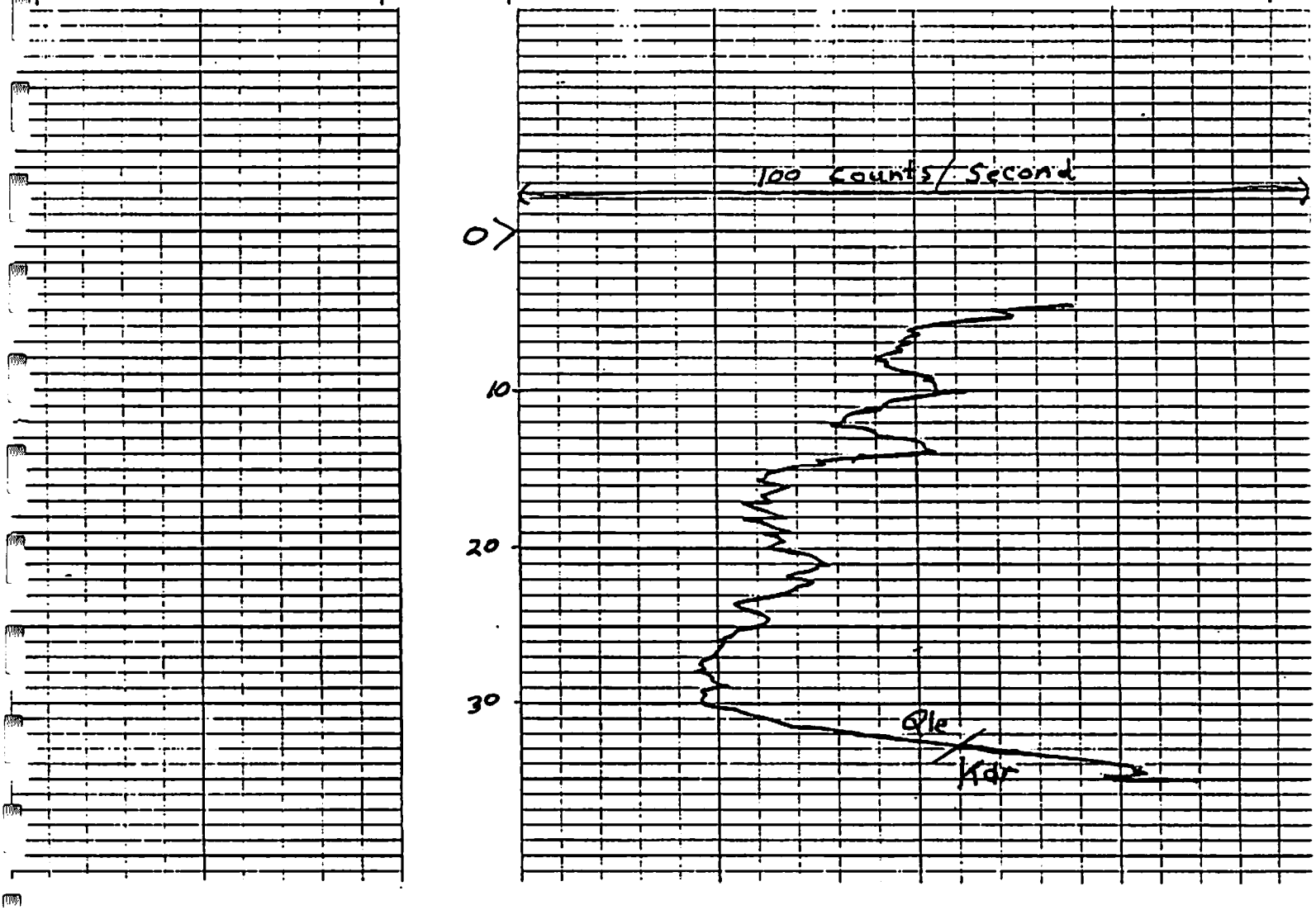
EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 14-MAY-87
WELL NO: YP-69-50-3 WELL DEPTH: 36.00 (BELOW LSD)
LATITUDE: 29-13-14 LONGITUDE: 99-45-48 (D-M-S)
OWNER: EUWD - Tommy Morris
LOCATION: 200'SE Hwy 90, Uvalde Eqpt. Co next to Kea 4

DRILLER: Williamson DRILLING METHOD: air rotary

CASING (1) DIA: 4.00	FROM: 0.00	TO: 36.00	(DIA = ID in INCHES)	
(2) DIA: 0.00	FROM: 0.00	TO: 0.00	(DEPTHS = FEET)	
HOLE (1) DIA: 0.00	FROM: 0.00	TO: 0.00		
(2) DIA: 0.00	FROM: 0.00	TO: 0.00		

LOG OPERATOR: Hoyt LOG MP:918.90 LOG TD:36.00 LSD: 918.90
ELECT LOG: NO CALIPER LOG: NO (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):26.00
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 10.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND:100.00/0.00 (CHART DIVISIONS)
COMMENTS: Qle 1 monitor well,topcasingmp=919.63 torch slotted casing

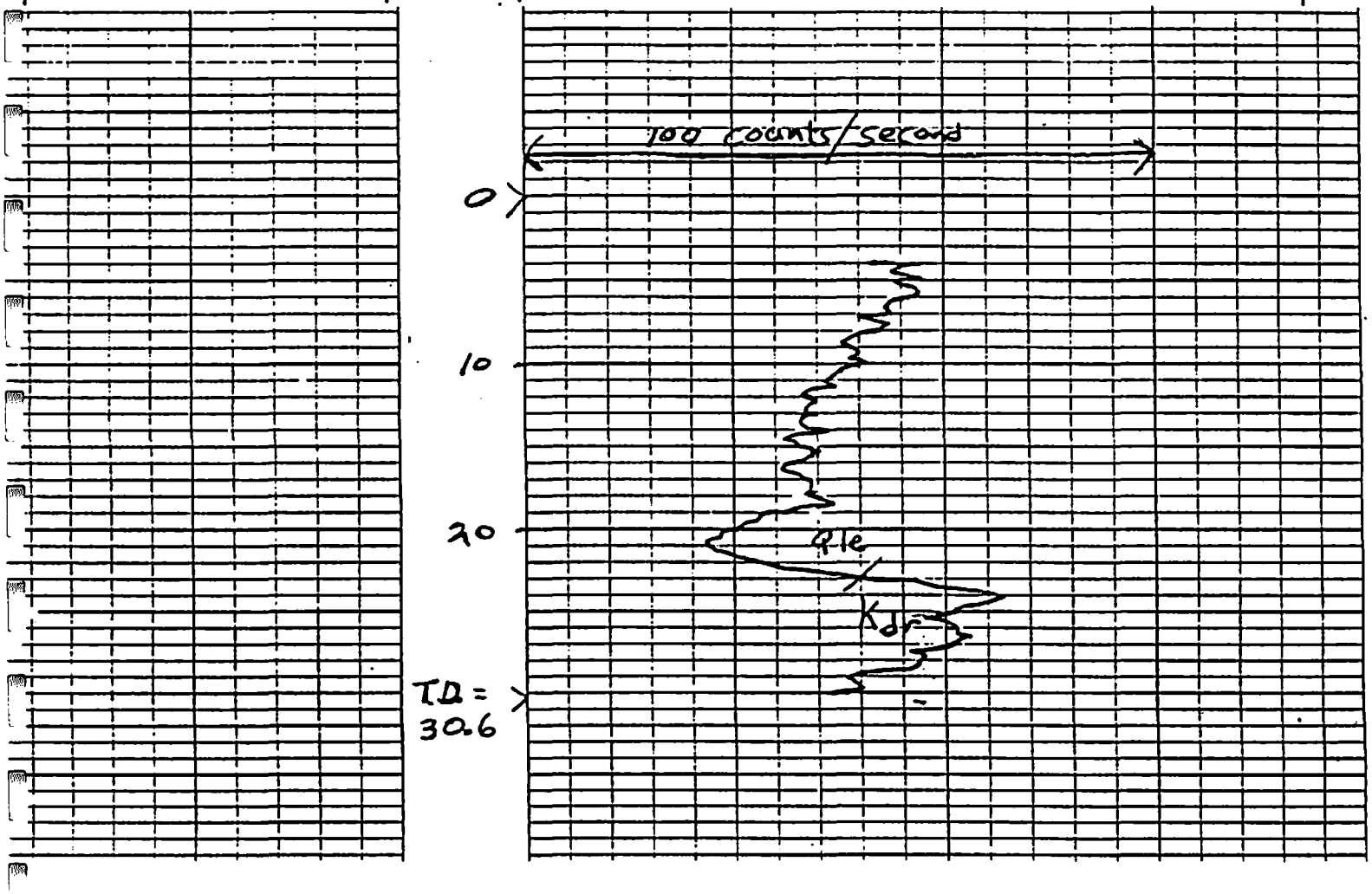


APPENDIX H, QLE 1

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 14-MAY-87
WELL NO: YP-69-50-3 WELL DEPTH: 30.60 (BELOW LSD)
LATITUDE: 29-13-14 LONGITUDE: 99-45-45 (D-M-S)
OWNER: EUWD - Tommy Morris
LOCATION: 400'SE Hwy 90,100' W Taylor Slough, Uvalde Eqpt Co

DRILLER: Williamson DRILLING METHOD: air rotary
CASING (1) DIA: 4.00 FROM: 0.00 TO: 30.60 (DIA = ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE (1) DIA: 0.00 FROM: 0.00 TO: 0.00
(2) DIA: 0.00 FROM: 0.00 TO: 0.00
LOG OPERATOR: Hoyt LOG MP:914.10 LOG TD:30.60 LSD: 914.10
ELECT LOG: NO CALIPER LOG: NO (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):0.00
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 10.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND:100.00/15.00 (CHART DIVISIONS)
COMMENTS: Qle 2 monitor well, Top casing mp = 915.66, V.O.C. study

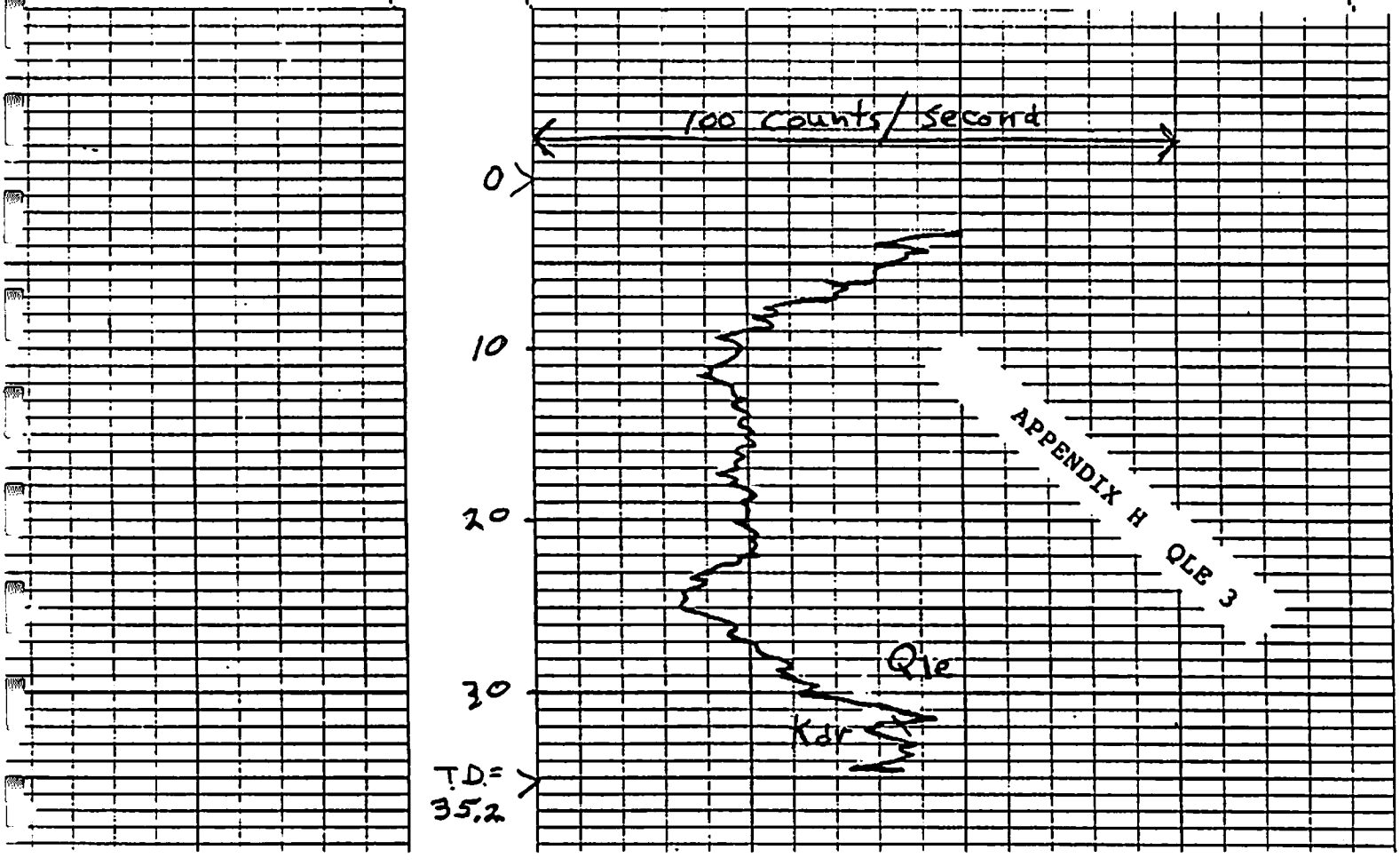


APPENDIX H, QLE 2

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 14-JUL-87
WELL NO: YP-69-50-3 WELL DEPTH: 35.20 (BELOW LSD)
LATITUDE: 29-13-16 LONGITUDE: 99-45-46 (D-M-S)
OWNER: EUWD - Tommy Morris
LOCATION: 280' Se of Hwy 90, 175'W Taylor Slough

DRILLER: EUWD - Tommy Morris DRILLING METHOD: air rotary
CASING (1) DIA: 4.00 FROM: 0.00 TO: 35.20 (DIA = ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE (1) DIA: 0.00 FROM: 0.00 TO: 0.00
(2) DIA: 0.00 FROM: 0.00 TO: 0.00
LOG OPERATOR: Hoyt LOG MP:916.60 LOG TD:35.20 LSD: 916.60
ELECT LOG: NO CALIPER LOG: NO (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):0.00
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 10.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND:100.00/15.00 (CHART DIVISIONS)
COMMENTS: Qle 3 monitor well, top casing mp = 918.51, V.O.C. study

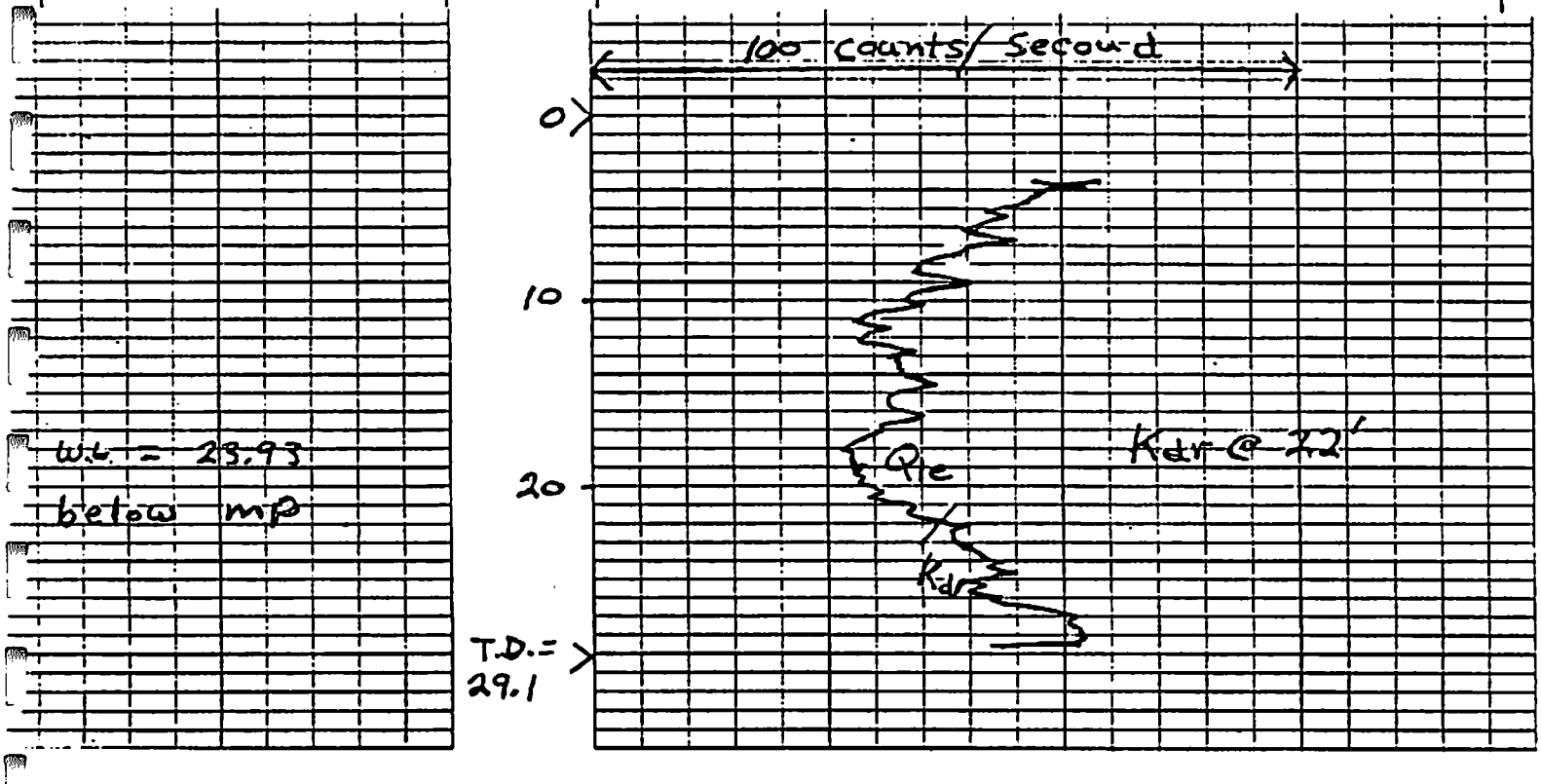


APPENDIX H, QLE 3

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 14-JUL-87
WELL NO: YP-69-50-3_____ WELL DEPTH: 29.10___ (BELOW LSD)
LATITUDE: 29-13-14_____ LONGITUDE: 99-45-44_____(D-M-S)
OWNER: EUWD - Tommy Morris_____
LOCATION: 490'SE Hwy 90 along W side Taylor Slough_____

DRILLER: Williamson_____ DRILLING METHOD: air rotary
CASING (1) DIA: 4.00____ FROM: 0.00____ TO: 29.10___ (DIA = ID in INCHES)
(2) DIA: 0.00____ FROM: 0.00____ TO: 0.00____ (DEPTHS = FEET)
HOLE (1) DIA: 0.00____ FROM: 0.00____ TO: 0.00____
(2) DIA: 0.00____ FROM: 0.00____ TO: 0.00____
LOG OPERATOR: Hoyt__ LOG MP:915.80__ LOG TD:29.10___ LSD: 915.80__
ELECT LOG: NO_ CALIPER LOG: NO_ (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):23.93___
LOG SPEED: 30.00_(FT / MIN) VERTICAL SCALE: 10.00_(INCHES / 100 FT)
TIME CONSTANT: 2.00__ COUNTS / SECOND:100.00/20.00_(CHART DIVISIONS)
COMMENTS: Qle 4 monitor well, top casing mp = 917.67,torch slotcasing



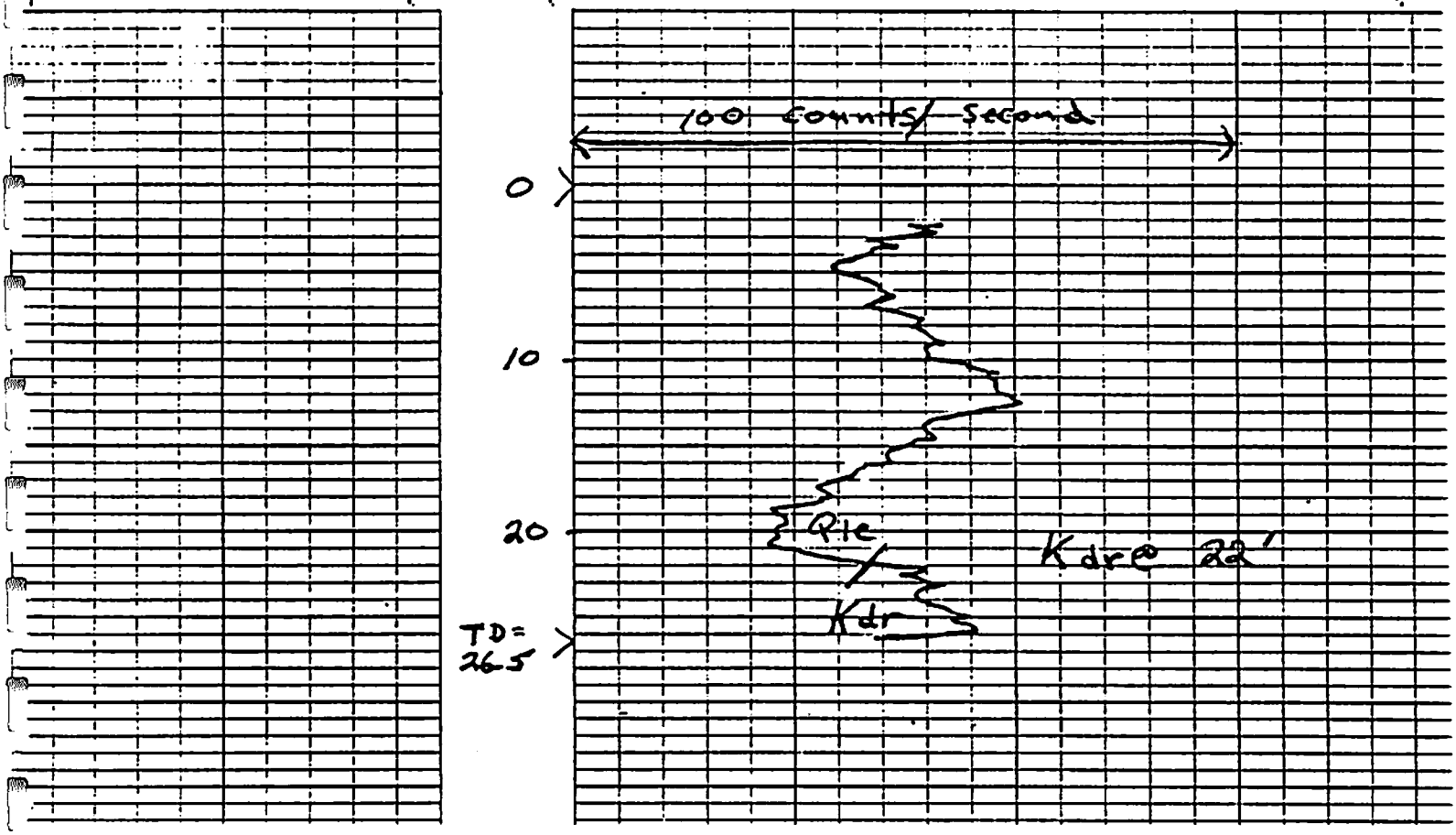
APPENDIX H, QLE 4

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 15-JUL-87
WELL NO: YP-69-50-3_____ WELL DEPTH: 26.50___ (BELOW LSD)
LATITUDE: 29-13-12_____ LONGITUDE: 99-45-45_____(D-M-S)
OWNER: EUWD - Tommy Morris_____
LOCATION: 525'SE Hwy 90,along W side Taylor Slough_____

DRILLER: Williamson_____ DRILLING METHOD: air rotary
CASING (1) DIA: 4.00____ FROM: 0.00____ TO: 26.50___ (DIA = ID in INCHES)
(2) DIA: 0.00____ FROM: 0.00____ TO: 0.00____ (DEPTHS = FEET)
HOLE (1) DIA: 0.00____ FROM: 0.00____ TO: 0.00____
(2) DIA: 0.00____ FROM: 0.00____ TO: 0.00____
LOG OPERATOR: Hoyt__ LOG MP:912.40__ LOG TD:26.50___ LSD: 912.40__
ELECT LOG: NO_ CALIPER LOG: NO_ (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):0.00____
LOG SPEED: 30.00_(FT / MIN) VERTICAL SCALE: 10.00_(INCHES / 100 FT)
TIME CONSTANT: 2.00__ COUNTS / SECOND:100.00/15.00_(CHART DIVISIONS)
COMMENTS: Qle 5 monitor well, Top casing mp = 915.18, V.O.C. study___

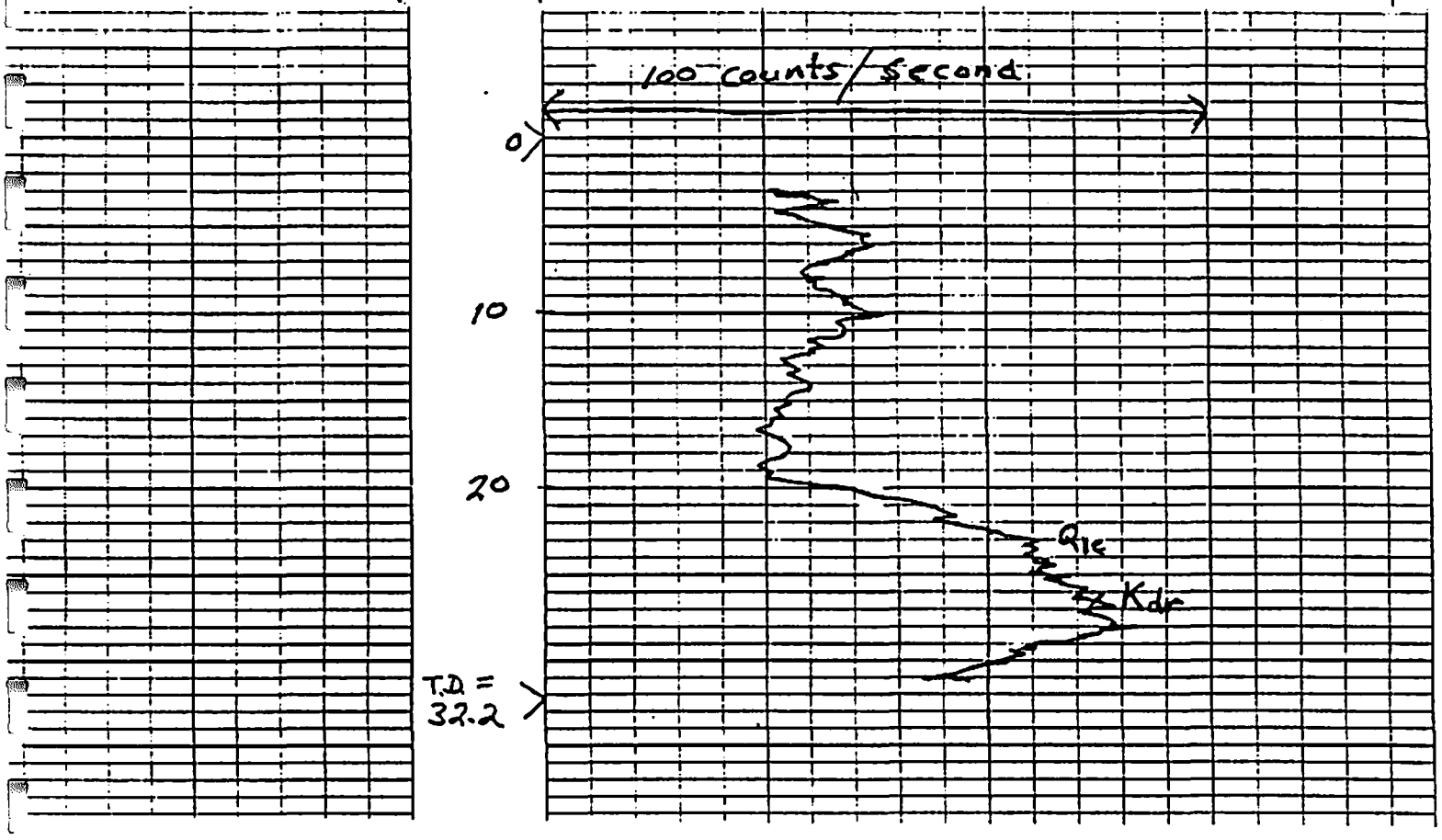
CASING COLLAR LOG	DEPTH	GAMMA LOG RADIATION INCREASES COUNTS / SECOND -->



EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 04-AUG-87
WELL NO: YP-69-50-3 WELL DEPTH: 32.20 (BELOW LSD)
LATITUDE: 20-13-18 LONGITUDE: 99-45-44 (D-M-S)
OWNER: EUWD - Tommy Morris
LOCATION: 50' SE of Hwy 90 nest to Taylor Slough

DRILLER: Williamson DRILLING METHOD: air rotary
CASING (1) DIA: 4.00 FROM: 0.00 TO: 32.20 (DIA = ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE (1) DIA: 0.00 FROM: 0.00 TO: 0.00
(2) DIA: 0.00 FROM: 0.00 TO: 0.00
LOG OPERATOR: Hoyt LOG MP:918.40 LOG TD:32.20 LSD: 918.40
ELECT LOG: NO CALIPER LOG: NO (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):0.00
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 10.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND:100.00/15.00 (CHART DIVISIONS)
COMMENTS: Qle 6 monitor well, top casing mp = 920.94, V.O.C. study

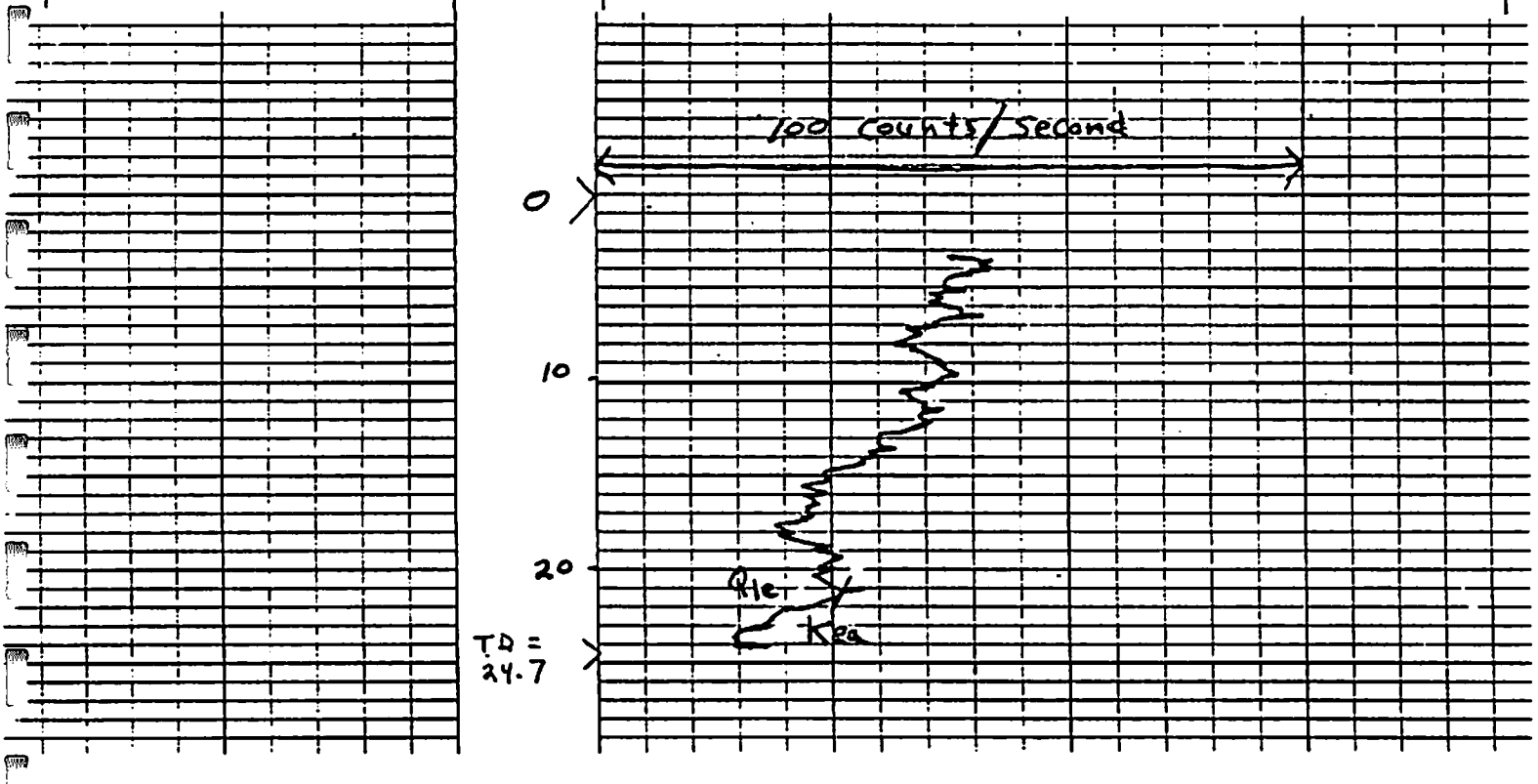


APPENDIX H, QLE 6

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 04-AUG-87
WELL NO: YP-69-50-3 WELL DEPTH: 24.70 (BELOW LSD)
LATITUDE: 29-13-18 LONGITUDE: 99-45-42 (D-M-S)
OWNER: EUWD - Tommy Morris
LOCATION: 350'SE Hwy 90, along E side Taylor Slough

DRILLER: Williamson DRILLING METHOD: Air rotary
CASING (1) DIA: 4.00 FROM: 0.00 TO: 24.70 (DIA = ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE (1) DIA: 0.00 FROM: 0.00 TO: 0.00
(2) DIA: 0.00 FROM: 0.00 TO: 0.00
LOG OPERATOR: Hoyt LOG MP:917.70 LOG TD:24.70 LSD: 917.70
ELECT LOG: NO CALIPER LOG: NO (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):0.00
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 10.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND:100.00/15.00 (CHART DIVISIONS)
COMMENTS: Qle 7 monitor well top casing mp = 919.63, TD in Kea



APPENDIX H, QLE 7

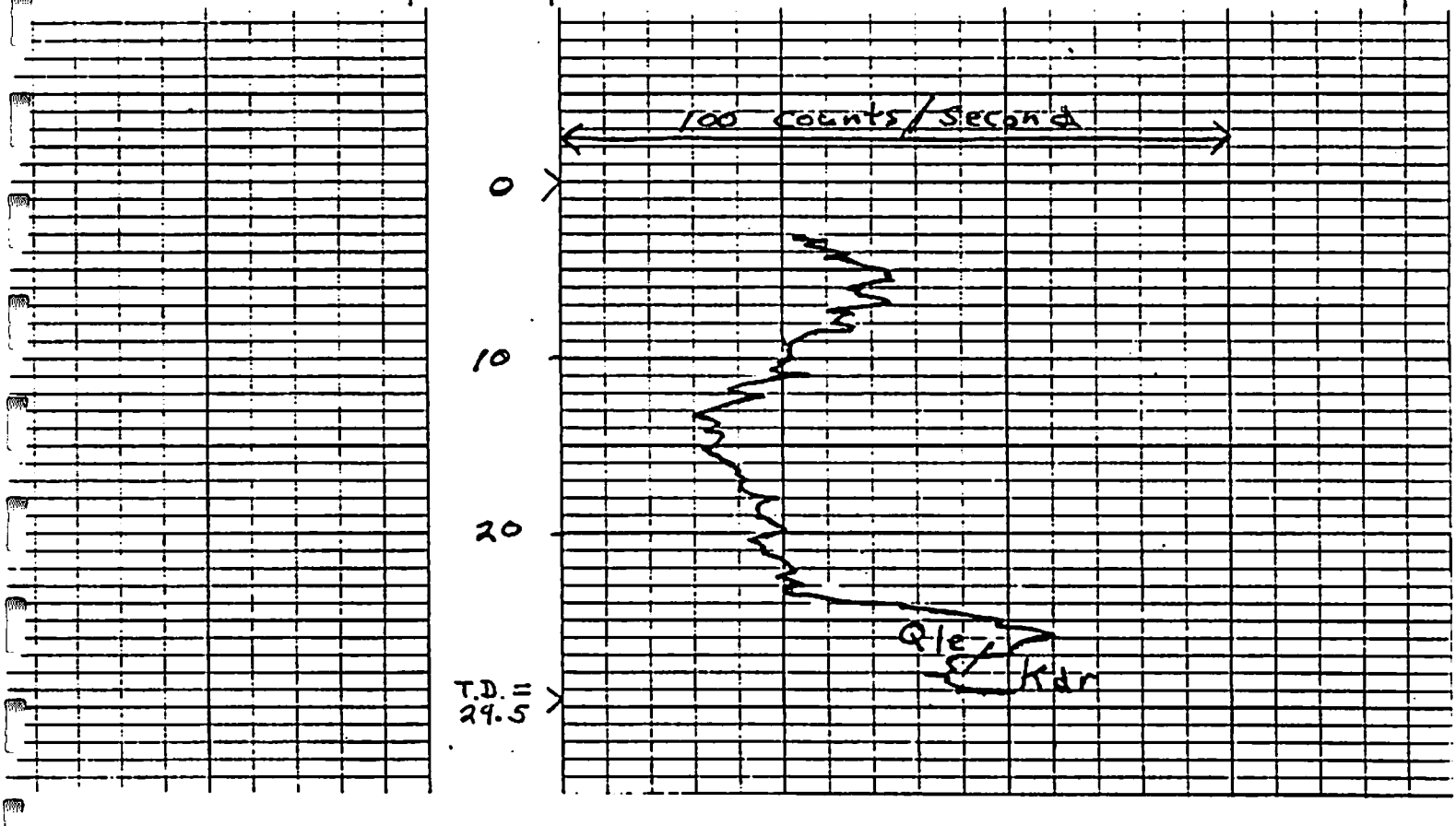
EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 04-AUG-87
WELL NO: YP-69-50-3 WELL DEPTH: 29.50 (BELOW LSD)
LATITUDE: 29-13-17 LONGITUDE: 99-45-48 (D-M-S)
OWNER: EUWD - Tommy Morris
LOCATION: 275' SE of Hwy 90, 150' W Taylor Slough

DRILLER: Williamson DRILLING METHOD: air rotary

CASING (1) DIA: 4.00	FROM: 0.00	TO: 29.50	(DIA = ID in INCHES)
(2) DIA: 0.00	FROM: 0.00	TO: 0.00	(DEPTHS = FEET)
HOLE (1) DIA: 0.00	FROM: 0.00	TO: 0.00	
(2) DIA: 0.00	FROM: 0.00	TO: 0.00	

LOG OPERATOR: Hoyt LOG MP: 917.70 LOG TD: 29.50 LSD: 917.70
ELECT LOG: NO CALIPER LOG: NO (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD): 25.00
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 10.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND: 100.00/15.00 (CHART DIVISIONS)
COMMENTS: Qle 8 monitor well, top casing mp = 919.17, V.O.C. study

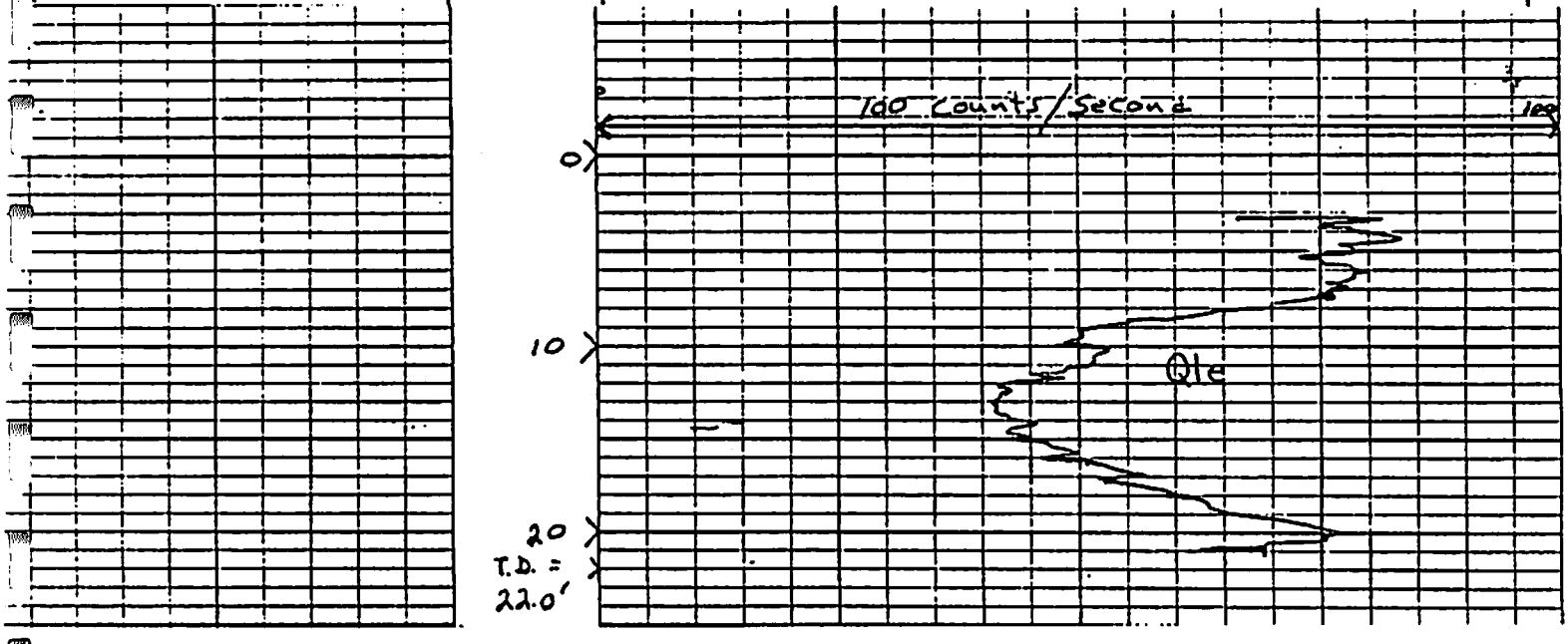


APPENDIX H, QLE 8

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 09-MAY-88
WELL NO: YP-69-50-3 WELL DEPTH: 22.00 (BELOW LSD)
LATITUDE: 29-13-14 LONGITUDE: 99-45-44 (D-M-S)
OWNER: EUWD-TOMMY MORRIS
LOCATION: 400' SE HWY 90, 40' W TAYLOR SLOUGH, UVALDE EQP CO

DRILLER: CHEN & ASSOC. DRILLING METHOD: AUGER
CASING (1) DIA: 2.00 FROM: 0.00 TO: 22.00 (DIA = ID in INCHES)
(2) DIA: FROM: TO: (DEPTHS = FEET)
HOLE (1) DIA: 4.00 FROM: 0.00 TO: 22.00
(2) DIA: FROM: TO:
LOG OPERATOR: BRYANT LOG MP: 917.00 LOG TD: 22.00 LSD: 917.00
ELECT LOG: NO CALIPER LOG: NO (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 10.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND: 100.00/20.00 (CHART DIVISIONS)
COMMENTS: KNOWN AS QLE 9, B-1, MW-1, PLUGGED 5-9-88, V.O.C. STUDY DAT87

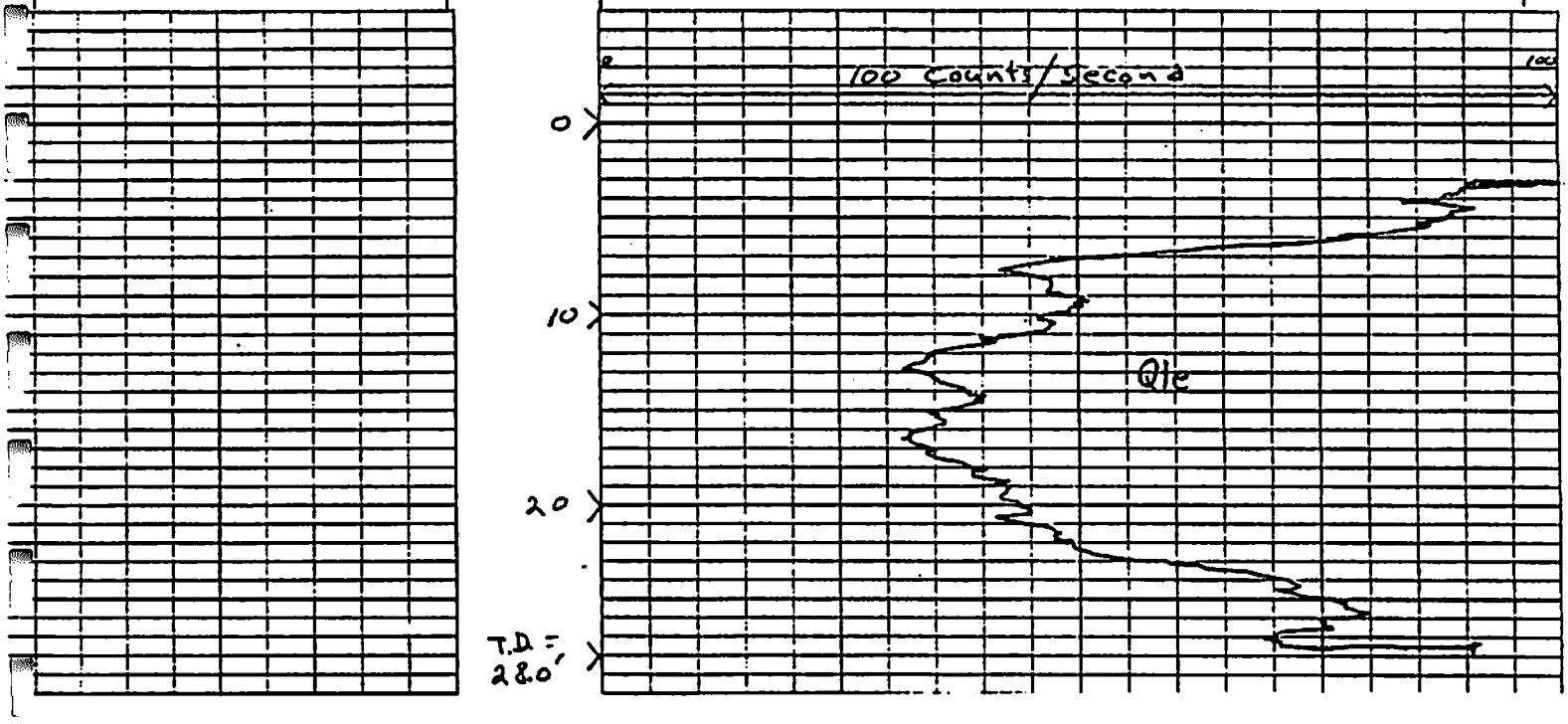


APPENDIX H, QLE 9

EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMMA AND CASING COLLAR LOG

DATE: 09-MAY-88
WELL NO: YP-69-50-3 WELL DEPTH: 28.00 (BELOW LSD)
LATITUDE: 29-13-14 LONGITUDE: 99-45-44 (D-M-S)
OWNER: EUWD-TOMMY MORRIS
LOCATION: 400' SE HWY 90, 80'W TAYLOR SLOUGH,UVALDE EQUIP CO

DRILLER: CHEN & ASSOC. DRILLING METHOD: AUGER
CASING (1) DIA: 2.00 FROM: 0.00 TO: 28.00 (DIA = ID in INCHES)
(2) DIA: FROM: TO: (DEPTHS = FEET)
HOLE (1) DIA: 4.00 FROM: 0.00 TO: 28.00
(2) DIA: FROM: TO:
LOG OPERATOR: BRYANT LOG MP:917.00 LOG TD:28.00 LSD: 917.00
ELECT LOG: NO CALIPER LOG: NO (Y/N) (LSD fr TOPO SHT)
WATER LEVEL (below LSD):
LOG SPEED: 30.00 (FT / MIN) VERTICAL SCALE: 10.00 (INCHES / 100 FT)
TIME CONSTANT: 2.00 COUNTS / SECOND:100.00/20.00 (CHART DIVISIONS)
COMMENTS: KNOWN AS QLE 10, B-2, MW-2, PLUGGED 5-9-88. V.O.C. STUDY DAT87



APPENDIX H, QLE 10