Volume 3

Sections 6-8

SELECTED TECHNICAL REFERENCES AND SUPPORTING DOCUMENTS

Prepared in Conjunction With

Report to Congress

Class V Injection Wells

- Current Inventory
- Effects on Groundwater
- Technical Recommendations

Compiled For

U.S. EPA, Washington, D.C.

November, 1987

Respectfully Submitted By:

EEI ENGINEERING ENTERPRISES, INC.

WATER RESOURCES SPECIALISTS

Under EPA Contract No. 68-03-3416

Assignment No. 0-5

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Foreword

These references and documents were compiled by Engineering Enterprises, Inc. from data gathered during preparation of Report to Congress Class V Injection Wells: Current Inventory, Effects on Groundwater, Technical Recommendations (EPA 570/09-87-006) under EPA Contract No. 68-03-3416. The references are representative of data gathered by the States, Territories, and Possessions of the United States in fulfilling the regulatory requirement of 40 CFR 146.52 (b). The EPA project manager was L. Lawrence Graham, and the EEI project officer was Lorraine C. Council.

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SECTION 6

Industrial, Commercial, Utility Disposal Wells

Section 6.1

Cooling Water Return Flow Wells Supporting Data

Section 6.1.1

TITLE OF STUDY: (or SOURCE OF INFORMATION)	"Cooling Water Return Flow Wells," Final Design for Arkansas' Class V Injection Well Inventory and Assessment
AUTHOR: (or INVESTIGATOR)	Arkansas Department of Pollution Control and Ecology
DATE:	September, 1985
STUDY AREA NAME AND LOCATION:	Arkansas USEPA, Region VI
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	This excerpt from the Arkansas Class V report describes typical cooling water return flow systems found in Arkansas, typical operating conditions, circumstances under which they may cause contamination, and the maintenance necessary to minimize well failure. Also included is a copy of the well construction report. (Note: section has been retyped for easier reading.)

Cooling Water Return Flow Wells (Closed-loop)

So far, there is only one closed-loop cooling water return flow well system on record in Arkansas. The system consists of two wells, a supply well and a return well, which were installed in April, 1985. The operator of these wells was issued a water permit from the ADPC&E. No UIC permit was issued for these wells because there are no UIC regulations for the construction and operation of cooling water return flow wells or any other type of Class V wells. From the completion reports on these two wells (Appendix D), it appears that they are relatively well constructed. Because of the shallow depths of these wells (only fresh water bearing formations are penetrated) and the simpleness of the system in which the water is being used, the Department sees no need for complicated regulations governing this type well except for to maintain that no intermingling of the system's water with foreign substances occurs between the supply well and the return well. A diagram of a typical cooling water return flow well can be found in Figure 3.

Typical Conditions of Operation

Under typical operating conditions, the potential for well failure is moderate to low. Problems that can potentially occur include casing and/or tubing leaks, deterioration of cement and resultant annular space channeling, transmission line leaks, packer failure, and pump breakdown. The main causes of well failure under typical operating conditions are the highly corrosive nature of the brine being injected and mechanical stress.

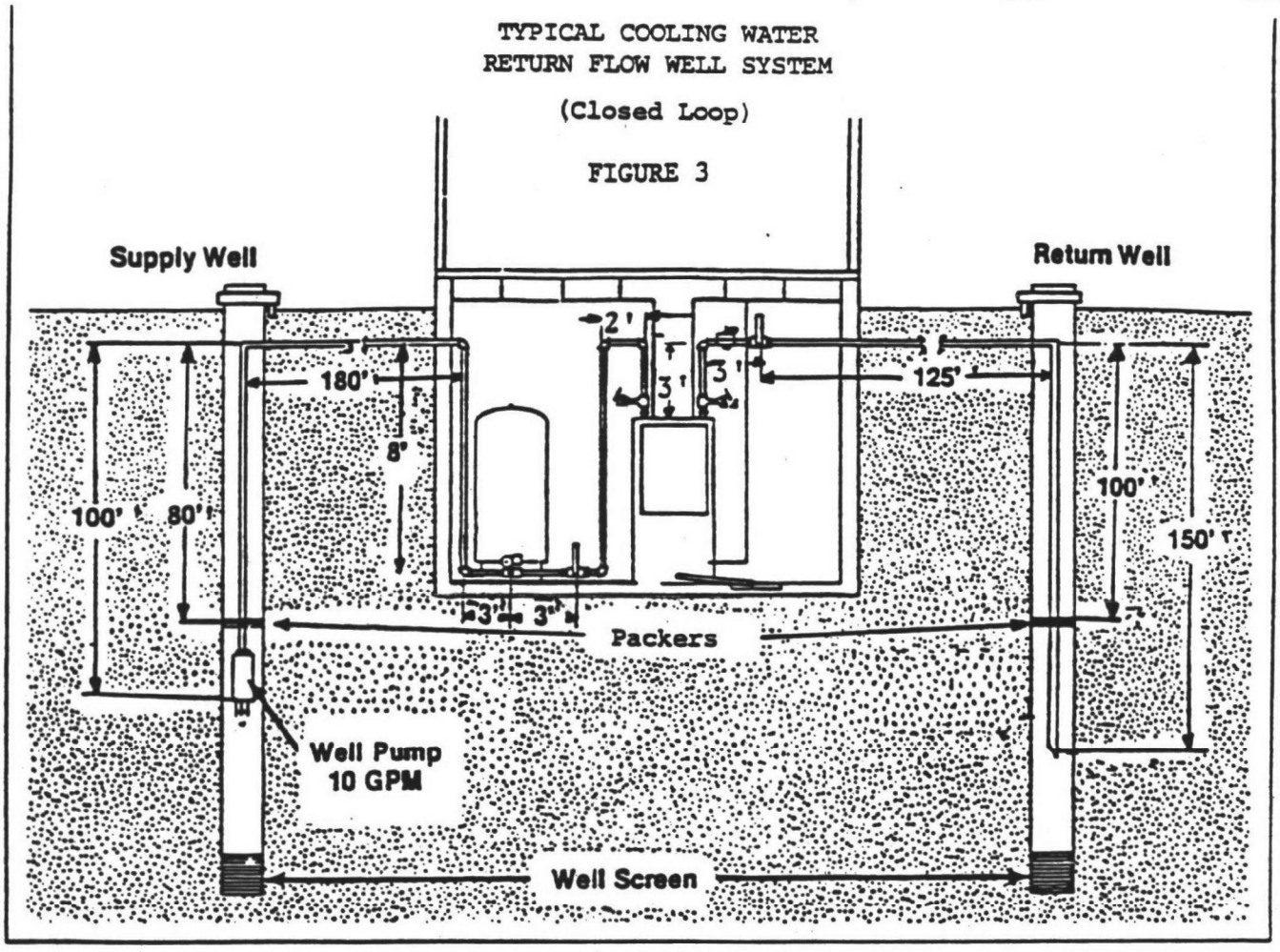
Extraordinary Circumstances

Some extraordinary circumstances that may possibly give rise to well failure are earthquakes, explosions, tornadoes, and vehicular collisions. Each of these circumstances varies in its degree of probability of occurrence. Earthquakes of significant magnitude to cause well damage are very unlikely to occur in areas of Class V brine disposal injection well activity. The reason for this is that south Arkansas is relatively well isolated from tectonically and seismically active areas. The chance of well failure due to explosions is very remove due to the fact that the chemical companies who operate Class V brine disposal injection wells do not handle many, if any, explosives, and the brine being injected is also not explosive. Tornadoes are one of the main threats to the wells. South Arkansas is frequented by tornadoes, therefore there is quite a substantial chance that a well might be damaged by this type of extraordinary circumstance. Vehicular collisions with wells are another of the main extraordinary circumstances which can potentially cause well failure. Some of the wells are located near highways and public roads and the potential exists for these wells to be struck and

TYPICAL COOLING WATER
RETURN FLOW WELL SYSTEM

(Closed Loop)

FIGURE 3



EVALUATION OF WELL FAILURE POTENTIAL

damaged due to vehicular accidents. Other wells are located on plant properties or in oil fields where the potential exists for tank trucks and other service vehicles to accidentally run into or run over the wells.

Although there is a potential for damage to Class V brine disposal injection wells as a result of the above mentioned extraordinary circumstances, the probability of such incidents actually occurring is relatively low.

Necessary Maintenance to Minimize Well Failure

During the drilling and completion of Class V brine disposal injection wells, a minimum of the following logs shall be obtained and the following procedure for demonstrating the mechanical integrity of the well shall be performed.

1. The maximum point at which a well penetrates the injection formation shall not unreasonably vary from the vertical drawn from the center of the borehole at the surface. Deviations in excess of three degrees from the vertical drawn from the center of the borehole at the surface shall be deemed to be unreasonable. Deviation checks on the hole shall be performed at sufficiently frequent intervals, depending on the lithology of the strata being penetrated, to assure that vertical avenues for fluid migration are not created during drilling.

2. Logs to be run during the installation of surface casing:

   a.) Resistivity, spontaneous potential and caliper logs before the casing is installed; and

   b.) Cement bond log, variable density log, noise and/or temperature log, and a pressure test after the casing is set and cemented.

3. Logs to be run during the installation of intermediate and/or long string casing:

   a.) Resistivity, spontaneous potential, porosity, and gamma ray logs before the casing is installed; and

   b.) Cement bond log, variable density log, radioactive tracer survey, noise and/or temperature log, and a pressure test after the casing is set and cemented.

4. If the results of the mechanical integrity test indicates that the cement job is poor in a particular zone, and that fluid movement may occur behind the casing, then a squeeze job or other method approved by the Director shall be employed to properly seal off this zone. Following a squeeze job, the Permitee must run a cement bone log, a variable density log, and a noise and/or temperature log through the interval from 100 feet above to 100 feet below the squeezed zone. A pressure test must also be conducted to ensure the integrity of the squeeze job. A report discussing the results of the squeeze job and subsequent mechanical integrity test shall be submitted to the Department within 30 days and approval must be received from the Department before injection may resume.

5. Mechanical integrity shall be demonstrated upon well completion and thereafter once every five years for the life of the well. The demonstration of mechanical integrity consists of the running of a cement bond log, a variable density log, a noise and/or temperature log, a radioactive tracer survey, and a pressure test. The Department shall be notified well in advance of any mechanical integrity tests so that, if possible, a qualified member of the Department staff may be on site to witness the tests. Subsequently, the results of the tests shall be submitted to the Department along with an interpretive analysis by the log analyst from the service company which ran the test. Based on staff review of logging and testing data, additional testing, corrective action, or a revision of permit requirements may be needed.

   Each well must also pass a pressure test at least once a year and a radioactive tracer survey at least once every two years. A pressure test must also be run after each workover and after each shut-down of the well in excess of 30 days. Mechanical integrity must be demonstrated to the satisfaction of the Director in accordance with 40 CFR 146.08 and within the guidelines established by the Department.

The Department recommends that all Class V cooling water return flow wells be adequately constructed so as to protect and preserve the State's underground sources of usable quality water. Specifically, all Class V cooling water return flow wells shall be constructed using the following construction requirements:

1. Both the supply well(s) and the return well(s) shall be cased at least from the surface down through the top of the uppermost supply and injection formation.

2. The casing shall be cemented in place from the top of the uppermost supply and injection formation to the surface.

3. A cooling water return flow well system shall, at a minimum, consist of two wells, a supply well and a return well.

4. The supply and return well system shall be constructed so that the formation from which the cooling water was extracted is the same formation into which the cooling water is reinjected.

5. There shall be no open-loop cooling water return flow wells as defined under "Potential Non-brine Class V Injection wells."

6. All cooling water return flow system wells shall be plugged upon abandonment by filling the well with cement.

7. Cooling water return wells shall receive nothing other than the used cooling water which originated at the cooling water supply well(s).

The preceding list consists of suggested requirements which the ADPC&E believes to be, at a minimum, necessary for the regulation of the construction and operation of Class V cooling water return flow wells. Regulations for the construction and operation of other types of Class V wells with potential for use in Arkansas will be suggested whenever a demand for such wells exists.

STATE OF ARKANSAS
REPORT OF WATER WELL CONSTRUCTION

ew Well X Work-over Well ____ Replacement Well ____

County Pulaski (in which well is located)

wner of Well Arkansas Electric Cooperative Corporation

ontractor Acklin Drilling Company, Inc. C-1032

iller Name and No. Travis H. Acklin, D-2053

ite Well was Completed 4-5-85

Total Depth of Well 255 Ft.

Water Producing Formation: From ____ Ft.
At 180-230 To ____ Ft.

Water Level Below Land Surface 60 ft.

Gallons per Hour 1,800

Well Disinfected with Clorox

Casing to 142 Ft.

Cased with 6+ in. Diameter Steel Casing

Cemented from 0 Ft. to 141 Ft.

id water source heat pump) ____ x
Use of Well: Domestic Irrigation Municipal Other

Well is near I-30 Road

Section 32 Township 1N Range 12W

Directions for Reaching Well: Well is located at 8000 Scott Hamilton Drive, 100 ft. (use permanent landmark) WNW of office buildings.

Description and Color of Formation (sand, shale, sandstone, etc.)	Depths from	in feet to
Sandy clay & gravel	0	4
Brown sandy slay	4	14
Midway clay (blue)	14	135
Light slate or limestone	135	180
Quartz, limestone and slate	180	237
Blue slate	237	255

Remarks: Diameter 6 3/16 in.

Signed: Keith A. Elkins Date: 4/11/85

rm No. AWD-3

Mail to: Committee on Water Well Construction, 7915 So Pine Street, Little Rock, Arkansas 72204

COMMITTEE COPY

STATE OF ARKANSAS
REPORT OF WATER WELL CONSTRUCTION

w Well X Work-over Well ____ Replacement Well ____

County Pulaski (in which well is located)

ner of Well Arkansas Electric Cooperative Corporation

ntractor Acklin Drilling Company, Inc C -1032

ller Name and No. Travis H. Acklin, D-2053

e Well was Completed 4-10-85

Total Depth of Well 275 Ft.

Water Producing Formation: From ____ Ft.
At 175, 214, 255-275 To ____ Ft.

Water Level Below Land Surface 65 ft.

Gallons per Hour 3,600

Well Disinfected with Clorox

Casing to 158 Ft

Cased with 6 in. Diameter Steel Casing

Cemented from 0 Ft. to 157 Ft.

Ground water source heat pump) ? x
Use of Well Domestic Irrigation Municipal Other

Well is near I-30 Road

Section 32 Township 1N Range 12W

Directions for Reaching Well: Well is located at 800 Scott Hamilton Drive, 20 ft. (use permanent landmark) N of office buildings near west end.

Description and Color of Formation (sand, shale, sandstone, etc.)	Depths from	in feet to
Top soil, sandy clay, & gravel	0	5
~~Brown clay~~	~~5~~	~~12~~
Blue clay	12	130
Light blue limestone	130	175
~~Quartz & lime~~	~~175~~	~~185~~
Light blue sandrock	185	225
Blue slate	225	236
~~Blue slate & blue sandrock mixed~~	~~236~~	~~250~~
Blue slate	250	275

Remarks Diameter 6 3/16 in.

Signed Keith A. Elkins Date 4-11-85

[6-9

rm No. AWD-3

Mail to: Committee on Water Well Construction, 7915 So Pine Street

Section 6.1.2

TITLE OF STUDY: (or **SOURCE OF INFORMATION**)	Summaries of Assessments of Cooling Water Return Flow Wells from Selected State Class V Reports.
AUTHOR: (or **INVESTIGATOR**)	Engineering Enterprises, Inc.
DATE:	November, 1986
STUDY AREA NAME AND LOCATION:	Minnesota, Nebraska, Wyoming, Massachusetts, and Hawaii
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	In preparing the Report to Congress on Class V Injection Wells, Engineering Enterprises, Inc. compiled summaries of the assessments of cooling water return flow wells from selected State Class V reports: Minnesota, Nebraska Wyoming, Massachusetts, and Hawaii.

MINNESOTA

The Minnesota State Report provided construction, flow rate, and operating information on four wells in the state. This information is summarized and presented in the following paragraphs.

The Stauffer Chemical Company began utilizing groundwater for the purpose of condensor cooling and crystalizer cooling in the processing of whey into edible sugars, proteins and ash. From 1971 to at least 1975, this facility utilized an injection well to dispose of spent cooling water. Groundwater was drawn at 250-800 gpm from a supply well 200 feet deep and was discharged 200 feet away in an injection well completed at approximately the same depth. In 1971 groundwater temperatures in the aquifer were about 42°F. After four years of injection, the water temperature at the supply well had risen 30°F to about 72°F. Stauffer Chemicals was unsure when injection stopped but has been disposing effluent to surface waters under an NPDES permit since the injection well was abandoned.

Imdieke Meats has been using groundwater in its cooling-refrigeration compressors for more than 5 years and discharging the heated waters into a large (5 foot diamter) shallow (15 foot deep) hand dug well located about 25 feet from the supply well. Heated water is estimated to be about 90°F and Imdieke Meats knew of no problems associated with the operation of this system.

Schaper-Coson Manufacturing Company, a toy manufacturer, used groundwater for cooling its injection-molding presses from 1968 to June 1980. The system is currently not operating, but may be used in the future. Groundwater is pumped from a 10-inch diameter 415 foot deep well completed in the Jordan Sandstone. The injection well is 200 to 250 feet away and finished in the Jordan Sandstone at approximately 360 feet deep. The system is closed above ground and no additives are used. It was estimated that 1,000,000 gallons were pumped in a 5 day week. According to Schaper, the system worked well with no major problems.

NEBRASKA

Nebraska reports eight existing cooling water return flow wells and one proposed well. These wells were registered with the DEC under NPDES and hazardous waste files. The assessment of contamination potential was carried out using a seven step rating system that was developed from previously designed rating systems for surface wastes. The seven steps include:

Step I Type of industry or facility using the injection well

Step II Capture zone of any nearby municipal supply wells in relation to the injection well

Step III Design of the injection well

Step IV Design of the injection system

Step V Quantity of water being injected

Step VI Number of injection wells on each site

Step VII Sum of Steps I through VI

The scoring range for Steps I through V is 2 to 35 with 35 having the highest potential for contamination. In Step VI the total number of wells at each site was multiplied by two to obtain a rating value. The scores of the eight active and one proposed cooling water return flow wells were distributed in a unimodal pattern as follows: Two scored 16-18, four wells scored 22-24, two wells scored 25-27, and one at above 28.

The conclusions made were that because all wells were found to be ungrouted and unsealed, a possibility exists for surface contaminants to reach ground water. Ungrouted wells provide a direct conduit for surface contaminants to reach groundwater not

only through the injection well, but also along the outside of the well casing. The contamination potential is magnified by the additional fact that most of the wells were found at sites likely to handle hazardous wastes and were located in or near hydraulic capture zones of municipal supply wells.

Two of the eight assessed cooling water return flow wells were contact systems. Both of these wells were rated as possessing high potential for contamination because the possibility for hazardous substances entering the wells is greatly increased in contact cooling water systems.

The Nebraska DEC made the following recommendations designed to aid in the protection of groundwater in Nebraska. (For C/W return).

1. Minimum design requirements for cooling water return flow wells including:
   a. Wells be grouted from a point at least 20 feet below land surface to the land surface.
   b. Wells be designed only for non-contact systems where injection water is not chemically altered.

2. A Class V injection well application form specifically for cooling water return flow wells which would require:
   a. A detailed map of well location.
   b. Locations of all drinking water supplies within one mile of the injection well.

c. A diagram of the injection well and injection system including screen depths, gravel pack and grout.

d. Name of well driller.

e. A well log.

3. Minimum locating requirements relative to any nearby municipal supply wells are recommended based on Nebraska aquifer characteristics, flow rates and hydraulic gradients.

WYOMING

Wyoming reported 5 cooling water return flow wells located in the developed areas of Park and Teton Counties. The wells are constructed with steel or PVC casing which is perforated opposite the aquifer. The annulus is cemented above the perforated zone. These wells are completed in sensitive aquifers which are generally the same aquifers used for supply waters. Hazards cited in the Wyoming State Report include change in groundwater temperature, change in chemical characteristic of groundwater if water from another source is used; increased solubility of formation constituents due to increase in temperature, change in bacteriological characteristics of groundwater due to increase in temperature; and potential introduction of coolant (freon) into the groundwater. It was further stated that thermal pollution would probably only occur in areas of considerable or intensive recharge of higher temperature water and will be partly cancelled when the same system is used in a heat pump. In addition, isolated instances are of little concern because the thermal capacity of the aquifer largely negates a temperature change.

MASSACHUSETTS

Facilities operating non-contact cooling water systems in Massachusetts require a permit to discharge if they dispose of more than 2000 gpd or the temperature of the discharge exceeds 40°C. There are only 2 sites inventoried in Massachusetts as operating non-contact cooling water return flow wells; one is in Acton, the other is in Stoughton. Both of these facilities are industrial facilities reinjecting non-contact boiler coolant. The Acton site has one well 10 feet deep disposing of 2,000 gpd while the Stoughton facility has two 20 foot deep wells disposing of 14,000 gpd.

The hydrogeology of the Stoughton area is generally glacial and stratified drifts of up to 150 feet thick exist. Generally these are found in lower lying areas with water levels often within 10 feet of the surface.

The Acton area is composed of fine to coarse grained glacial deposits. The materials are 50 to 60 feet thick and overlie fine grained schists and gneisses.

The contamination potentials of these facilities have been rated as low because they are both operating non-contact systems. In addition, these sites and the surrounding areas are supplied with municipal water.

HAWAII

An inspection of Hawaiian Electric Light Company's electric power generating stations cooling water injection system was carried out by EEI in 1985. The power generating plant uses large amounts of potable quality water derived from seven on-site deep wells. This supply water is passed through condenser cooling units in portions of the plant.

Hill #5 uses an average of 15 million gallons per day and a maximum of 22.5 Mgd. Hill #6 uses an average of 27 Mgd and a maximum of 35 Mgd. The cooling water is once through and reaches temperatures of about 90 - 94^{o} before being disposed in injection wells via gravity flow. Cooling water from Hill #5 is piped directly to its 39 foot deep, 16 foot wide disposal well. Cooling water from Hill #6 is first piped to a seal pit with a weir and then to a 20 foot wide, 41 foot deep disposal well. Visual inspection showed water in the seal pit to be very clean with some indications of algal growth. These wells are both completed oceanward of Hawaii's UIC line in an exempt aquifer in the Kau volcanic series.

EEI felt that there was a low potential for contamination present in these wells, but that more detailed information on constituents of injected water, receiving water, and hydrogeology including monitoring data for nearby wells was needed to fully assess the impact of these wells.

Section 6.2

Industrial Process Water and Waste Disposal Wells
Supporting Data

Section 6.2.1

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Effluent Discharge Study, Components, Inc. Kennebunk, Maine
AUTHOR: (or INVESTIGATOR)	E.C. Jordan Co., Consulting Engineers
DATE:	June, 1983
FACILITY NAME AND LOCATION:	Components, Inc. Kennebunk, Maine USEPA Region I
NATURE OF BUSINESS:	Capacitor Manufacturer
BRIEF SUMMARY/NOTES:	Used an acid solution process involving dilute solutions of nitric acid, sulfuric acid, and tantalum powder. Groundwater was determined to be locally contaminated with manganese, nitrates, and sodium. Company moved. Monitoring continues. (Note: Appendices were omitted.)

E.C. JORDAN CO.

CONSULTING ENGINEERS

EFFLUENT DISCHARGE STUDY
COMPONENTS, INC.
KENNEBUNK, MAINE

JUNE 1983

EFFLUENT DISCHARGE STUDY

COMPONENTS, INC.

KENNEBUNK, MAINE

E.C. JORDAN CO.

JUNE 1983

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APPENDICES

Appendix A

- A-1 Logs of Subsurface Exploration
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- A-4 Flow Monitoring Data

Appendix B

- B-1 Soil Quality Results
- B-2 Sediment Quality Results
- B-3 Groundwater Quality Results
- B-4 Effluent Quality Results
- B-5 Surface Quality Discharge Results
- B-6 Grain Size Distribution Curves

Appendix C

- C-1 KKWWD Typical Drinking Water Quality Results

I. INTRODUCTION

A. Background

Components Inc. of Biddeford, Maine, a subsidiary of Corning Glass Works of Corning, New York, uses manganese nitrate in coating capacitors at its Kennebunk plant. Concentrations of manganese above the maximum allowable effluent discharge criteria set by the Maine Department of Environmental Protection (DEP) were discovered by Components in two dry wells that are used to discharge wastewater into the ground. These dry wells consist of approximately 5-foot diameter concrete basins with an open base to allow infiltration of the effluent into the subsurface soils. Components has been required by the Town of Kennebunk Hazardous Materials Control Board and the State of Maine Department of Environmental Protection to obtain a discharge license to permit continuance of discharge of effluent from their plant into the two existing dry wells.

B. Purpose

The purpose of this investigation is to determine if wastewater discharges from the plant pose a risk to the environment and human health. The investigation was to: 1) determine the quantity and quality of effluent; 2) characterize the wastewater effluent sediment in the dry wells; 3) sample the soil immediately adjacent to the dry wells to determine if discharged chemicals had accumulated in the soils ; and 4) initiate a groundwater monitoring program; and 5) evaluate the risks to the environment and human health and provide recommendatins to remediate conditions, if necessary.

C. Scope

In accordance with the Components agreement with the Maine EP, the E.C. Jordan Co. provided the following scope of services:

1. Establish a point of access in each of the effluent lines that discharge into the dry wells. The access points would permit meter[2] ing of the effluent flow rate and allow sampling for water quality testing.

2. Determine the concentrations of sodium, manganese, silver, nitrates and total organic carbon in the soils adjacent to each dry well and in any sediment on the bottom of the dry wells.

3. Assess the groundwater conditions existing at the site, including its flow direction, rate of flow and quality.

4. Make a preliminary site inspection of the facility operating practices and identify possible wastes which may have entered the soils through the dry wells.

5. Prepared this written report of the results and conclusions of the study.

D. Site Conditions

The Components plant is located in West Kennebunk at the intersection of State Route 35 and Alfred Road, as shown in Figure 1. The site is nearly flat but slopes gently toward the southeast. The developed portion of the site has been cleared and landscaped. Shallow groundwater conditions were observed on portions of the site during this study. Surface water flows from the site through perimeter ditches and discharges into the Mousam River.

II. DATA ACQUISITION

A. Field Data

The field exploration program for the site consisted of nine soil borings, the installation of five monitoring wells, construction of two access manholes and in situ permeability testing.

1. Soil Borings. Nine soils borings were completed during the period of May 2 to 8, 1983 by Henry Michaud and Son and Con-Tec Inc., drilling contractors. The approximate location of the borings, identified as B-1 through B-4 and MW-1 through MW-5, are shown on Figure 2.

Borings B-1 through B-4, located adjacent to the dry wells, were advanced using hollow stem augers. The soils were continuously sampled to depths of between 8 and 9.5 feet. The soil samples were obtained using a split-spoon sampler. The purpose of these borings was to characterize the subsurface conditions and obtain samples of soil for visual classification and chemical analysis.

Five borings, designated MW-1 through MW-5, were completed at the proposed monitoring well locations. The purpose of these borings was to characterize the soil conditions and obtain samples for visual and laboratory classification. These borings were advanced using conventional wash boring techniques with 4-inch I.D. casing. Samples of soil were generally obtained at 5-foot intervals using a split-spoon sampler driven in accordance with the Standard Penetration Test procedure (ASTM D-1586). The soil information was used to select the length and depth of the well screen for each monitoring well. Logs for each boring are presented in Appendix A-1. The driller's logs have been annotated by our geologist based on visual examination and laboratory testing of soils samples.

2. Monitoring Wells. Five monitoring wells, one well in each boring, were installed in the MW-1 through MW-5 bore holes. One monitoring well (MW-5) was installed as a background well, up-gradient relative to groundwater flow from the two dry wells. The remaining four wells were located down-gradient from the dry wells. The monitoring wells consist of threaded 2-inch diameter PVC well screen with 0.01-inch slot openings and pipe risers. Clean filter sand was used to fill the annulus around the screened section of each well. Starting at approximataly one foot above the screened interval the annulus was backfilled with bentonite to provide a seal. The wells were developed by flushing and pumping to remove silt and to provide a good hydraulic connection with the groundwater system. A protective black iron pipe with a locking cap was placed around each PVC pipe riser. A summary of well installation details is included in Appendix A-2.

The protective pipe and ground surface elevations at each monitoring well were surveyed by E.C. Jordan Co. staff. All elevations are referenced to a previously established bench elevation of 106.5 feet (i.e., finished floor, concrete slab near the rear door).

3. In-Situ Permeability Testing. Rising-head permeability tests were conducted on the five wells. This testing consisted of pumping the wells down and measuring the rate of recovery. These results are shown in Appendix A-3. The soils showed permeability values ranging from 3.7×10^{-4} to 2.7×10^{-6} cm/sec.

4. Effluent Discharge Monitoring. Presently there are two industrial waste discharges from the plant. These are located at the extreme ends of the facility from Building No. 1 and Building No. 2. Both discharge to the ground via buried dry wells. These wells are equipped with overflow and vent openings. The overflow pipe for Dry Well 1 discharges to the road drainage ditch for Rt. 35. The overflow pipe for Dry Well 2 discharges to vacant land adjacent to the northern entrance driveway for the facility. The location of the dry wells, discharge lines and overflows are shown in Figure 2.

Since there is no internal or external access to these lines, previous sampling of the wastewater has been through the vent opening of each dry well. Samples obtained in this manner have been suspect as to whether or not they are representative of the actual discharge quality. In addition, the volume of the discharges into the dry wells has been unknown and could only be estimated.

To quantify the effluent flow rate and obtain representative samples for determination of water quality, it was decided to install effluent monitoring manholes on each discharge line prior to the discharge at the dry wells. Precast concrete manholes, purchased from superior Concrete, and the manholes were installed by Bob Nest & Sons of Kennebunk, Maine. A sketch of the installation is shown in Appendix A-4. The location of each manhole is shown in Figure 2.

The Jordan Company installed temporary flow monitoring equipment in each manhole. This instrumentation consists of 30° V-notch weirs and Stavens depth measuring and recording devices. Collection of data commenced on May 17, 1983. Hourly flow data for May 17 to May 24 is presented in Appendix A-4). The following table summarizes average flow rates for the period covered:

TABLE 1
Measured Flow Rates
Gallons Per Day

Building	Total Period Average Flow	Weekday Average Flow	Weekday Range	Weekend Flow Range
No. 1	606	820	588-1092	141-219
No. 2	1036	833	656-1034	1436-1447

B. Laboratory Data

1. Soil Sampling and Chemical Analysis. Borings B-1 through B-4 were drilled adjacent to the dry wells to obtain soil samples for chemical analysis. These borings were made within 4 to 6 feet of the dry well vent opening which was assumed to be at the center of the dry well. In general, the explorations encountered a very bouldery gravel fill to depths of between 5 and 6.5 feet. A

dense glacial till was encountered below the fill to the termination depth of each boring, which ranged from 8 to 9.5 feet. It should be noted that the soil samples for chemical analyses were selected based on visual indications of dark staining. The selected sample depths are shown graphically in Appendix B-1. The results of the laboratory analyses are shown on Figure 3, and in Appendix B-1.

2. Dry Well Sediment Sampling and Chemical Analysis. Two sediment samples (one sample per dry well) were obtained on May 11, 1983 through the dry well vent opening by using a hand-held stainless steel sampling scoop. The samples were handled with a cleaned stainless steel spatula and placed in laboratory prepared glass containers. Sediment samples were analyzed for sodium, manganese, silver and nitrate. Specific conductance and pH were also measured. The sediment consisted of soft dark sediment which covers the base of each dry well. The results of the laboratory analyses of the sediment samples are shown on Figure 3 and in Appendix B-2.

3. Groundwater Sampling and Chemical Analysis. Sampling of the groundwater monitoring wells took place on May 10, 1983. Prior to sampling, the wells were purged of standing water using a hand-operated diaphragm pump. This purging replaces the stagnant groundwater within the well bore with groundwater flowing within the soils outside the well, and provides a representative specimen of groundwater.

Sampling from the wells was accomplished using a peristaltic pump and flexible plastic tubing. The wells were again purged of standing water before the actual sample was collected. The duration of adequate purging was determined by inserting a temperature and conductivity probe into the well just above the top of the well screen. The values for temperature and conductivity were monitored, and upon stabilization of these values during purging the pump was turned off and the suction tubing lowered to approximately the mid-point of the well screen. The pump was turned back on and the sample collected.

Immediately upon collection, pH and reduction-oxidation potential (Eh) were determined followed by filtration and preservation for the various analytical parameters. The samples were filtered through a 0.45 micron membrane filter to remove any interferences from suspended and dissolved sediments which are not moving in the normal undisturbed groundwater flow. Preservation with ultra-pure acid to lower the pH to 2.0 or below minimized adsorption or sedimentation of elemental parameters before laboratory analysis. The samples were iced before transport to the laboratory. The results of the laboratory analyses are shown on Figure 3 and in Appendix B-3.

4. Effluent Sampling and Chemical Analysis. After the effluent monitoring manholes were installed, a 24-hour composite sample was collected at each location. [redacted] The results of the effluent analysis are shown on Figure 3, and in Appendix B-4. [redacted] effluent location was collected from mid-morning of [redacted] to mid-morning of June 1, 1983 and tested for manganese only The results of this test are also shown on Figure 3 and in Appendix B-4.

5. Surface Waste Samples and Chemical Analysis. Surface water samples were collected below the outfall of both Dry Well 1 and 2 on June 1, 1982. This was after Components ceased discharging manganeous waste into the effluent. The results are shown on Figure 3 and in Appendix B-5.

6. Soil Geotechnical Testing. Four soil samples, two from each of the general strata encountered, were selected for grain size and natural water content analyses. These results are shown as grain size distribution curves in Appendix B-6.

Based on the laboratory analysis, the strata consist of fill and outwash over glacial till. The surficial stratum of fill and outwash material is a moderately well sorted, silty medium to fine sand with occasional cobbles and boulders. The underlying glacial till is a moderately well graded gravelly, silty sand with some clay.

III. HYDROGEOLOGY

A. Geology

The surficial soils at the site have been mapped as outwash material over glacial till and marine clay (Prescott, 1963). The explorations made for this study encountered a very thin surficial stratum of sandy outwash over dense glacial till. The sandy outwash stratum, containing occasional boulders, ranged from approximately 3 to slightly more than 5 feet in thickness. Based on two laboratory grain size analyses, the outwash is a silty sand with trace amounts of gravel. The underlying glacial till ranged from a brown to gray gravelly silty sand to sandy silt. Laboratory analysis of the till indicates a fines content (i.e., percent by dry weight passing the U.S. No. 200 sieve size) ranging from 40 to 57 percent. Based on the standard penetration resistance the till consistency ranges from firm to compact. While the upper portion of the till stratum is brown the contact with the overlying granular soils appears sharp and well defined. Permeabilities of the till, based on in-situ rising head tests, range from 2.7×10^{-6} cm/sec to 3.7×10^{-4} cm/sec (see Appendix A-3). Permeability of the surface sand and fill stratum was estimated from the grain size distribution analysis to range from 10^{-4} to 10^{-3} cm/sec. It appears that the higher permeability encountered at MW-4 (3.7×10^{-4} cm/sec) may be due in part to the fact that the screened interval penetrates the overlying outwash stratum.

B. Hydrology

The interpretation of groundwater flow beneath the site is based on water level observations made in the monitoring wells, dry wells, sump pit, catch basin and drainage ditches on the north, south and east sides of the property. These water elevations were made on May 9, 1983 and are shown on the attached site plan (Figure 2). It should be noted that the existing subsurface septic systems located along the east side of the plant facility may slightly alter the water table contour lines. The maximum groundwater flow appears to be restricted to the thin surficial stratum of outwash and flows to the east with a slope of approximately 2 to 3 percent.

The geometric mean of the measured permeabilities of the glacial till is about 1×10^{-5} cm/sec. Seepage rates for the till with the observed 2 to 3 percent groundwater slope range from about 0.7 to 1.4 feet per year. Seepage rates of the overlying sand and granular fill layer range from 200-300 feet per year, based on an estimated permeability of 3×10^{-3} cm/sec and an effective porosity of 0.3. The data indicate that the downward (vertical) seepage is minimized by the less permeable glacial till and that maximum horizontal flow takes place within the sandier fill and outwash.

Based on the exploration data, the surficial deposits encountered at the site do not constitute a significant water-bearing resource or aquifer. A review of available geologic data for both the surficial (Prescott, 1963) and bedrock (Caswell, 1975) materials also does not indicate significant ground water resources in the area.

IV. EVALUATION

A. Effluent and Dry Well

Effluent discharged into Dry Well 1 is associated with waste from processes in Building No. 1. The principal waste chemical is manganese nitrate, which is applied pyrolytically to the tantalum capacitors. Dry Well 2 serves building No. 2, which features some intermediate manufacturing and finishing processes for the capacitors. Only minor amounts of neutilized manganese nitrate are occasionally discharged to Dry Well 2. Sodium hydroxide or hydrochloric acid is used for neutilization. Therefore, only the Building No. 1 effluent system presently contains significant quantities of manganese nitrate. The analytical values for chemical parameters in the effluents and the sediments for each of the dry wells is indicative of the activities in each building, both past and present.

The effluent concentrations from Building No. 1 showed manganese (240 mg/l) and nitrate (140 mg/l) roughly in the same proportion they would be in the manganese nitrate solution. Silver, not currently used in this manufacturing area, was slightly elevated above background ground water quality, but at 0.004 mg/l was still below the DEP effluent criterion of 0.05 mg/l. The sample of sediments from Dry Well 1 also showed the effects of manganese usage. Manganese has preciptated out in the dry well to produce a concentration of 73,000 mg/kg in the sediment. The presence of 62 mg/kg of silver is indicative of the precipitation of this metal and also of past years when both ends of the plant performed similar manufacturing processes. Sodium and nitrates were relatively low considering the effluent concentrations but indicative of their solubilities and their likelihood of passing through the dry well uninhibited (i.e., not retained by the sediments).

The effluent from Building No. 2 shows elevated manganese, sodium and nitrate relative to the allowable effluent criteria. Although manganese nitrate is not currently used in processes in Building No. 2, stocks and waste manganese solutions are stored there and drain piping may have accumulated manganese scale over past years. This residue still may be leaching out under certain pH conditions. The 0.62 mg/l of manganese measured at the manhole should, however, receive dilutions in the range of 10-20 times with the cooling water blowdown before discharge. Sodium was present at 36 mg/l and nitrate was 3.1 mg/l. While the sodium balance in this area cannot be determined with the available data, the nitrate will most likely be further diluted in the dry well to below limits by the cooling water. Silver in the Building No. 2 effluent at 0.026 mg/l was greater than found in the Buiding No. 1 effluent which was expected, but was still well below the 0.05 mg/l effluent criteria even before further dilution with the cooling water.

As stated above, no processing with manganese is currently being done in Building No. 2. However, in past years each building housed similar manufacturing operations utilizing the manganese nitrate solution. Thus residual sediments in Dry Well 2 still contain 15,900 mg/kg manganese. Nitrate, found in low concentrations in the sediment, is probably associated with the liquid portion of the sample. Silver was found in the sediment at 110 mg/kg, slightly higher than Dry Well 1, and shows that some of the small amounts of silver used in the process has precipitated out in the dry well. The sodium value of 2000 mg/l is unexpected and unexplainable based on process flows and

sources. The sodium would be expected to be soluble and therefore would generally not be associated directly with the sediments. Crystals of a sodium salt may have dislodged from the dry well and been collected with the sedmiant sample, or the sample could have been taken at a time when slugs of sodium salts were released over a short period of time. Possible sources for the sodium could be regenerative chemicals used for the deionization unit, the sodium hydroxide neutrilization discharge or the sodium hypochlorite used to control algae in the cooling water recirculation system which is hydraulically connected to Dry Well 2 (See Figure 2).

Analyses for manganese in the effluents from Building No. 1 and Building No. 2 were conducted on samples collected subsequent to steps taken by Components to eliminate manganese nitrate discharges from Buildng No. 1. The value of 16 mg/ℓ for manganese in the Building No. 1 effluent is about 20 times less than the previous analyses and may be attributed to residual manganese in the drain pipes. This value is expected to decrease as the system attains equilibrium. As indicated by the 0.62 mg/ℓ manganese value obtained in the Building No. 2 effluent, however, the reservoirs of manganese scale in the pipes may contribute long-term low level manganese concentrations in the effluent, despite complete containment of the manufacturing source.

Samples of the effluent overflow were also taken in the drainage courses associated with each discharge point subsequent to the process changes. A value of [illegible] mg/ℓ was associated with the effluent overflow from Building No. 1. This value likely indicates both manganese removal in the dry well and possible dilution with some cooling waters. However, it could also represent contributions from the reservoir of manganese in Dry Well 1. Future samples will help define relationships of manganese and flow through this system. A value of 0.02 mg/ℓ was obtained at the overflow discharge point of combined flows from Building No. 2. This shows the considerable decrease of the manganese concentration due to dilution by the cooling water system overflow. These data suggest that actions combining source removal with flow equalization (combining all flows) may result in an acceptable effluent with no required treatment.

B. Soil Concentrations

Two samples were selected for analysis from each of the four borings. Specific conductance and pH were well within normal ranges for soils. Sample 3 in boring B-3 at 140 μmho/cm showed the highest conductivity. Nitrate levels in all samples ranged only slightly, from 0.13 to 0.57 mg/kg, demonstrating the solubility and mobility of that ion. Manganese ranged from 790 to 6800 mg/kg. The lower number is not significantly different than naturally occuring concentrations of manganese in soils. Rollin Glenn, Professor of Soil Chemistry at the University of Maine at Orono, indicates that manganese concentrations in southern Maine soils generally range from 500 to 1000 mg/kg. Concentrations in B-1 (6800 and 1700 mg/kg), and in B-3 (1200 and 1100 mg/kg), however, may be elevated in the context of the setting. Silver concentrations in B-3 and B-4 were much lower than sediment silver concentrations in either dry well. The small quantities of silver used at the plant and the silver reclamation procedure limits potential concentrations of silver. Ranges for sodium varied from 5 to 380 mg/kg. In three borings, B-1, B-2 and B-3, concentrations were significantly higher in the lower sample, but this was reversed for B-4. Specific conductances measured did not correlate well with the concentrations of either sodium or manganese.

Manganese concentrations in borings B-1 and B-3 relative to the nitrate concentrations again strongly emphasized the point that the nitrates are much more soluble and mobile than the manganese. The lack of correlation of specific conductance with manganese concentrations possibly suggests that the manganese is probably present mostly in non-ionic forms, possibly as oxides or hydroxides.

C. Groundwater

Groundwater samples were taken from the four downgradient wells MW-1, MW-2, MW-3, and MW-4, and the one upgradient well MW-5. Based on the groundwater level data, monitoring well MW-1 appears to be directly down-gradient of Dry Well 1 and MW-4 appears to be down-gradient Dry Well 2. Wells MW-2 and MW-3 did not exhibit water quality significantly different than the background well for the parameters analyzed. ~~Of interest was the value of 0.09 mg/l for manganese in the background well.~~ This is almost twice the recommended drinking water standard, but certainly not surprising of in areas with naturally occuring manganese. Chemical analyses of groundwater from 12 selected wells in southwestern Maine (Prescott and Drake, 1962) showed manganese concentrations of 0.0 to 0.3 mg/ℓ. In addition, Rollin Glenn (1983) indicates typical concentrations of up to 2 mg/ℓ in soil pore water.

Specific conductances for wells MW-2 through MW-5 were essentially the same. The conductance in ~~MW-1~~ was much higher, probably due to the higher concentrations of ~~nitrate (28 mg/l), sodium (44 mg/l) and manganese (2.9 mg/l)~~ found in this well. Notice that the ratio of nitrate to manganese has risen to about 10 from the effluent ratio of about 0.58, again demonstrating the removal of manganese from the groundwater as it moves through the soils. Furthermore, the manganese concentration was about 100 times greater in the dry well effluent (240 mg/ℓ) suggesting the rapid attenuation of the manganese by the soils. This attenuation will continue down-gradient of MW-1 and values approaching background quality are expected by the time the groundwater reaches Rt. 35.

Manganese levels in wells MW-2 and MW-3 were less than the background level shown in MW-5. The concentration of manganese in MW-4, 0.28 mg/l, is about one-third of the effluent concentration and indicates dilution and attenuation by the soils. However, at such a low concentration it is difficult to differentiate the value from background groundwater quality given the site setting.

Oxidations-reduction potentials were measured for the monitoring wells. MW-2, MW-3 and MW-5 had values ranging from +202 to -225 millivolts (mv). Readings for MW-1 and MW-4 were lower at +178 mv and +180 mv. Lower than background values such as these are usually indicative of effluent effects.

The concentration of silver in all wells was reported as less than 0.001 mg/l, i.e. limit of detection.

D. Environmental Impact

The combined evaluation of all the geohydrologic and chemical data indicates that the manganese nitrate is predominantly associated with Dry Well 1, although Dry Well 2 indicates some residual effects. The effluent discharge

into the soils is presently retarded by the sediment layer in both dry wells. Manganese which enters the soil is absorbed to the soil particles and rapidly attenuates in the groundwater. The groundwater concentrations probably begin to approach background by the time it reaches Rt. 35. However, even at the highest observed on-site value, i.e. 2.9 mg/ℓ, concentrations are within acceptable health levels. (Drinking water and Health, 1977). Despite a recommended limit of 0.05 mg/ℓ for manganese in drinking water supplies, much of the concern is for aesthetics, as higher concentrations can lead to discoloration or noticeable taste in the water and may taint laundry whites (ibid). Manganese is an essential micronutriant for man and daily requirements are normally attained through ingestion of foodstuffs. The average human intake is approximately 10 mg/day (USEPA, 1976). With this in mind, it becomes apparent that the 0.05 mg/ℓ drinking water criterion is extremely conservative from a health standpoint. Nitrate also dilutes and possibly reduces to ammonia or is used by tree and plant roots. Nitrate concentrations of less than 10 mg/ℓ, i.e. the recommended drinking water standard, are probably obtained prior to movement beyond Rt. 35. The other parameters tested do not indicate significant health risks. Furthermore, the groundwater which carries these compounds probably remains in the shallow, more permeable soils and doesn't penetrate downward. There are no known well water supplies downgradient of the site. The groundwater discharges into Punky Swamp to the east and eventually enters the Mousam River after significant natural attenuation and dilution.

The effluent quality values are above the DEP criteria, i.e. 0.05 mg/ℓ for manganese, 10 mg/ℓ for nitrate, 20 mg/ℓ for sodium and 0.05 mg/ℓ for silver. Based on the original results, Components initiated a program to eliminate process discharge of manganese nitrate to Dry Well 1. This was successful, as indicated by the subsequent manganese testing described above. The values dropped at least an order of magnitude after only a few days. This decrease will likely continue to a value similar to Dry Well 2. Since this also reduces the effluent loading on the soil, effluent effects in the groundwater should begin to decrease.

Based on the data, the results of the study suggest that no significant environmental degradation has occurred and the activities have not resulted in any significant human health risks.

V. CONCLUSIONS

1. Concentrations of manganese and nitrate in the effluent are higher than DEP effluent criteria, particularly the effluent associated with Building No. 1.

2. Concentrations of manganese in the dry wells, the soils and the groundwater indicate that the manganese is attenuated in the soils and concentrations in the groundwater decrease rapidly with distance away from the dry wells. Significant changes in groundwater quality off-site (relative to background water quality) is doubtful.

3. Sodium discharges are slightly above the DEP effluent criteria.

4. Present levels of silver in the effluent and groundwater are below the Drinking Water Standards and do not appear to be a threat to local groundwater quality.

5. Groundwater remains shallow and moves toward the east at several hundred feet per year. There are no known drinking water wells down-gradient of the site.

6. Considering the rapid decline in the concentrations of manganese and nitrate in the groundwater, it would appear that the subsurface disposal of these wastewaters do not present a significant risk to the health or safety of local residents.

VI. RECOMMENDATIONS

1. The principal source of manganese and nitrate from the facility is from the rinsing and cleaning of solution trays used in the manufacture of the tantalum capacitors. In order to achieve the established groundwater limits, it is recommended that the rinsing and cleaning of these trays be done in a still tank. The contents of the still tank would be pumped into drums for disposal, as the cleanliness of the rinse water dictated.

2. Mixing of concentrates with water should be done in an area isolated from drains.

3. A program emphasizing the need to curtail all losses of solutions to the drains should be addressed to employees to seek their cooperation and understanding in achieving considerably reduced discharge of the manganese nitrate.

4. Monitoring of wells MW-1, MW-4 and MW-5 should be conducted on a routine basis to observe the impact of implementing discharge controls on the manganese nitrate.

5. The dry wells should be cleared out and the system operated as is, or the effluent lines should be combined with the cooling water to form a single surface discharge to the small brook north of the site. This second option would involve removal of the dry wells and may require resubmission of the discharge license applications; the most cost-effective, practical solution should be selected.

6. Periodic monitoring of the effluent(s) should be undertaken.

VII. REFERENCES

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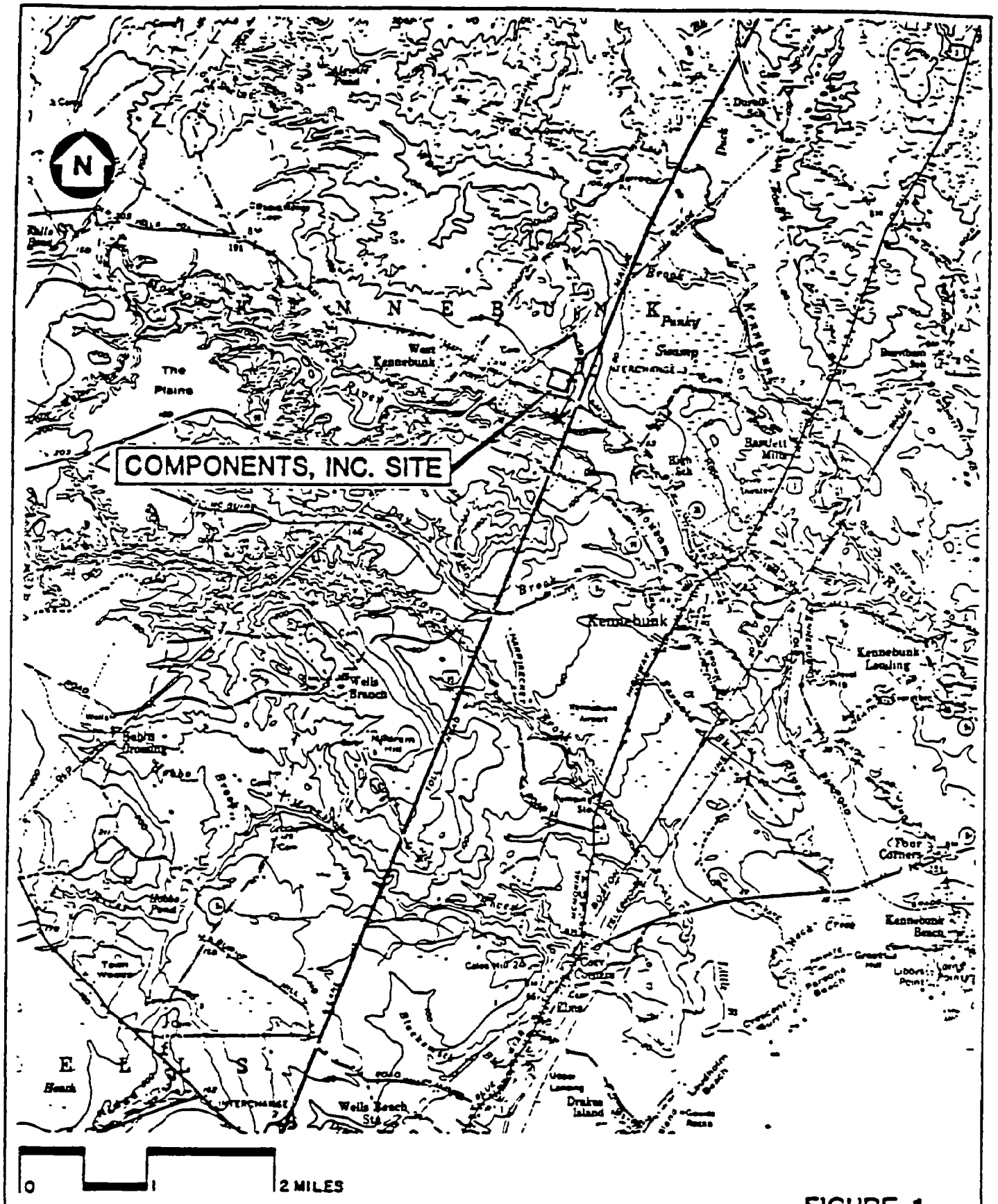
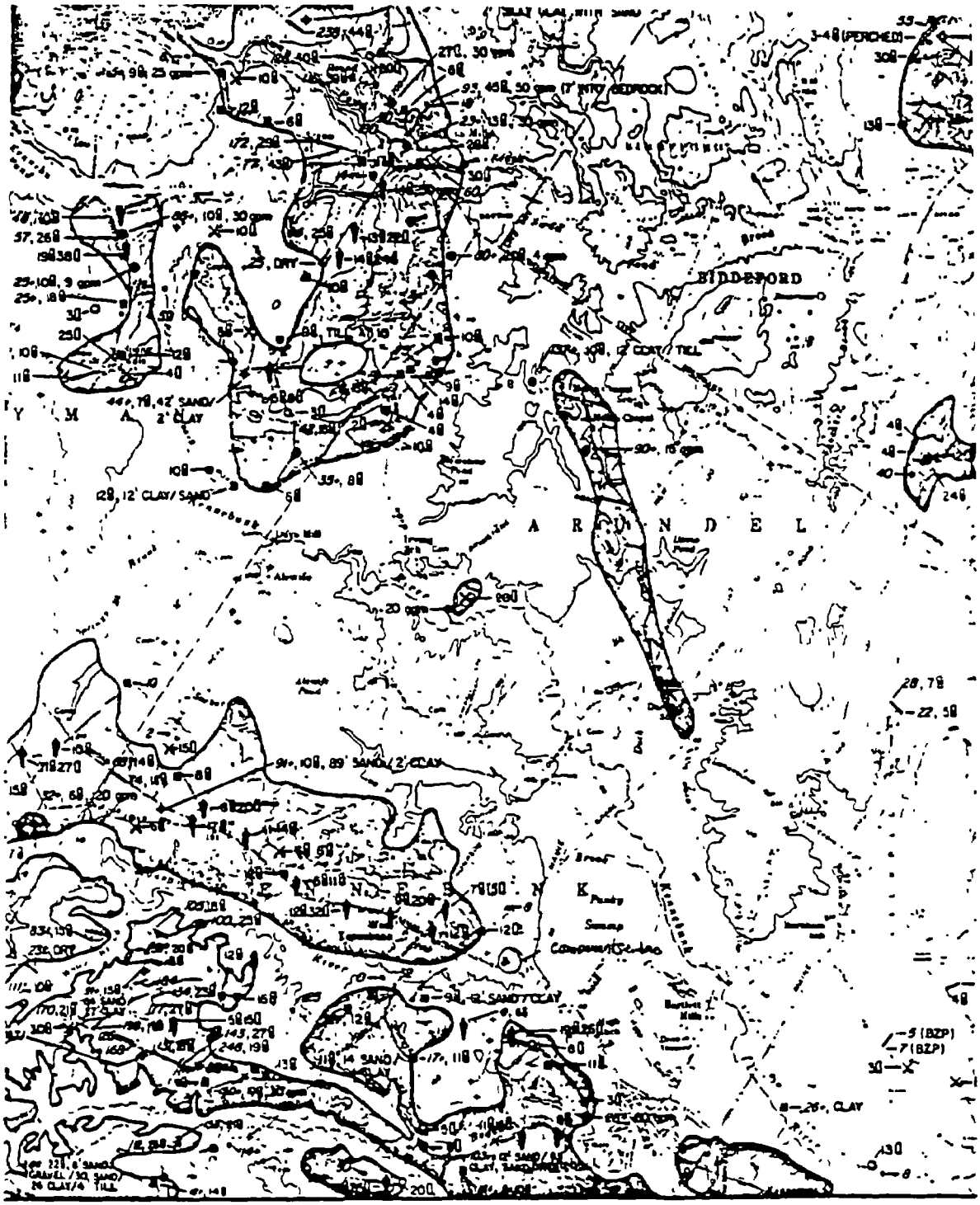


FIGURE 1
EFFLUENT DISCHARGE STUDY
COMPONENTS, INC.
KENNEBUNK, MAINE

ECJORDANCO


BIDDEFORD
A R U N D E L
1 : 50,000
0 1 2 3
MILES
0 1 2 3 4 5
KILOMETERS
N
National Geodetic Vertical Datum of 1929

of well, spring, test boring, test pit, and seismic data. The aquifer boundaries and yield designations are generalized and subject to modification based on more detailed investigations.

LOCATION MAP

SYMBOLS

- Aquifer boundaries
- Sand and gravel aquifer (10-50 gallons per minute)
- Sand and gravel aquifer (50 or more gallons per minute)
- 50 Depth to bedrock (ledge) in feet
- 13' Minimum depth to bedrock, in feet
- 6 Depth to water table in feet below natural ground surface (observed in well, spring, test boring, pit, or seismic line)
- 15 Minimum thickness of sand or gravel in feet (observed in well, test boring, or pit)
- Gravel pit
- 4 gpm Yield (flow) of well or spring in gallons per minute
- Spring
- Gravel well
- Dug well
- Observation well (project)
- Test boring
- Driven point
- Test pit
- Drilled well
- Potential source of ground water contamination
- Bedrock outcrop

SEISMIC LINE INFORMATION

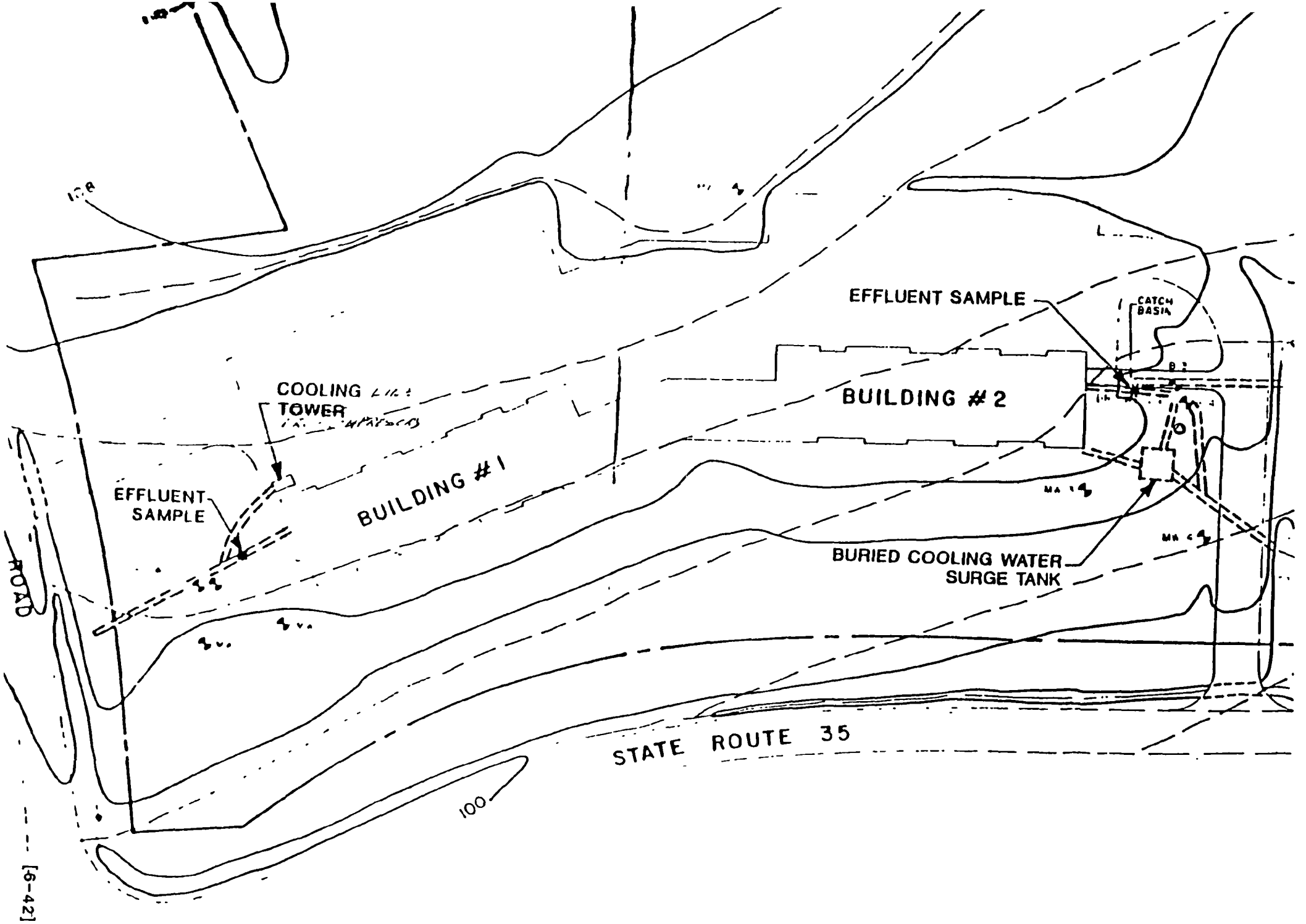
- 53 Depth to bedrock, in feet below land surface
- 53+ Depth to bedrock (based on calculations) exceeds depth shown
- 10 Depth to water table, in feet below land surface
- DRY No water table was encountered above the bedrock surface
- BZP A blind zone problem was encountered at one or both ends of the line. An intermediate layer (usually the saturated zone) was too thin to be detected using the seismic method. If the presence of this layer was suspected, calculations were done according to Mooney (1980) to determine the minimum and maximum possible thickness of this layer.
- 11 6 — 11 6 12-channel seismic line, with depth to bedrock and depth to water level shown at each end of the line
- 17 9 / 1 Single-channel seismic line, with average depth to bedrock and average depth to water level

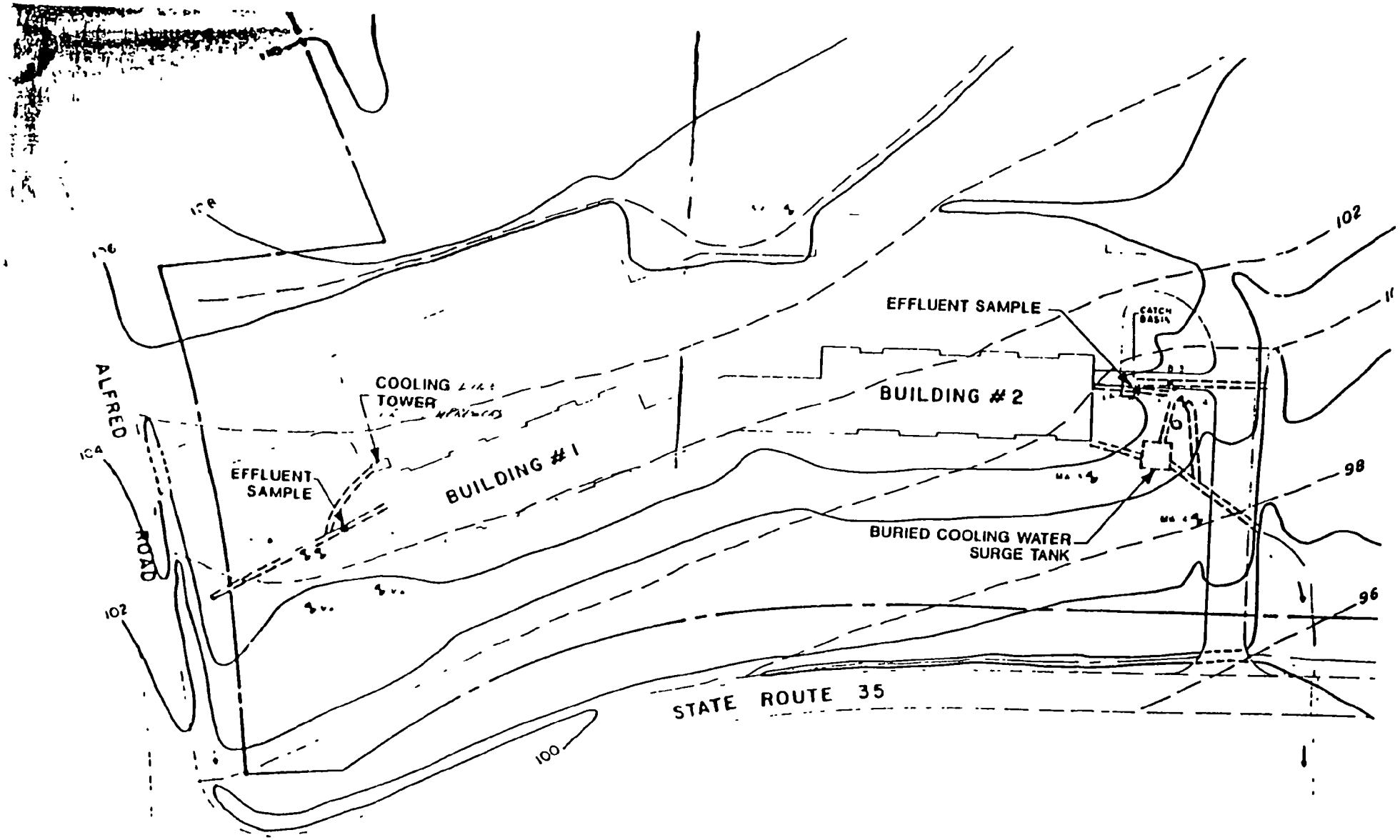
43° 22'30"
70° 48'

Additional information concerning this study and the hydrogeology of this area is presented in Open-File Report #83-1

A.L. Tolman. ., USGS Open-976a) and 10 Maine ic 1978-1984

Cartography by Robert A Johnston


EFFLUENT SAMPLE
CATCH BASIN
COOLING TOWER
BUILDING #2
BUILDING #1
EFFLUENT SAMPLE
BURIED COOLING WATER SURGE TANK
ROAD
STATE ROUTE 35
100


EFFLUENT SAMPLE
CATCH BASIN
COOLING TOWER
BUILDING #2
ALFRED
EFFLUENT SAMPLE
BUILDING #1
ROAD
BURIED COOLING WATER SURGE TANK
STATE ROUTE 35
102
98
96
100
104

Section 6.2.2

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Field Trip Report - Southern Maine Finishing Company
AUTHOR: (or INVESTIGATOR)	GCA Corporation, Technology Division
DATE:	December, 1985
FACILITY NAME AND LOCATION:	Southern Maine Finishing Co. East Waterboro, Maine USEPA Region I
NATURE OF BUSINESS:	Metal Plating and Fabricating Plant
BRIEF SUMMARY/NOTES:	The facility operated a rudimentary wastewater treatment plant which resulted in contamination of ground and surface water. Subsequently a new treatment system was designed which could treat cyanide chromium acid and alkali.

GCA

GCA CORPORATION
Technology Division

213 Burlington Road
Bedford, Massachusetts 01730
Telephone 617-275-5444
Telex 92-3339

2 January 1986

Mr. Robert Jackson
U.S. EPA, Region I
150 Causeway Street
Boston, MA 02203

Subject: Southern Maine Finishing Corporation
East Waterboro, Maine
Work Assignment #263-02

Dear Bob:

Enclosed is a copy of the field trip report for the SMF site investigation conducted Monday, 16 December 1985. The enclosed figures illustrate the approximate location of the site boundaries, residential wells in the vicinity, existing and proposed monitoring wells and surface water sampling points. Your field notes are also enclosed.

Recommendations on a two part water quality sampling plan are attached. The plan provides for immediate sampling of surface waters, residential and existing monitoring wells. Installation of additional monitoring wells has been recommended in order to further delineate the vertical and horizontal extent and migration of contaminated groundwater.

If you have any questions, do not hesitate to call.

Sincerely,

Robert N Clemens

Robert H. Clemens, Manager
Water Resources Section

Enclosures

FIELD TRIP REPORT
Southern Maine Finishing (SMF)

Conducted Monday, 16 December 1985 - 6-8" Snow on Ground

On 16 December 1985 GCA conducted a preliminary site investigation of Southern Maine Finishing (SMF), East Waterboro, Maine under EPA work assignment number 263-02. The scope of work entailed a visual assessment of Cooks Brook and surrounding environment for wetlands determination; confirmation of the number and location of private and groundwater monitoring wells within 1/2 mile of the facility and development of a base map for SMF. Following is a summary of field observations and wetlands evaluation.

Personnel:

Bob Jackson, EPA Region I
Paul Turina, GCA
Patty Rodden, GCA
Anne Sergeant, GCA
Joan Kimsey, GCA

Purpose:

- do general area reconnaisance and field observations
- confirm location and condition of SMF monitoring wells & production wells
- identify domestic wells within vicinity of site
- identify & describe wetland areas

Observations:

Figure 1 indicates the approximate site boundaries of SMF and location of residential wells in the vicinity of the site. Existing and proposed monitoring well locations are shown on Figure 2. Description points for the wetlands evaluation are shown on Figure 3.

Monitoring wells-

- Verified location of Monitoring Well #101 to be approximately 66m from Junkins barn and 80m from SE corner of SMF treatment facility. Well #101 is not cased or locked and appeared not to be grouted.

- Located two unidentified wells. One located to SE of SMF treatment plant. The other was approximately 65m NW of monitoring well #101. Both wells were cased and locked. According to a revision of Figure 1 from Gerber's June 1982 report dated 8/82 these wells appear to be those identified as 201(B) and 202(A). No information was available on either well.*

- Monitoring well #102 was located. It appears to be 30 feet from stream. This was not cased or locked and appeared not to be grouted.

- Monitoring well #103 could not be located. It is assumed to have been destroyed.

- Area to the SW of the SMF facility was investigated, however no monitoring wells were located.

* At the direction of EPA, GCA staff did not engage in discussions with SMF personnel concerning the facility monitoring well network or its condition.

Residential Wells-

- A house by house survey of homes in the vicinity of the SMF site was conducted. Location of residential wells are shown on Figure 1. A list of homes visited and survey results are as follows:

1. Doris Junkins - 1 point well in basement - abandoned due to high contaminant concentration. Present water source is a point well in front yard 12' below grade, 25' from road, 50' from SMF.

2. Wade Junkins - 1 point well 12' below grade located between barns, abandoned due to high contaminant concentration. Domestic water source is a 1 point well located in bulkhead below kitchen 12' below grade.

3. Edna Roberts - 1 point well in basement 14'.

4. Lumber Yard - Ponzetti - 2 point wells, one located 12' below grade 60' off road on driveway near shack. Second point well located 12' below grade 30' East of other well.

5. Daley Residence and Insurance Company - 1 well approximately 120' in depth located 30' off road.

6. T.J. Carrigan - 1 well point located in basement of home 9' below cellar floor approximately 17' below grade. 1 well point located at trailer adjacent to Carrigan residence.

7. Leah Bradeen - Not Home

8. Victoria Bradeen - Not Home

9. James Monteith - Well point 9' below grade 40' off road.

10. Louise Arsenault - 1 point well, no further information.

11. Albert Goodwin - 1 point well located in basement, approximately 45' off road, 10' below basement floor approximately 18' below grade.

Wetlands Evaluation-

Southern Maine Finishing (SMF) is believed to have contaminated the local ground and surface waters with heavy metals and cyanide. These substances have been found in several nearby drinking water wells and in Cooks Brook, which flows through SMF's property.

Cooks Brook flows south under Route 5, via a 3 ft. culvert, (Point A on Figure 3) about 500 ft. northwest of the main building and continues south, then southeast, through the property, eventually passing under Routes 4 and 202, turning eastward, and discharging into a unnamed pond about 1.1 mi east-southeast of SMF.

The U.S. Fish & Wildlife Service's National Wetlands Inventory map shows only a small pond near where Cooks Brook crosses under Route 5 and the area where it crosses under Routes 4 & 202 as seasonal wetlands, but the scale of the map (15' series) and sometimes ephemeral nature of the brook (discussed below) probably account for the differences in interpretation.

The stream has a well-defined channel where it enters the property and soon passes through a 3' culvert, (Point B on Figure 3) but it wanders through a wet bottomland after several hundred feet (Point C on Figure 3). This area is forested primarily (60-70%) with red maple (Acer rubrum) with some black oak (Quercus velutina), grey and river birches (Betula populifolia and B. lenta), hemlock (Tsuga canadensis) and white pine (Pinus strobus). Most trees are between 3 and 6 in diameter at breast height (DBH); this indicates that the area was cleared 20 to 30 years ago. The tree stratum appears fairly dense (80-90% cover), while the shrub stratum is sparsely populated (about 30% cover) with silky dogwood (Cornus amomum), witherod (Viburnum cassinoides) red maple samplings and sprouts, sheep laurel (Kalmia angustifolia) and winterberry (Ilex verticillata).

The 6-8 in. of snow cover made it difficult to fully characterize the herb stratum and impossible to estimate percent cover, but several species of ferns (including sensitive fern (Onoclea sensibilis), and royal fern (Osmunda regalis), mosses (including Sphagnum), grasses and sedges were found.

Snowcover also precluded delineation of the wetland boundaries, but the area seemed to range from 5 to 30' away from the brook in either direction. The wetland was narrowest (about 10' wide) about 500' southwest of SMF; the stream trace there could not be found because of the snow cover and frozen ground. According to Dennis Merrill of the Maine Department of Environmental Protection (12/12/85 personal communication) this portion of the stream often dries up for part of the summer.

Further downstream, near routes 4 and 202 (Point E on Figure 3) the vegetative community becomes completely dominated by red maple, with almost no understory and hummocks of grasses and sedges in almost-motionless water. However, shrubs dominate the area where Cooks Brook passes under routes 4 and 202 (Point F on Figure 3).

Water quality appears fairly good throughout the brook: the water is somewhat tannic but clear, and there are occasional faint traces of iron deposits on the sandy bottom and some manganese films in quieter areas. GCA found no evidence of stressed vegetation (although the season would probable have masked any signs of stress) in any portion of the brook. Invertebrate diversity surveys conducted by the Maine Department of Environmental Protection in August 1984 show that very few individuals, representing only 3 invertebrate groups (Trichoptera, Hemiptera and Diptera), inhabit the stream; this could be a manifestation of stress to the aquatic community.

Southern Maine Finishing (SMF)
Sampling Recommendations

A two part water quality sampling plan has been developed for SMF. The first phase provides for immediate sampling of surface waters, residential and existing monitoring wells. The water quality results from phase one would primarily serve as a basis for evaluating current health and environmental impacts. Phase two would involve the installation of additional monitoring wells for water quality and water level sampling and further delineation of the contaminant plume. Placement of nested well groups would provide information on vertical flow gradients as well as horizontal extent of contaminant migration. Location of the proposed monitoring wells are shown on Figure 2 and are discussed in the sampling plan outline below.

Phase one:

Residential Wells (Driven points)-

Water quality for health impacts (see recommended parameters list below)

Monitoring Wells-

Water quality and static water level measurements at existing monitoring wells (101 & 102).

Surface Water-

Water quality samples in Cooks Brook at previously designated sample locations (as specified in Gerber June 1982 report and shown on Figure 3).

Phase two:

Install additional monitoring wells for water quality sampling and delineation of contaminant plume-vertical gradients and horizontal extent.

Location of Proposed Monitoring Wells-

Additional wells adjacent to existing wells 101 & 102. New wells to be screened at greater depth than existing wells. Screened intervals to the adjusted according to soil boring information.

Two nested wells groups placed west of Cooks Brook. One group to the southwest of monitoring well 101 in relatively close proximity to disposal site. The other group to be downgradient of the site in vicinity of well 102. Location shown on attaced Figure 2.

Nested well group adjacent to well at Junkins Barn.

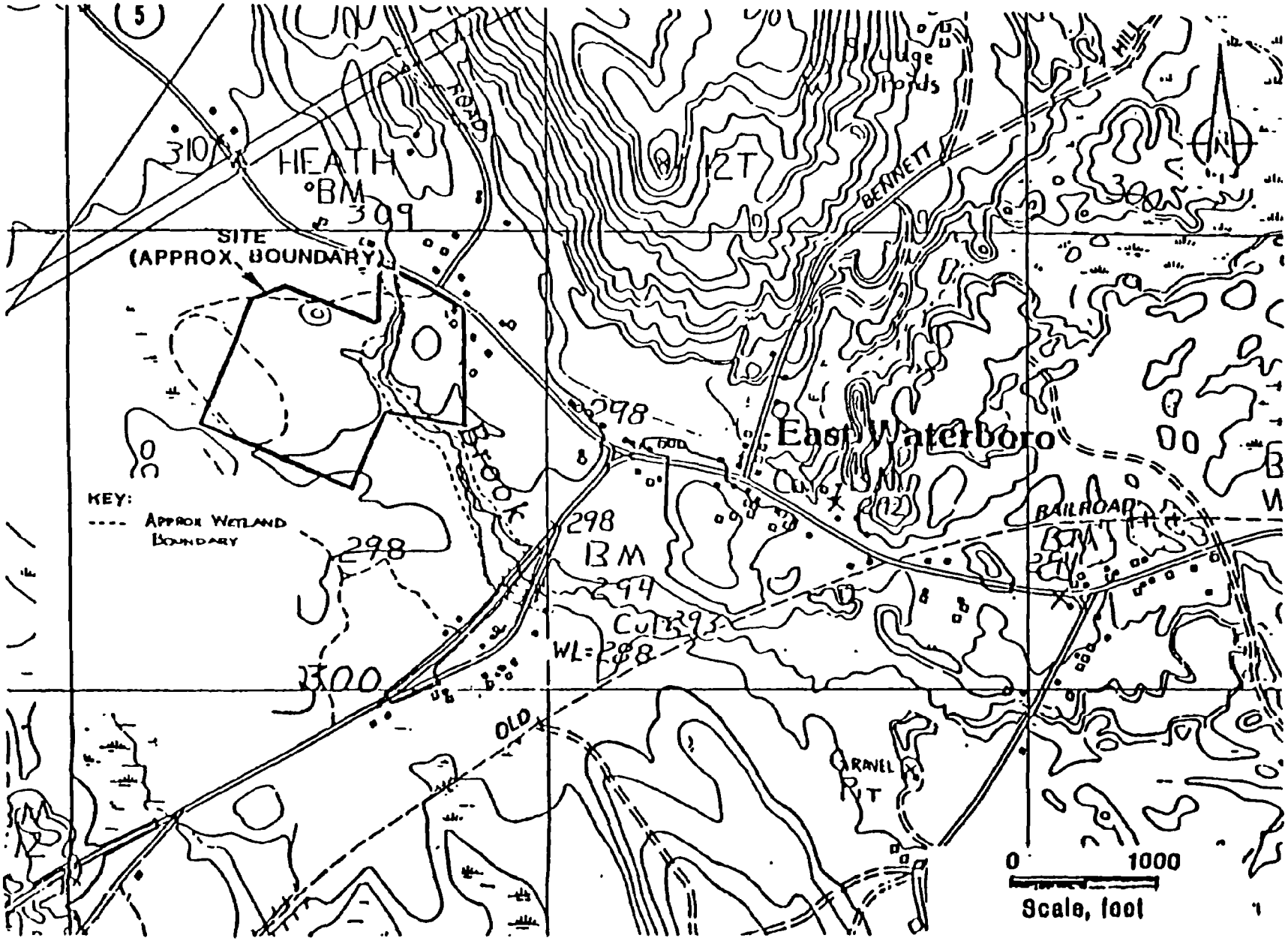
Additional nested well group to the northeast of 102.

Single wells for background water quality information and regional water level measurements. Suggested locations -

Northwest of site across Rt. 5 near Cooks Brook
Northeast of site across Rt. 5 from G. Junkins residence
South of disposal site on west side of Cooks Brook.

Recommended Parameters:

Cadium
Chromium total
Chromium (hex)
Nickel
Silver
Lead
Iron
Aluminum
Zinc
Copper
Tin
Cyanide
Nitrite
Nitrate
Phosphates
Chloride
Sulfate
pH
Conductivity
Total Metals



Source: U.S.G.S. map of Waterboro, Maine Quadrangle.

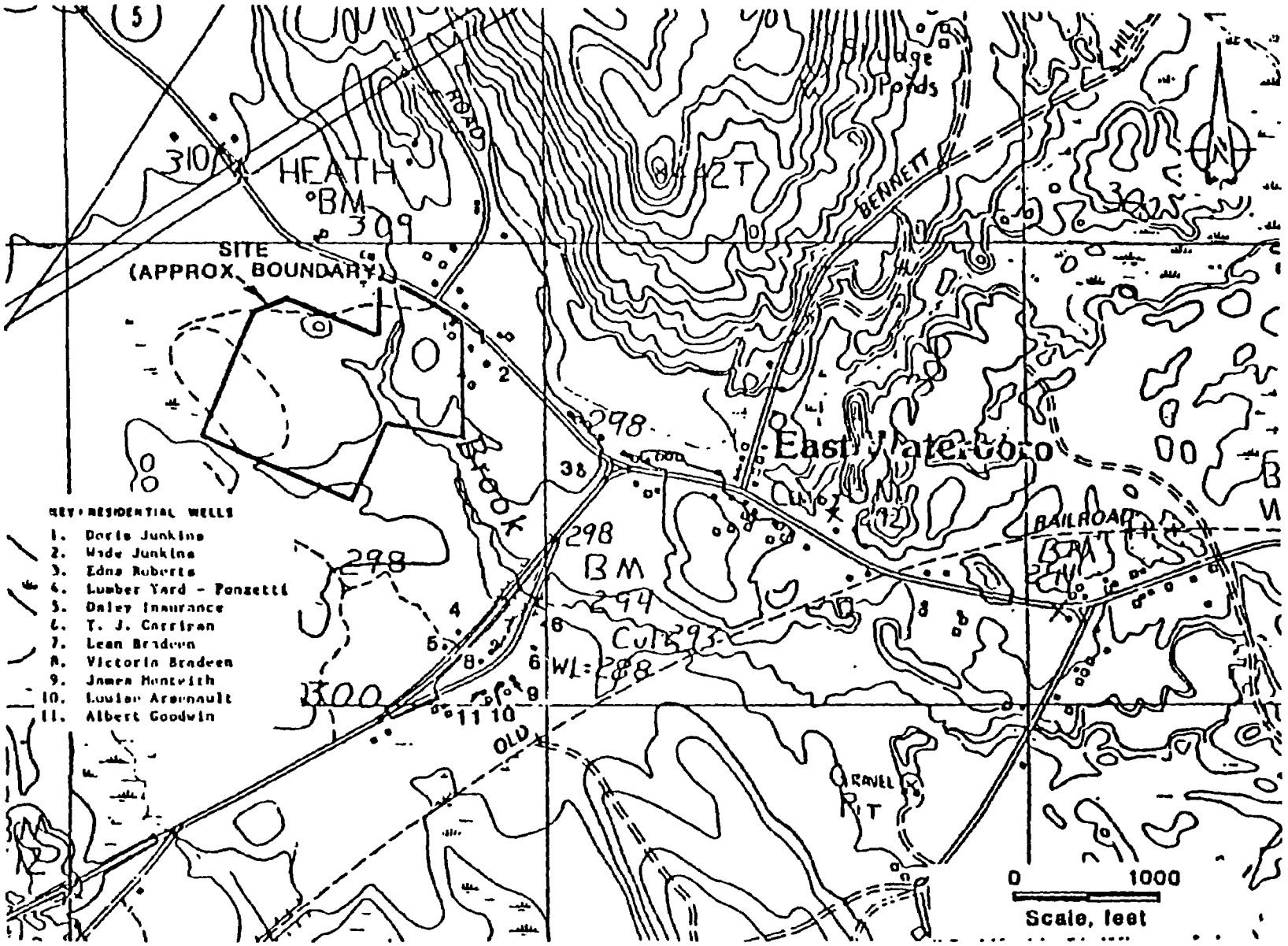


Figure 1. Site location. Numbers indicate location of residential wells.
Source: U.S.G.S. map of Waterboro, Maine Quadrangle.

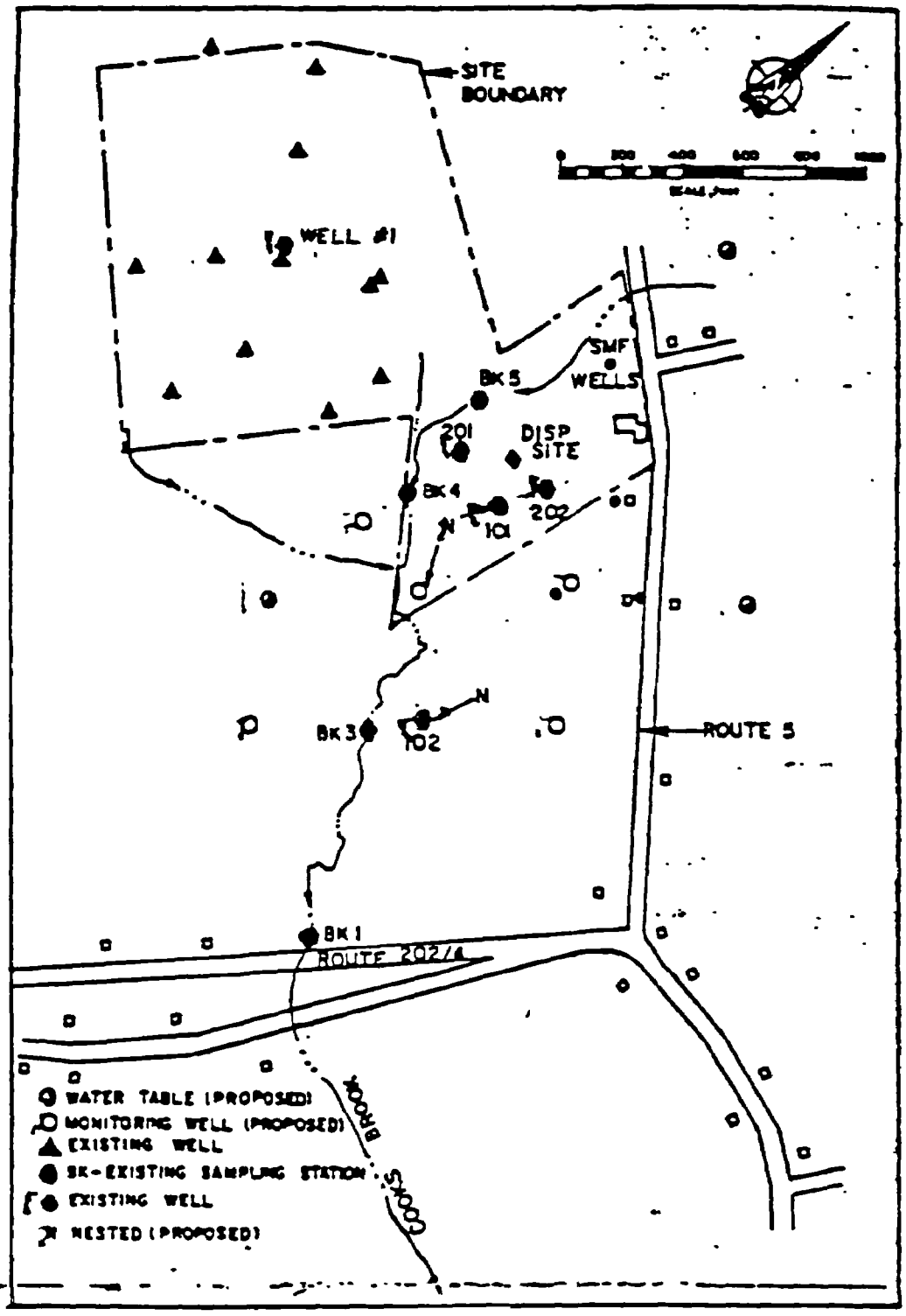


Figure 2. SMF existing and proposed monitoring well location.

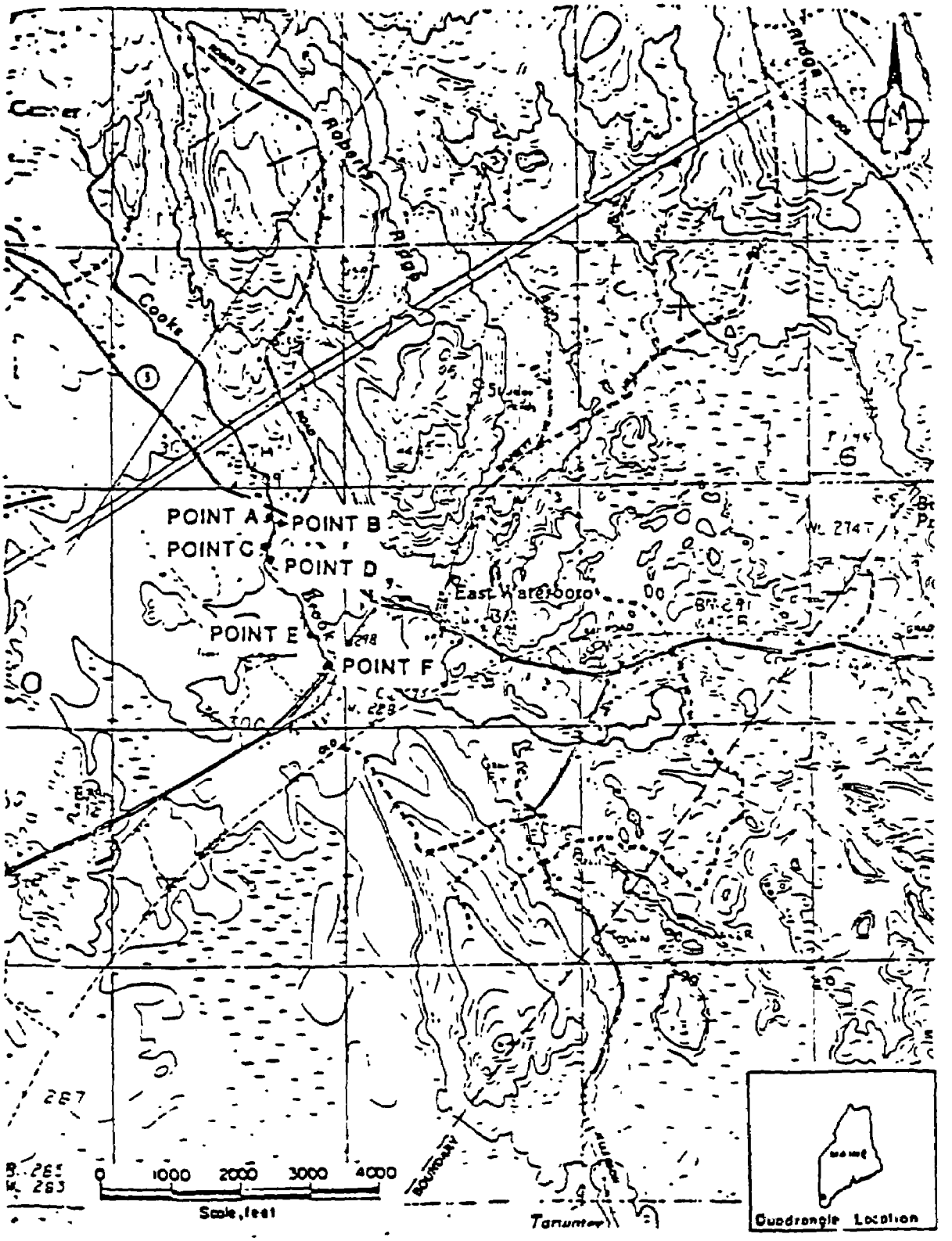


Figure 3. Description points of the wetlands evaluation.

STATE OF MAINE
Department of Environmental Protection

MAIN OFFICE, RAY BUILDING, HOSPITAL STREET, AUGUSTA
MAIL ADDRESS, State House Station 17, Augusta, 04333

JOSEPH E. BRENNAN
GOVERNOR

HENRY E. WARREN
COMMISSIONER

July 19, 1982

Stuart Gannett
Southern Maine Finishing
East Waterboro, Maine 04030

Dear Stuart:

Our staff has completed review of Bob Gerber's report of hydrogeologic investigations of the area surrounding your plant. We are in general agreement with Bob's findings and recommendations. The report may be used as the basis for design of the final effluent disposal system. It is our understanding that this will consist of subsurface system similar to a conventional leachfield located at or near the present disposal site.

As you are aware, the firm's discharge license requires that groundwater monitoring wells be maintained for routine sampling to evaluate the impact of the treated discharge. (See Special Condition 1(c) in the license). For the background well, Bob Gerber recommends the one designated Well-1, located near OW-5 be used. Wells 101 and 102 should be sampled for down-gradient monitoring. Additionally, it is requested that as part of his design of the effluent disposal system, Bob evaluate the need for additional monitoring wells in the disposal area.

If any questions arise, please give me a call.

Sincerely,

Dennis Merrill
Division of Licensing and Enforcement
Bureau of Water Quality Control

DM:pmf
cc: Bob Gerber

ROBERT G. GERBER, INC.
ASH POINT ROAD • SOUTH HARPSWELL, MAINE 04079
207-833-6334

25 August 1982

Mr. Joseph Poirier
Southern Maine Finishing Corp.
Route 5, Box 188
East Waterboro, Maine 04030

Re: transmittal of design of wastewater disposal system

Dear Mr. Poirier:

With the assistance of Mr. Walter Stinson, P.E., consulting engineer in North Windham, I have completed a design of a disposal facility to handle the discharge from Southern Maine Finishing Co.'s (SMF) new wastewater treatment process. The new disposal system will be located in the same area as the present system, but will be of different construction. A location plan and details for the new disposal system as drawn by Mr. Stinson and modified by me is enclosed. This letter describes the design criteria and rationale for the disposal system design.

SYSTEM LOCATION

As a result of the studies that I have completed of the hydrogeology of the area, my 25 June 1982 report recommended that the present discharge site by utilized for the discharge from the new wastewater treatment plant. It is my understanding that both SMF and the Maine Department of Environmental Protection (DEP) have accepted this recommendation.

DESIGN CONCEPT

We have chosen a trench system with pressurized distribution to handle a design loading of 30,000 gallons per day. We obviously gave serious thought to whether or not the existing series of cascading well tiles could be used, but had to conclude that this system is ineffective in creating an appropriate distribution of the wastewater. Continued use of this type of system would continue to create surface discharge of the wastewater in localized areas of the disposal system, which has occurred historically at this site. I would have preferred to use a concrete leaching chamber design but initial cost estimates based upon a preliminary design were over $30,000. In light of your statement to Mr. Stinson that this system may only be used for one year, we have chosen the cheapest system that can still fulfill your purposes.

The system is designed to be effective for a soil permeability of 1 foot per day, which is the minimum permeability that I could conceive of at this site, based upon all of the testing that I have done for this project. Therefore, there should be allowance for some system clogging, which will

inevitably occur. The final size of the system represents about one-half the area that would be required under the Plumbing Code for a domestic wastewater disposal design on soils requiring a "small" system. The estimated position of the seasonally high water table is elevation 94.0' (local project datum), which is about 4.6' below the bottom of the trench as presently designed.

One important point to note is that there may be a need to dispose of some soil and the well tiles that are in the existing system. The DEP has agreed (Ed Logue) to visit the site to determine whether these materials need to be treated as "hazardous wastes". Depending upon how much soil must be removed, the final grade of the system may be adjusted slightly, since it accounts for use of soil excavated from the trenches. It is imperative that the DEP do its determinations prior to the construction of the new system.

DESIGN DETAILS

The system is composed of a total of 4400 linear feet of trench. Each trench has 15" of stone below the 4" distribution line. A 1½" PVC perforated pipe will receive effluent from dual alternating pumps. The 1½" pipe is located within standard 4" distribution pipe. The system is divided into two separate areas of equal size, which are dosed alternately by dual alternating pumps that will provide a dose of about 2000 gallons. The large 10" manifold pipe is required in order to keep the pressure loss within the accepted standard. Internal pressure in the distribution pipes during pumping will be 1 foot of head. The dual pumps will each pump about 300 gallons per minute at a head of 11.6'. The series arrangement of two residential septic tanks results in a cheaper wet well capacity than would a 3000 gallon commercial septic tank. (There is no septic tank in the present system.)

Our preliminary cost estimate for the system is $15,000. Mr. Stinson intends to get a refined estimate from a contractor named Les Wilson & Sons, who would like to bid on the job, if you put the job out to bid.

CONSTRUCTION SUPERVISION

In order for us to assume proper responsibility for the operation of this system, we must supervise its construction. Several last minute changes in design may be necessary, including the selection of final grade, as discussed above. The layout of the project and setting of grade stakes will be very important since there are relatively small tolerances allowed. The plans also call for our approval of the stone and other materials used in the construction. Assuming you retain me to oversee construction, Mr. Stinson will provide field surveying and design changes as approved by me.

ADDITIONAL GROUND WATER QUALITY MONITORING

As a result of my recommendation, the DEP conducted water quality tests on residential wells in the maximum conceivable area of impact of the historical wastewater discharge plume. Two nearby wells were found to contain some indication that they had been contaminated by the SMP discharge. These well owners have been notified by the State. On the basis of the DEP tests, it appears that these wells contained metal concentrations of about 1% of the discharge concentrations, which is what the computer model predicts.

I recommend that an additional set of water quality tests be taken from the Doris Junkins well, and each of the two Giga Junkins wells. During the construction of the new disposal system, I would like to have Walt Stinson locate these wells by survey. The test parameters for the new set of tests should include cadmium, trivalent and hexavalent chromium, nickel, iron, zinc, copper, aluminum, cyanide, nitrite-N and nitrate-N.

Permanent monitoring wells for use in following the effectiveness of the new discharge in purging the present plume area of contaminants will include the wells shown on the enclosed Figure 1. Well #1 near OW5 (see Figure 3 of 25 June 1982 report) will be used for background water quality monitoring as necessary in the future. Wells #101 and #102, which were installed this spring will be used as part of the continuing monitoring program. I recommend that two new monitoring wells, #201 and #202, be added as part of the long-term program. These wells should be added at the time when the new disposal system is being constructed. They would be screened in a zone between 5 and 10 feet below the average ground water table position. Their position in proximity to the disposal area will allow for a determination of the rate of reduction in contaminant concentrations that are presently quite high in this area. In summary, the long-term monitoring program would consist of quarterly sampling in wells #101, #102, #201, and #202; and annual sampling in Well #1 (near OW5) and the three Junkins wells.

I am sending a copy of this report and the disposal plans directly to Dennis Merrill of the DEP. Minor design revisions to the plans will be forwarded to you and Mr. Merrill as they are made.

Respectfully submitted,

Robert G. Gerber, P.E. 3165

Enc: one disposal area design plan
one Figure 1

c: Dennis Merrill, DEP

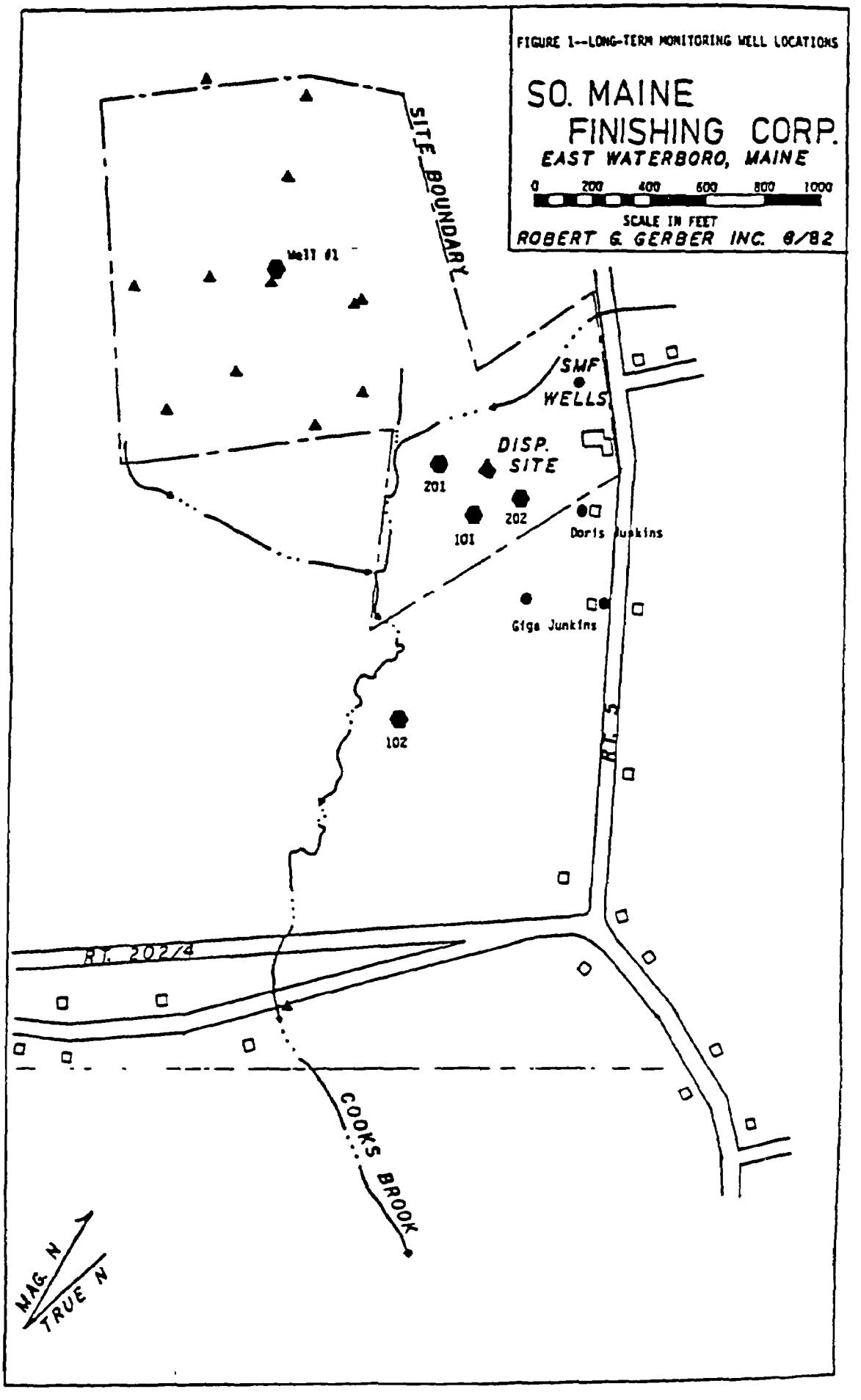


FIGURE 1--LONG-TERM MONITORING WELL LOCATIONS
SO. MAINE
FINISHING CORP.
EAST WATERBORO, MAINE
0 200 400 600 800 1000
SCALE IN FEET
ROBERT G. GERBER INC. 6/82
SITE BOUNDARY
Well #1
SMF
WELLS
DISP.
SITE
201
202
101
Doris Junkins
Giga Junkins
102
RT. 5
RT. 202/4
COOKS BROOK
MAG. N
TRUE N

GROUNDWATER SAMPLING PROGRAM

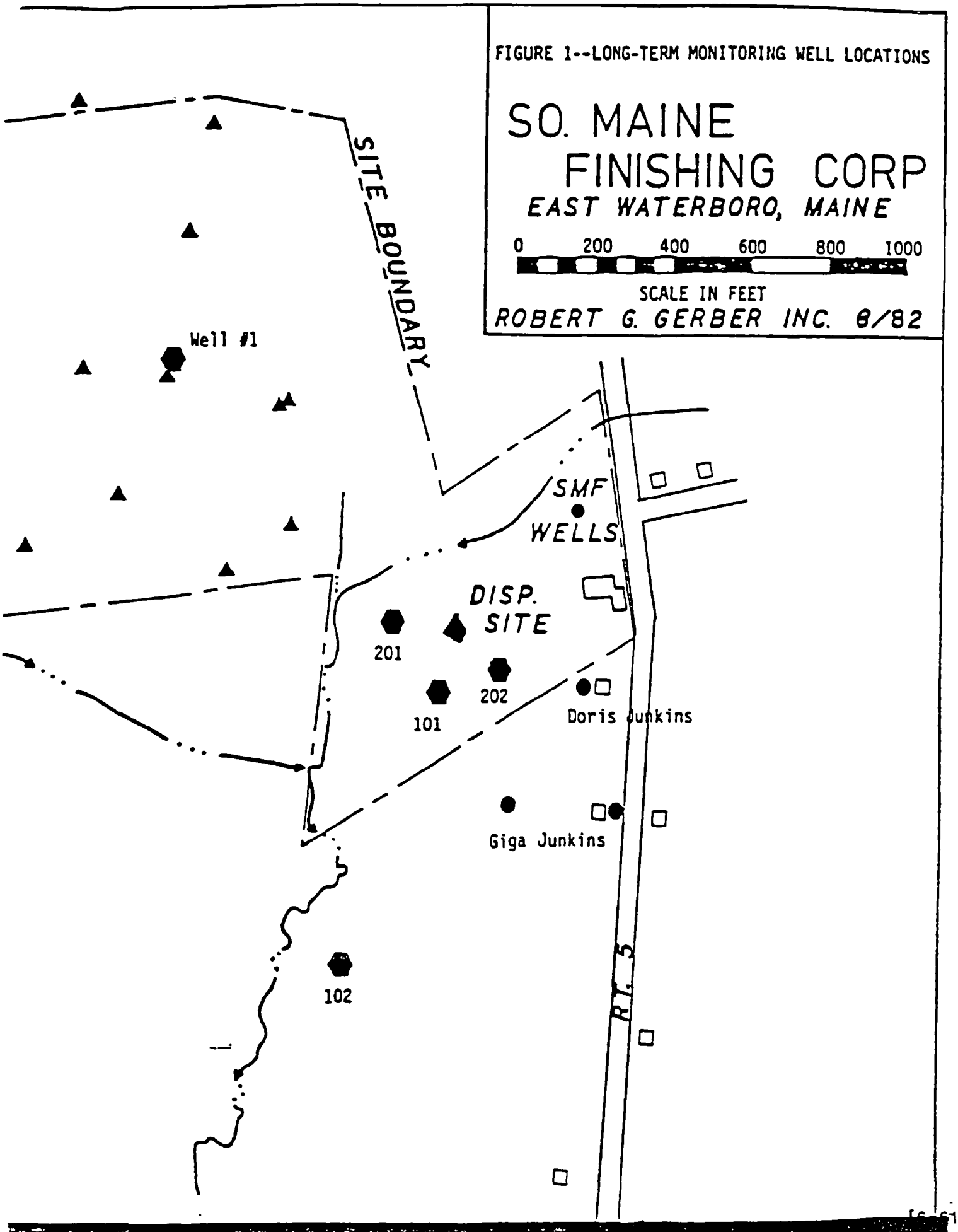
In order to monitor the impact of pollutants discharged by Southern Maine Finishing Corp. on the groundwater in the area, the following sampling program should be instituted. This program is based on the requirements of the Company's Waste Discharge License, approval granted by the Department of Environmental Protection staff pursuant to the license, and the recommendations of an independent hydrogeologist who has studied the area. Since private wells in the vicinity of the discharge have been contaminated, the monitoring of these is included to protect the health and interests of these persons.

Locations of monitoring wells: Wells designated by hydrogeologist Robert Gerber in his report as wells 101, 102, 201, and 202 should be used as the primary monitoring locations to access the impact of pollutants discharges. Wells 101 and 102 are in place while wells 201 and 202 are not. Well #1, so called, which is in place will serve to provide background water quality data. Private wells owned by Doris Junkins (1 well) and Giga Junkins (2 wells) should also be monitored. The attached drawing shows the location of all wells.

Frequency of sampling: Wells #1, 101, 102, 201, and 202 should be sampled quarterly starting immediately and lasting until two years after the treatment system becomes operational. Thereafter sampling may be reduced to semiannually. Wells owned by the Junkins' should be sampled semiannually, starting immediately.

Analyses to be performed: Each sample should be tested for those pollutants listed in the waste discharge license, using proper testing methods. Also, the water level in each well should be recorded. In addition to reporting all results to the Department of Environmental Protection the Junkins' should be provided with results on their wells.

FIGURE 1--LONG-TERM MONITORING WELL LOCATIONS



Section 6.2.3

TITLE OF STUDY: (or SOURCE OF INFORMATION)	From Revised Interim Report: Maine's UIC Program
AUTHOR: (or INVESTIGATOR)	Maine Department of Environmental Protection
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Sanford Airport Industrial Park Maine USEPA Region I
NATURE OF BUSINESS:	Aircraft Maintenance
BRIEF SUMMARY/NOTES:	Waste paint, spent solvents, and asssociated material were washed to a collection dump. After removal of solids, wastewater was disposed in a drainfield. Matter is under investigation by Maine's Department of Environmental Protection.

111

York Aviation. York Aviation ran an aircraft maintenance business located at the Sanford Airport Industrial Park until 1986. Attachment 8-A provides maps showing the location and geohydrological setting of York's operation. In 1981 York was included in Maine's initial inventory of underground injection facilities.

In early 1985 York Aviation was the subject of a complaint to DEP regarding the improper disposal of hazardous wastes. An investigation by DEP staff revealed that York was painting new aircraft and repainting used aircraft using various solvents. Waste paint, spent solvents and associated materials were washed to a collection dump. After removal of solids, the wastewater was disposed of in a drainfield adjacent to York's hangar. On the basis of ground water sampling in and around the site, DEP's Bureau of Oil and Hazardous Materials Control has begun an investigation into potential violations of state and federal hazardous waste law by York Aviation. York Aviation has filed for bankruptcy and discontinued its operation. Because the matter is under investigation, detailed information regarding the facility is being withheld from publication. Upon completion of the investigation, DEP will decide whether York should be retained on Maine's inventory of underground injection facilities.

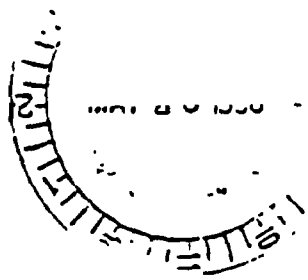
Section 6.2.4

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Initial Environmental Assessment Eastern Air Devices, Inc. Facility Dover, New Hampshire
AUTHOR: **(or INVESTIGATOR)**	Balsam Environmental Consultants
DATE:	May, 1986
FACILITY NAME AND LOCATION:	Eastern Air Devices, Inc. Dover, New Hampshire USEPA Region I
NATURE OF BUSINESS:	Electric Motor Manufacturer
BRIEF SUMMARY/NOTES:	Two dry wells had been used for waste disposal. The wells were cleaned out, and fluids and solid samples were analyzed. Some organic compounds were identified (primarily tetrachloroethylene, or PCE). Hydrogeology of the area was assessed and contamination is believed to be contained.

IV E

We don't know what the actual injection fluid consists of. App A reads "... two dry wells ... for disposal of some aqueous waste streams from the plant." Cleaning out the wells revealed some volatile organic compounds.

New Hampshire 5W20



INITIAL ENVIRONMENTAL ASSESSMENT
EASTERN AIR DEVICES, INC. FACILITY
DOVER, NEW HAMPSHIRE

Prepared for

EASTERN AIR DEVICES, INC.
One Progress Drive
Dover, NH 03820

Prepared By

BALSAM ENVIRONMENTAL CONSULTANTS, INC.
5 Manor Parkway
Salem, NH 03079

May 27, 1986

alsam Environmental Consultants, Inc.

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May 27, 1986

Mr. Michael Donahue, P.E.
State of New Hampshire
Water Supply and Pollution Control Commission
Hazen Drive
Concord, NH 03301

Mr. Timothy Drew
State of New Hampshire
Office of Waste Management
Hazen Drive
Concord, NH 03301

Re: Transmittal of Initial Environmental Assessment
Eastern Air Devices, Inc.
Dover, New Hampshire

Dear Sirs:

In response to the letter issued by the New Hampshire Water Supply & Pollution Control Commission, dated May 14, 1986, Balsam Environmental Consultants, Inc. (Balsam) has prepared the enclosed report on behalf of Eastern Air Devices, Inc. (EAD) of Dover, New Hampshire. This report contains an initial environmental assessment of the EAD facility based on the preliminary site investigation as described in our letter to the New Hampshire Office of Waste Management, dated February 11, 1986, and a proposed work scope to further evaluate the EAD property.

After your review of this assessment and proposed work scope, EAD and Balsam are prepared to meet with you should you have any questions. We are also prepared to proceed with the proposed work scope immediately upon your approval of this plan, and wish to implement this further investigation as expeditiously as possible so that this matter may be promptly resolved.

Please feel free to call us to discuss any aspect of this assessment or the proposed scope of work.

Sincerely,

BALSAM ENVIRONMENTAL CONSULTANTS, INC.

Stephen B. Ransom
Project Engineer

Leonard C. Sarapas, P.E.
Project Manager

Enclosure

cc: J. Burtelow, EAD
W. Evans, NHWSPCC
K. Marschner, NHOWM
R. Sattler, PB&L

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I. INTRODUCTION AND OBJECTIVES

1.0 Introduction

Balsam Environmental Consultants, Inc. (Balsam) has conducted an initial environmental assessment of Eastern Air Devices, Inc. (EAD) facility located in Dover, New Hampshire. EAD is a manufacturer of electronic motors that has operated at this current location since 1977. The operating facility is a 120,000 square foot building located on a 14 acre site. A site location map and a facility site plan are presented as Figures 1 and 2 respectively.

2.0 Objectives

Balsam's objectives in conducting this initial environmental assessment were as follows:

* Monitor potential off-site receptors which might be impacted by the EAD facility,
* Confirm direction of groundwater flow,
* Confirm the initial hydrogeologic model for the EAD facility,
* Determine the need for further evaluation of the EAD facility, and develop a work scope to meet these needs.

II. SITE ASSESSMENT HISTORY

Based on a review of EAD's past waste management practices, two dry wells located on the EAD property were identified and subsequently cleaned out. A description of EAD's past waste management practices involving the use of these dry wells was transmitted to the U.S. Environmental Protection Agency (EPA), the New Hampshire Office of Waste Management (OWM) and the New Hampshire Water Supply and Pollution Control Commission (WSPCC) in a letter

dated January 6, 1986; this letter is included with this report as Appendix A. Following receipt of this letter, OWM requested a more detailed description of the dry well clean-out program. In response to that request, Balsam prepared a letter to OWM and WSPCC, dated February 11, 1986, included in this report as Appendix B, which described in greater detail the clean-out of the two dry wells, contained an initial hydrogeologic model for the EAD facility area, and presented a work scope to perform an initial environmental assessment of the EAD facility.

III. INITIAL ENVIRONMENTAL FACILITY ASSESSMENT

1.0 Development of Hydrogeologic Model

Based on a review of existing data and literature discussed in our February 11, 1986 letter, an initial hydrogeologic model was developed for the EAD facility area. This information indicated that the subsurface geology at the EAD facility consists of marine deposits underlain by slate or quartz bedrock. A Geological Survey report separated the marine deposits into two zones: an upper zone of olive-drab to gray sandy silt and clay, and a lower zone of blueish-gray silt and clay. Due to the fine grained and impermeable nature of these deposits, they were not considered an aquifer by the Geological Survey.

Boring logs documenting work performed adjacent to the EAD facility in 1969 indicate an overburden stratigraphy of topsoil underlain by brown and gray silts and clays to a depth of 10 to 17 feet, at which point the borings met refusal on bedrock, described as shale.

2.0 Further Development of Hydrogeologic Model

To expand upon the data and information available concerning the hydrogeologic characteristics beneath the EAD facility, four small diameter

piezometers were installed at EAD. The locations of these piezometers are presented in Figure 2. After the installation of the piezometers, Balsam performed a level survey in February, 1986 to determine the site datum elevations of the piezometers and a surface water datum point for Knox Marsh Brook. Water levels were then measured in the four piezometers. However, due to the shallow depth of ground water at EAD and the low temperatures which existed at that time, the water in two of the piezometers, P-1 and P-3, had frozen, making data from these two piezometers unreliable.

To confirm the expected direction of ground water flow, water elevations were then also obtained from Knox Marsh Brook and an open excavation by the south EAD dry well. These data, in combination with water level data from piezometers P-2 and P-4, indicated the direction of ground water flow to be to the west. On this basis, receptor surface water monitoring proceeded in Knox Marsh Brook in the locations shown in Figure 2.

After a period of warmer temperature conditions had existed, Balsam again obtained water level measurements from the four piezometers on the EAD site. At that time, the ice in piezometer P-3 was observed to have melted and ground water was observed to be present. However, piezometer P-1 was found to be plugged and thus, was re-installed at that time. Water level measurements were then obtained in the vicinity of the EAD property, and are presented in Table 1. Potentiometric contour maps indicating the direction of ground water flow and hydraulic gradient have been developed based on these data, and are presented as Figures 3 and 4.

3.0 Receptor Monitoring

Based on the information obtained from the initial hydrogeologic model and evaluation of on-site conditions, the nearest expected receptor of ground water from the EAD facility was judged to be Knox Marsh Brook. To evaluate this potential ground water receptor, surface water samples were obtained from this brook at four locations; upstream of EAD, mid-stream of EAD, and at two locations downstream of EAD. These sample locations and designations are presented in Figure 2.

Review of EAD's processes, waste management practices, and analyses performed on samples from the two closed dry wells provided the basis to select the chemical analyses for the surface water samples. All surface water samples were analyzed in the field for the following indicator parameters; specific conductance, pH, and temperature. These analytical results are presented in Table 2. The samples were then analyzed by an analytical laboratory for two heavy metals, zinc and chromium, and the thirty-six hazardous substances list (HSL) volatile organic compounds (VOC's). A complete quality assurance/quality control (QA/QC) program was followed for sample collection and analysis which included submittal of trip blank and blind duplicate samples for chemical analyses.

4.0 Results of Initial Assessment

Selected ground water and surface water elevations measured at the EAD facility are presented in Table 1: potentiometric contour maps developed using these data are presented in Figures 3 and 4. These data indicate that ground water flow at the site flows in a south to southwest direction toward Knox Marsh Brook.

The rate of flow, based on the initial hydrogeologic model of the EAD facility, has been estimated to range from 0.002 feet/year to 0.2 feet/year assuming a hydraulic conductivity of 10^{-7} cm/sec. to 10^{-5} cm/sec., an effective porosity of 0.4 to 0.6, and a hydraulic gradient of 0.009 feet/foot.

The analytical results of the surface water samples obtained as part of the receptor monitoring program are presented in Tables 2, 3 and 4. The results of the laboratory analyses indicated that none of the analyzed parameters were present at concentrations above the method detection limits: levels of indicator parameters supported this finding. The results of the metals and VOC analyses are also presented on Figure 5 and Figure 6, respectively.

To verify laboratory performance and sample collection procedures, a trip blank as well as a blind duplicate sample from a downstream sample location (KMB-D3) were submitted for analysis. These analytical data indicated acceptable laboratory and sampling performance.

The laboratory analytical reports associated with the receptor monitoring program have been included with this report as Appendix C.

IV. ASSESSMENT SUMMARY

This initial assessment has provided a basis to better evaluate ground water flow direction and gradient. The gradient, measured to be less than 0.01 ft/ft, and direction of flow, judged to be to the south to southwest, indicate that Knox Marsh Brook is the nearest probable receptor for ground water flowing beneath the EAD facility. However, based on Balsam's knowledge of the hydrogeology at the EAD facility, it is unlikely that contaminants, if released by EAD, would have migrated with ground water as far as Knox Marsh Brook. The analysis of surface water samples collected from Knox Marsh Brook do not indicate a detectable impact from conditions existing at the EAD facility and serve to confirm the opinion that a low rate of ground water flow in the overburden exists at the project area.

V. ADDITIONAL SCOPE OF WORK

1.0 Objectives

In order to confirm this initial environmental assessment and provide data to further assess hydrogeologic and water quality conditions on the EAD property, Balsam proposes to implement an expanded ground and surface water monitoring program at EAD including the installation and sampling of ground water monitoring wells. This program will provide data describing ground and surface water quality, ground water flow characteristics, and subsurface geologic conditions at the site. These data, combined with the information

obtained in Balsam's initial environmental assessment, will enable further evaluation of potential environmental impacts associated with the EAD facility.

2.0 Location of Ground Water Monitoring Wells

Five ground water monitoring wells are proposed to evaluate the EAD facility. Locations of these five proposed wells are shown in Figure 7. As illustrated in this figure, monitoring well MW-1 will be placed upgradient of the facility, wells MW-2 and MW-3 will be located downgradient of the northwest dry well, and wells MW-4 and MW-5 will be located downgradient of the southern dry well. Actual boring locations may vary slightly from those indicated in Figure 7, depending upon field conditions.

2.1 Well Installation Materials and Procedures

The five monitoring wells are expected to fully penetrate the shallow saturated overburden and terminate on the underlying shale (approximately 10-17 feet). Wells will be screened over a single vertical interval through the saturated overburden, as possible. All wells will be constructed of 2-inch ID Schedule 40 PVC threaded pipe. Well screen will consist of 2-inch ID PVC screen having a 0.01 inch slot opening. Grout used for monitoring well installation will consist of powdered bentonite and cement mixed with a sufficient quantity of water to pump or pour the grout. Locking steel protective casings will be installed around the PVC riser of each well and secured with a surface cement seal.

The five wells will be installed using 3-1/2 inch ID hollow stem augers. Two of the five borings will be advanced into shale by coring or drilling to confirm the presence of the shale layer. Wells will be screened from one foot above the shale to within three feet of the ground surface. A sand filter pack will be installed in the annular space to a depth of three feet below ground surface as the augers are withdrawn from the boring. A minimum

two-foot-thick seal of pelletized bentonite will then be installed and a cement grout will then be placed in the remaining annular space above the bentonite seal. A locking, steel protective casing will be installed in the grout to protect the PVC riser and inhibit well tampering. A typical design of the monitoring wells to be installed at EAD is shown in Figure 8.

Decontamination of equipment used for the installation of the monitoring wells will be performed to prevent cross contamination of the bore holes. Decontamination of the drilling equipment will be accomplished by a steam or high-pressure wash and rinse procedure, while hand tools and sampling equipment will be cleaned with a trisodium phosphate (TSP) wash and a potable water rinse.

Balsam will use an HNU photoionization meter to monitor ambient air quality in the vicinity of the bore holes, and to perform head space analysis on selected soil samples as described in Section 2.3.

2.2 Well Development Procedures

During the drilling process, the side of the bore hole may become smeared with clays or other fine sediments. This plugging action may substantially reduce the permeability of the aquifer in the zone of the boring and retard the movement of water into the well. In addition, sediment may enter the filter pack or clog the well screen slots during installation of the well materials.

Following the completion of well installation, well development will be performed to restore the natural permeability of the formation adjacent to the bore hole, remove clay, silt and other fines from the filter pack and well screen so that subsequent ground water samples will not be abnormally turbid or contain residual suspended matter, and remove contaminants that may have been introduced during the time of drilling.

Well development will be performed by bailing and will entail the removal of five to ten well casings of water from each well, as possible. Surging of the well may also be employed to improve well yield. Well development will follow the completion of well installation a minimum of two days to minimize the potential of drawing uncured grout into the filter pack of the monitoring well.

2.3 Collection of Soil Samples from Monitoring Well Borings

Soil sampling will be performed at 5-foot increments in the monitoring well borings. In addition to the use of these samples for visual classification and logging in the field, Balsam will perform head space analyses with the HNU on selected samples. These samples will be collected using steel split spoon samplers which will be decontaminated prior to sample collection.

Boring logs will also be prepared for each boring by the Balsam field engineer. The logs will be prepared based on observations made in the field including the nature of auger cuttings, soil samples, drilling difficulty, sampling methodology, and other pertinent information. These logs will serve to further refine our initial hydrogeologic model.

3.0 GROUND WATER SAMPLING

Two sets of ground water samples will be obtained from each of the five monitoring wells installed at the EAD facility. The first set of samples will be obtained approximately one week after well development has been completed. A second set of samples will be obtained approximately one week later to confirm the initial analyses. These ground water quality data, in combination with potentiometric data obtained from monitoring wells and piezometers, should provide the information needed to assess ground water at the EAD property.

For QA/QC purposes, 15% of the samples collected (one for each sample round) will be submitted as blind duplicate samples to the contract laboratory, and a trip blank will also accompany the samples to the laboratory for analysis.

Ground and surface water samples will be analyzed for the 36 HSL VOC's, and selected heavy metals which will include chromium and zinc. Ground water samples which will be analyzed for metals will be filtered in the field with a 0.45 micron filter prior to acid preservation.

Field analyses will also be conducted to analyze ground and surface water samples for the following indicator parameters; temperature, pH, and specific conductance.

Prior to the collection of a sample from the monitoring wells, the ground water elevation will be obtained from the monitoring well. Water elevations will also be obtained from each of the on-site piezometers as well as Knox Marsh Brook during each day of sampling. Wells will then be flushed prior to sampling to remove potentially stagnant water by removing approximately three well volumes of water from the well or until the well is dry, whichever occurs first. Flushing will be performed by bailing.

Ground water samples obtained from the monitoring wells will be collected using a dedicated PVC bailer assigned to the well. Prior to being used, the bailer will be cleaned with TSP and water, and rinsed with distilled water. Due to the expected level of ground water on site, the assigned bailer will be stored in separate PVC containers placed in locked storage, rather than being hung in each of the monitoring wells.

The first volume of water removed from the monitoring well following flushing will be used to fill the vials for VOC analyses. Subsequent volumes of water will be used to fill the remaining sample containers. Sample containers will be provided by the contract laboratory. These containers will be prepared in accordance with standard QA/QC protocol prior to arrival on the site. All samples for organic compound analyses will be placed in glass containers with teflon lined lids. Samples will be placed in the following containers: (1)

one 250-ml LPE bottle with HNO_3 for metals analyses, (2) two 40-ml vials for VOC analyses, (3) an open LPE container for field analyses.

Water samples obtained from the site will be transferred to the contract laboratory under appropriate project chain-of-custody in accordance with specified preservation methods and holding times for the desired analysis.

4.0 SURFACE WATER SAMPLING

To confirm results of surface water samples collected during the initial environmental assessment, additional surface water monitoring will be performed in Knox Marsh Brook. Samples will be obtained from established locations, KMB-U and KMB-D2, as well as a third location downstream of KMB-D2. Analyses for these samples will be the same as for ground water samples, with the exception that samples for metals analyses will not be filtered.

VI. PROJECT SCHEDULE AND REPORTING

EAD is prepared to proceed with the proposed site investigation program immediately after receiving approval from WSPCC and OWM. Assuming approval is received for this program in early June, 1986, it is anticipated that project field work would be completed by late July, 1986.

Following the completion of sample analysis, Balsam will prepare a report presenting and assessing these data. This report will be transmitted to both WSPCC and OWM for their review and comment. Following this review, EAD and Balsam will meet with the involved regulatory agencies to discuss this report.

TABLE 1

SURFACE AND WATER LEVEL DATA

Eastern Air Devices, Inc., Dover, NH

Piezometer and Surface Water Designation	Site Datum Elevation in Feet (Top of Casing or Head Wall)	Water Level Elevation 4/29/86 (Feet)	Water Level Elevation 5/2/86 (Feet)
P-1	99.54	96.3	96.4
P-2	98.45	94.9	94.9
P-3	100.69	98.4	98.3
P-4	100.54	98.1	98.3
Knox Marsh Brook Head Wall	97.0	91.0	NM

NOTES:

NM = Not Measured

TABLE 2

WATER QUALITY DATA: INDICATOR PARAMETERS

EASTERN AIR DEVICES, INC., DOVER, NH

PARAMETER	MONITORING POINT			
	KMB-U	KMB-M	KMB-D1	KMB-D2
SPECIFIC CONDUCTANCE (MICRO-MHOS/CM)	200	195	215	215
pH (pH UNITS)	6.1	6.0	6.1	6.1
TEMPERATURE (^{0}C)	1.	1.	1.	1.

NOTES: ANALYSES PERFORMED IN FIELD ON FEBRUARY 25, 1986

TABLE 3

WATER QUALITY DATA: TOTAL METALS

EASTERN AIR DEVICES, INC., DOVER, NH

PARAMETER	MONITORING POINT					
	KMB-U	KMB-M	KMB-D1	KMB-D2	KMB-D3	Trip Blank
Chromium	ND(0.01)	ND(0.01)	ND(0.01)	ND(0.01)	ND(0.01)	ND(0.01)
Zinc	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.005)

NOTES:

1) SAMPLES COLLECTED ON FEBRUARY 25, 1986.
2) ND = COMPOUND NOT DETECTED (AT THE LEVEL INDICATED)
3) ALL RESULTS EXPRESSED AS MILLIGRAMS/LITER (ppm)
4) KMB-D2 AND KMB-D3 ARE DUPLICATE SAMPLES
5) TRIP BLANK ANALYZED AS PART OF QUALITY ASSURANCE/QUALITY CONTROL PROGRAMS

TABLE 4

WATER QUALITY DATA: VOLATILE ORGANIC COMPOUNDS

EASTERN AIR DEVICES, INC., DOVER, NH

VOLATILE ORGANICS	MONITORING POINT					
	KMB-U	KMB-M	KMB-D1	KMB-D2	KMB-D3	TRIP BLANK
ACROLEIN	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
ACROYLONITRILE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
BENZENE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
BROMOFORM	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
CARBON TETRACHLORIDE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
CHLOROBENZENE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
CHLORODIBROMOMETHANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
CHLOROETHANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
2-CHLOROETHYLVINYLETHER	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
CHLOROFORM	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
DICHLOROBROMEMTHANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
1,1-DICHLOROETHANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
1,2-DICHLOROETHANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
1,1-DICHLOROETHYLENE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
1,2-DICHLOROPROPANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
1,3-DICHLOROPROPYLENE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
ETHYLBENZENE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
METHYL BROMIDE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)

NOTES:

1) ND = COMPOUND NOT DETECTED (AT THE LEVEL INDICATED)
2) SAMPLES COLLECTED ON FEBRUARY 25, 1986
3) ALL RESULTS EXPRESSED AS MICROGRAMS/LITER (ppb)
4) KMB-D2 AND KMB-D3 ARE DUPLICATE SAMPLES
5) TRIP BLANK ANALYZED AS PART OF QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

TABLE 4

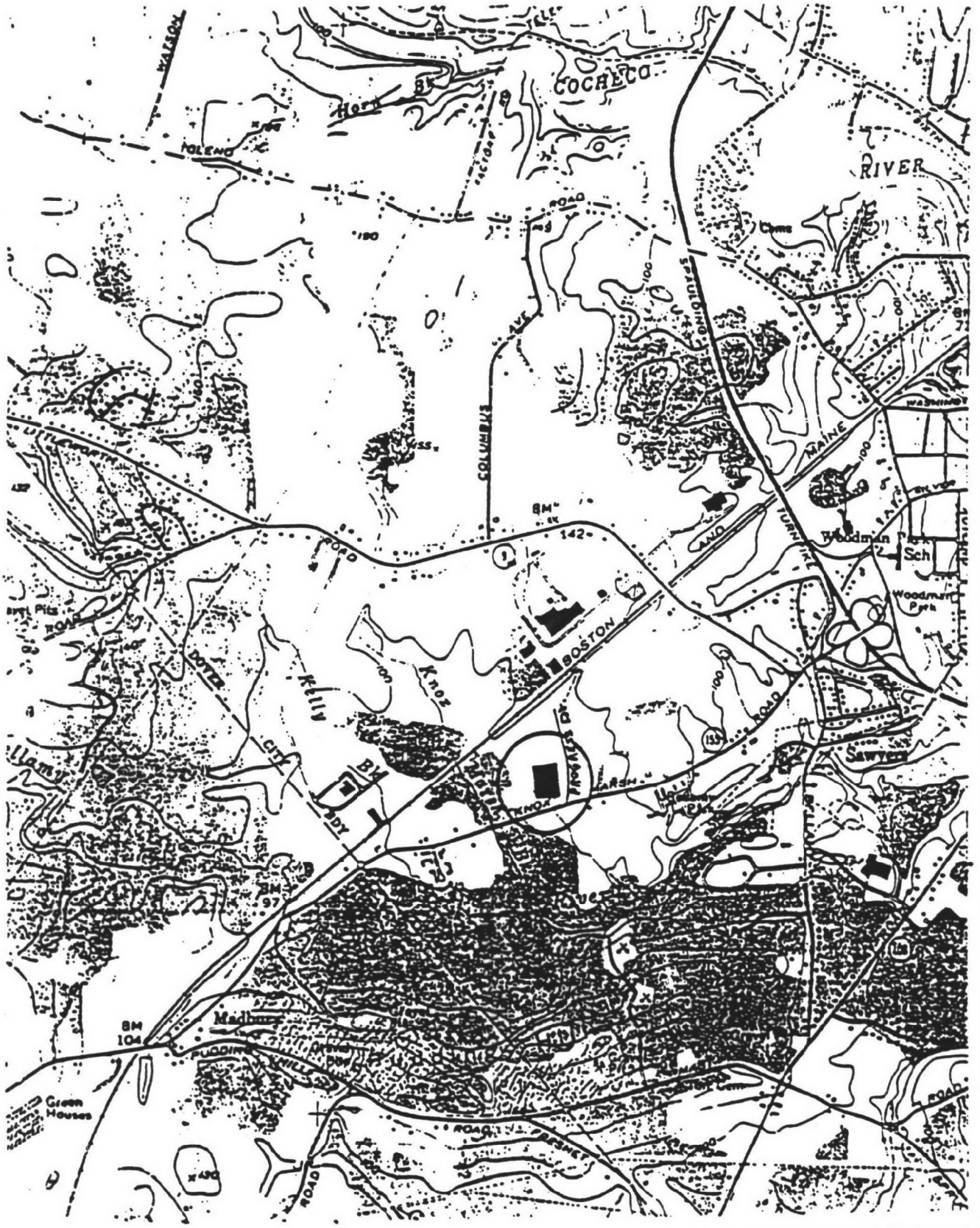
WATER QUALITY DATA: VOLATILE ORGANIC COMPOUNDS

EASTERN AIR DEVICES, INC., DOVER, NH

VOLATILE ORGANICS	MONITORING POINT KMB-U	KMB-M	KMB-D1	KMB-D2	KMB-D3	TRIP BLANK
METHYL CHLORIDE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
METHYLENE CHLORIDE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
1,1,2,2-TETRACHLOROETHANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
TETRACHLOROETHYLENE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
TOLUENE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
1,2-trans-DICHLOROETHYLENE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
1,1,1-TRICHLOROETHANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
1,1,2-TRICHLOROETHANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
TRICHLOROETHYLENE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
TRICHLOROFLUOROMETHANE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
VINYL CHLORIDE	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
METHYL ETHYL KETONE	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)
ACETONE	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)
CARBON DISULFIDE	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)
METHYL ISOBUTYL KETONE	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)
TETRAHYDROFURAN	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)
STYRENE	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)
XYLENES	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)
2-HEXANONE	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)	ND(25)

NOTES:

1) ND = COMPOUND NOT DETECTED (AT THE LEVEL INDICATED)
2) SAMPLES COLLECTED ON FEBRUARY 25, 1986
3) ALL RESULTS EXPRESSED AS MICROGRAMS/LITER (ppb)
4) KMB-D2 AND KMB-D3 ARE DUPLICATE SAMPLES
5) TRIP BLANK ANALYZED AS PART OF QUALITY ASSURANCE/QUALITY CONTROL PROGRAM



LEGEND

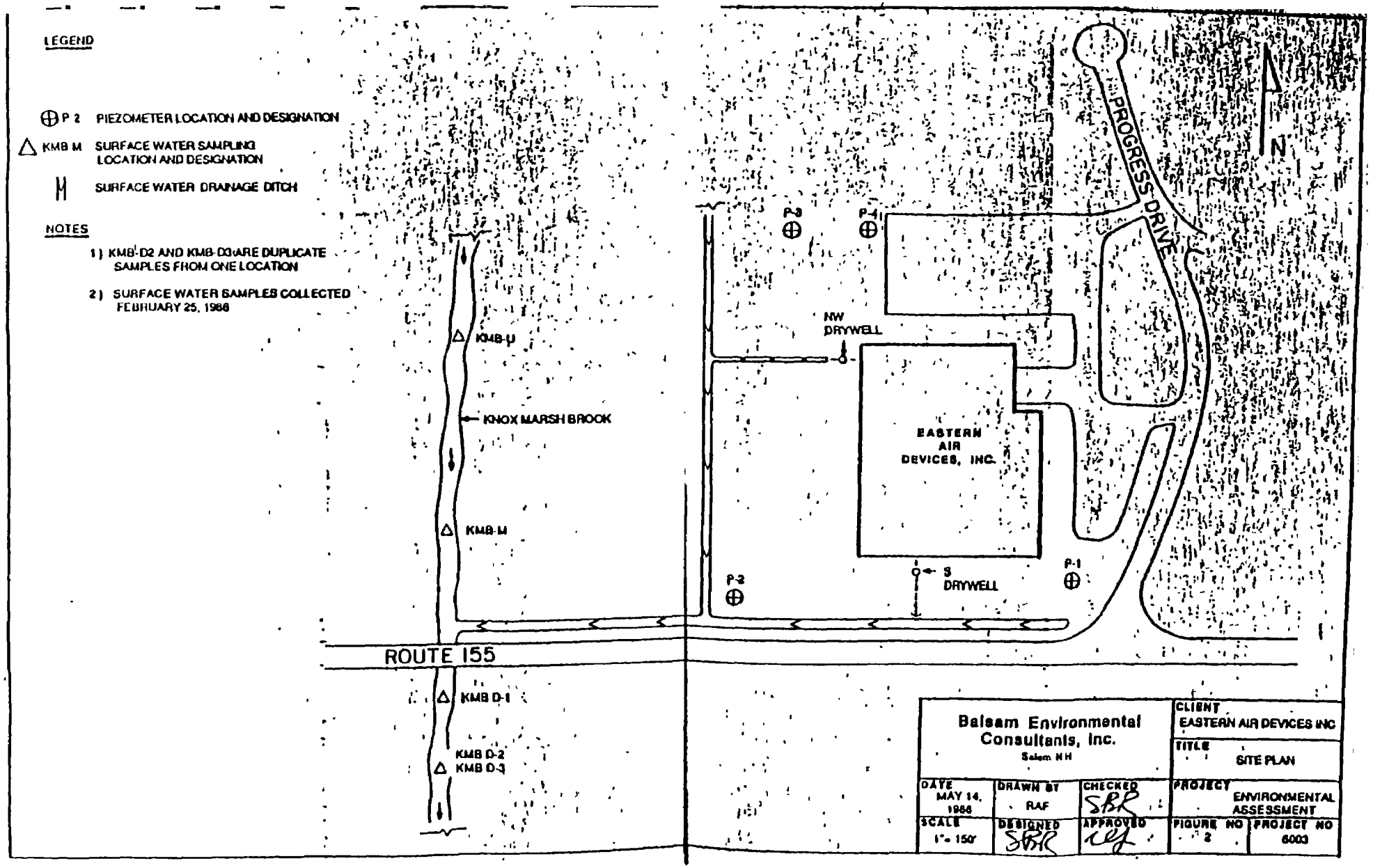
■ LOCATION OF EASTERN AIR DEVICES, INC.

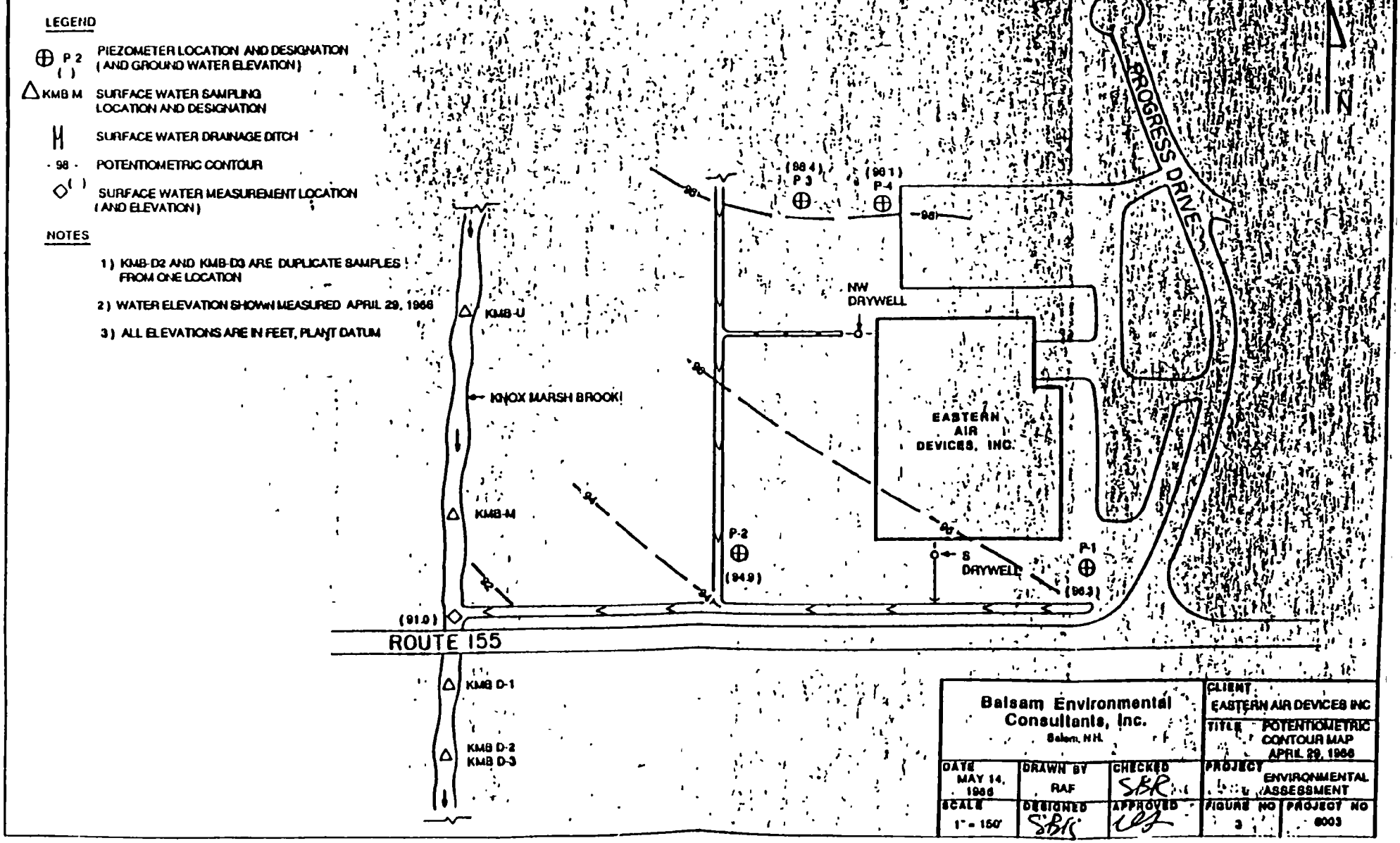
N

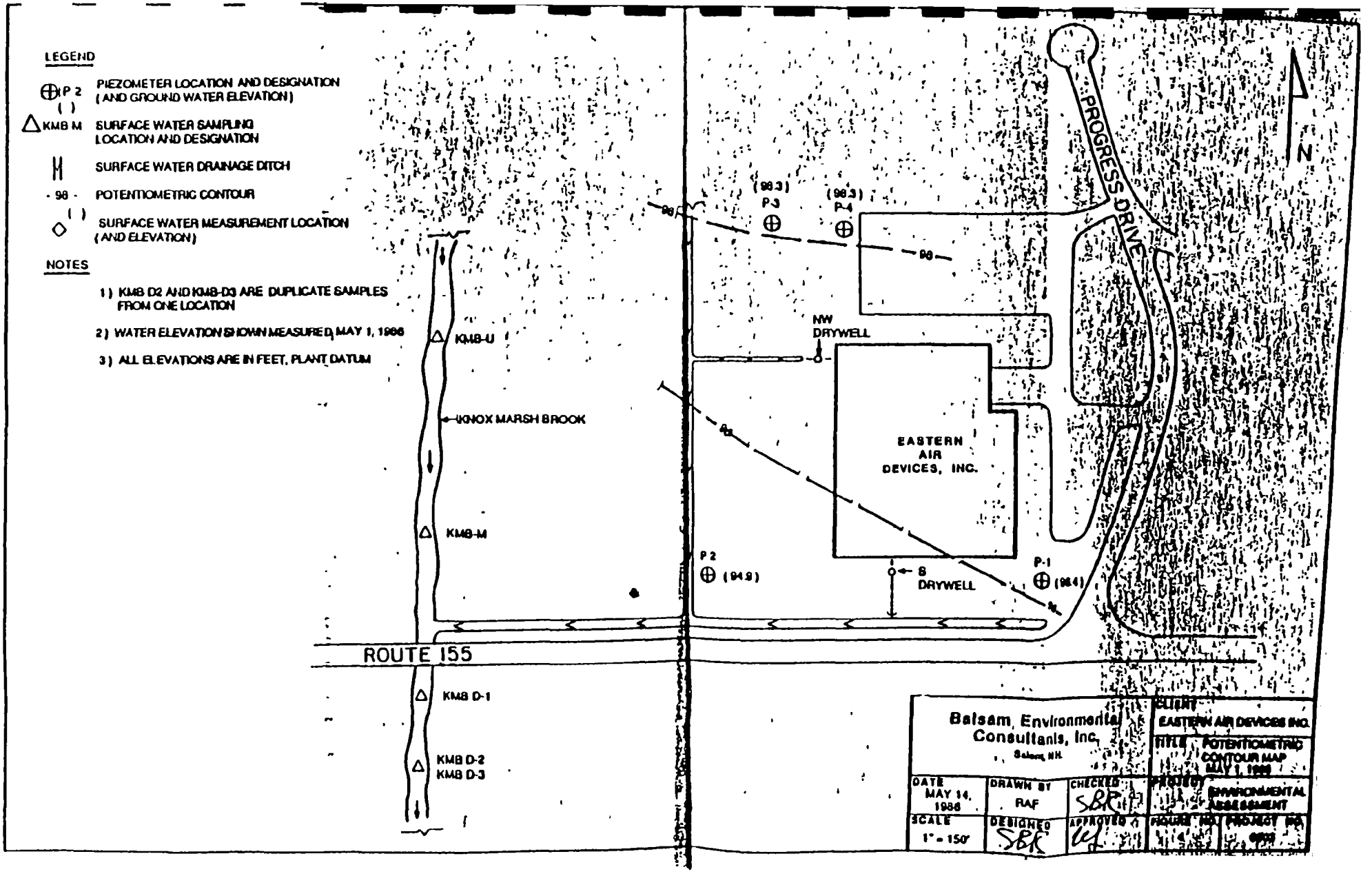
NOTES

DOVER WEST QUADRANGLE
SCALE 1:24000

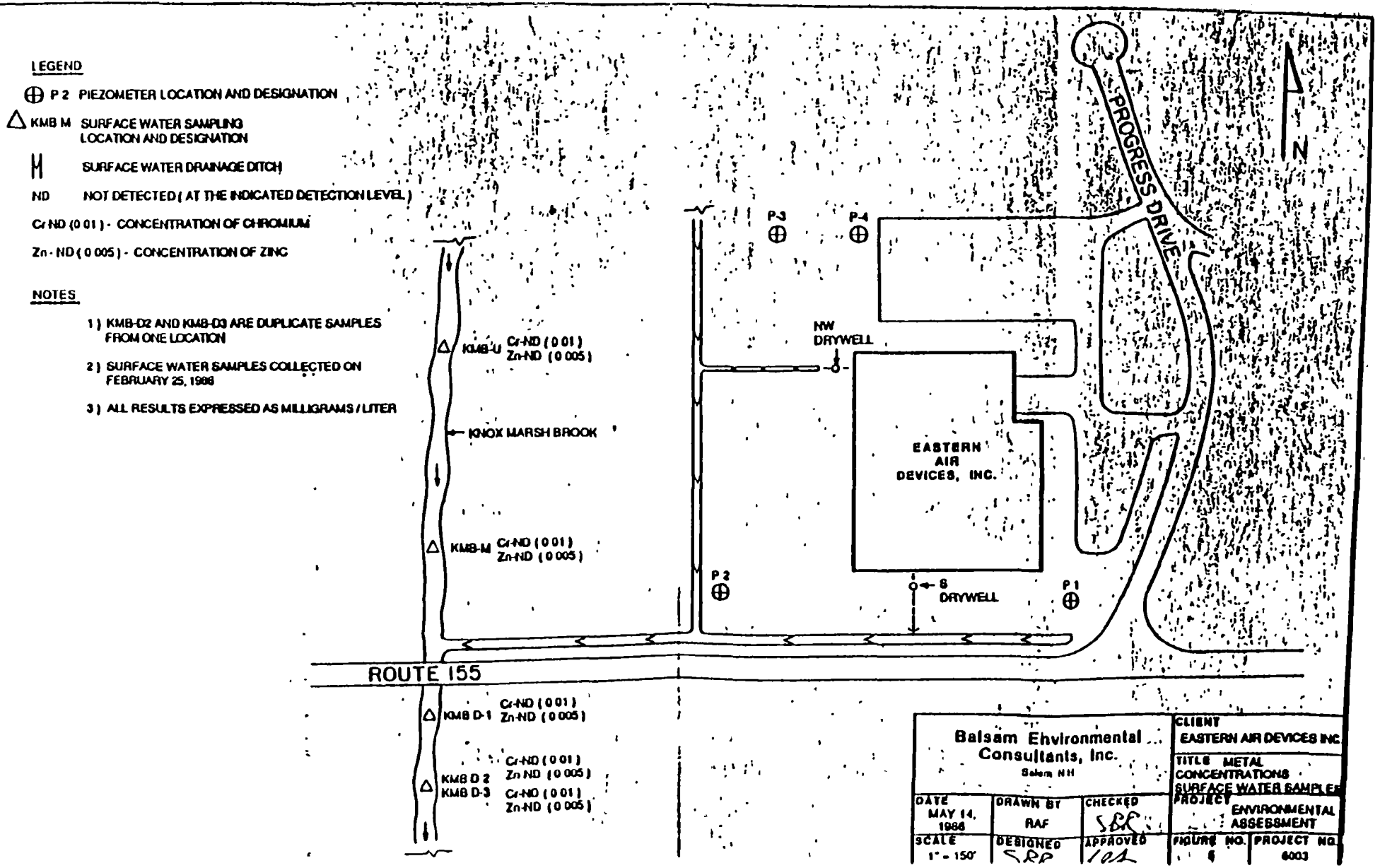
Balsam Environmental Consultants, Inc. Salem, N H	BALSAM PROJECT NO. 6003
	DRAWN BY
	CHECKED BY SRK
TITLE SITE LOCATION MAP EASTERN AIR DEVICES, INC	FIGURE NO. 1

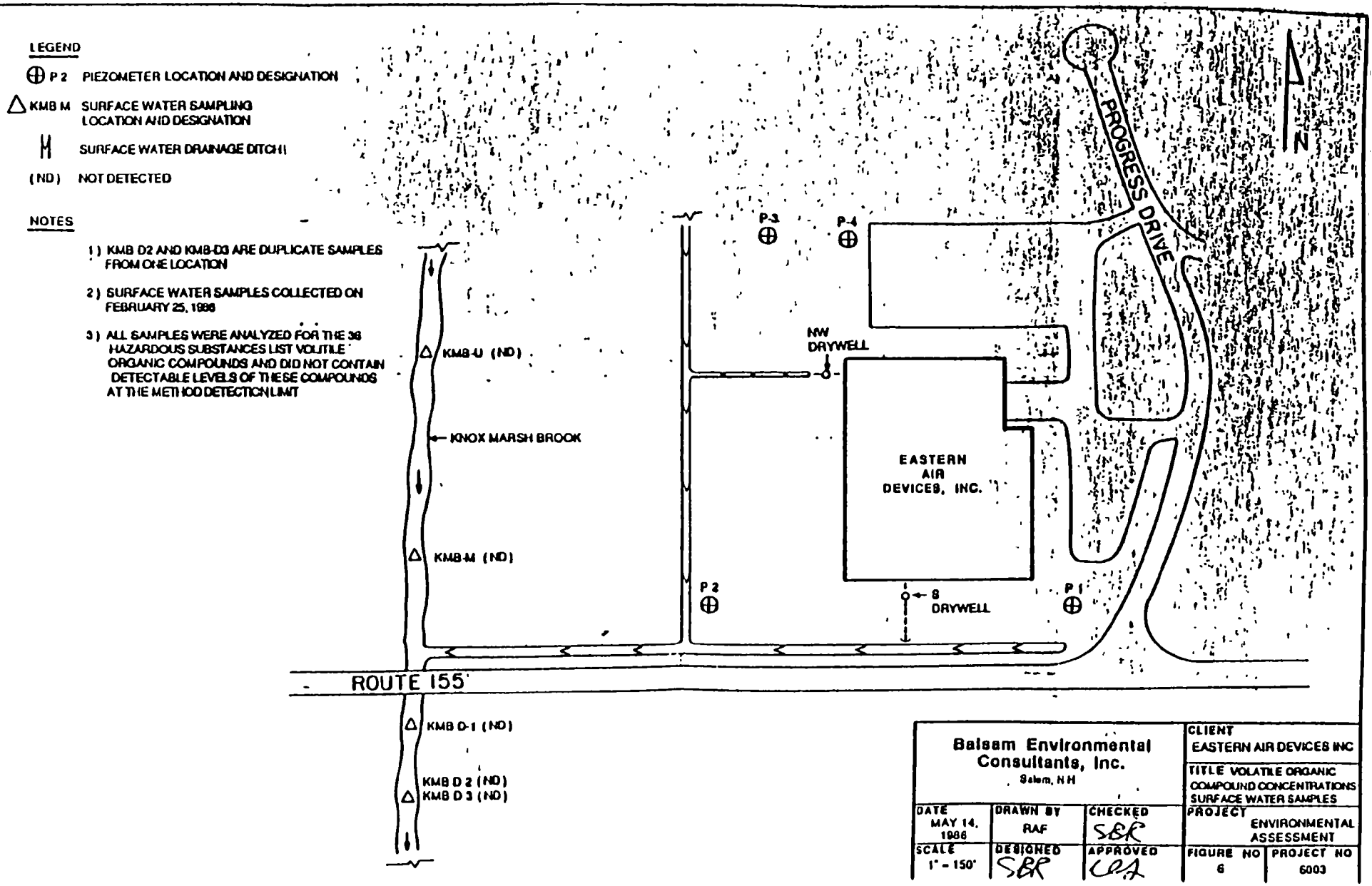

LEGEND
P 2 PIEZOMETER LOCATION AND DESIGNATION
KMB M SURFACE WATER SAMPLING LOCATION AND DESIGNATION
SURFACE WATER DRAINAGE DITCH
NOTES
1) KMB-D2 AND KMB-D3 ARE DUPLICATE SAMPLES FROM ONE LOCATION
2) SURFACE WATER SAMPLES COLLECTED FEBRUARY 25, 1988
PROGRESS DRIVE
N
P-3
P-4
NW DRYWELL
KMB-U
KNOX MARSH BROOK
EASTERN AIR DEVICES, INC.
KMB-M
P-2
S DRYWELL
P-1
ROUTE 155
KMB D-1
KMB D-2
KMB D-3
Balsam Environmental Consultants, Inc.
Salem NH
CLIENT
EASTERN AIR DEVICES INC
TITLE
SITE PLAN
DATE
MAY 14, 1988
DRAWN BY
RAF
CHECKED
SBR
PROJECT
ENVIRONMENTAL ASSESSMENT
SCALE
1" = 150'
DESIGNED
SBR
APPROVED
FIGURE NO
2
PROJECT NO
6003


LEGEND
P 2 ( ) PIEZOMETER LOCATION AND DESIGNATION (AND GROUND WATER ELEVATION)
KMB M SURFACE WATER SAMPLING LOCATION AND DESIGNATION
SURFACE WATER DRAINAGE DITCH
- 98 - POTENTIOMETRIC CONTOUR
( ) SURFACE WATER MEASUREMENT LOCATION (AND ELEVATION)
NOTES
1) KMB-D2 AND KMB-D3 ARE DUPLICATE SAMPLES FROM ONE LOCATION
2) WATER ELEVATION SHOWN MEASURED APRIL 29, 1988
3) ALL ELEVATIONS ARE IN FEET, PLANT DATUM
PROGRESS DRIVE
N
(98.4) P-3
(98.1) P-4
NW DRYWELL
KMB-U
KNOX MARSH BROOK
EASTERN AIR DEVICES, INC.
KMB-M
P-2
(94.9)
S DRYWELL
P-1
(96.3)
(91.0)
ROUTE 155
KMB D-1
KMB D-2
KMB D-3
Balsam Environmental Consultants, Inc.
Salem, NH
CLIENT EASTERN AIR DEVICES INC
TITLE POTENTIOMETRIC CONTOUR MAP APRIL 29, 1988
DATE MAY 14, 1988
DRAWN BY RAF
CHECKED SBR
PROJECT ENVIRONMENTAL ASSESSMENT
SCALE 1" = 150'
DESIGNED SBR
APPROVED
FIGURE NO 3
PROJECT NO 8003

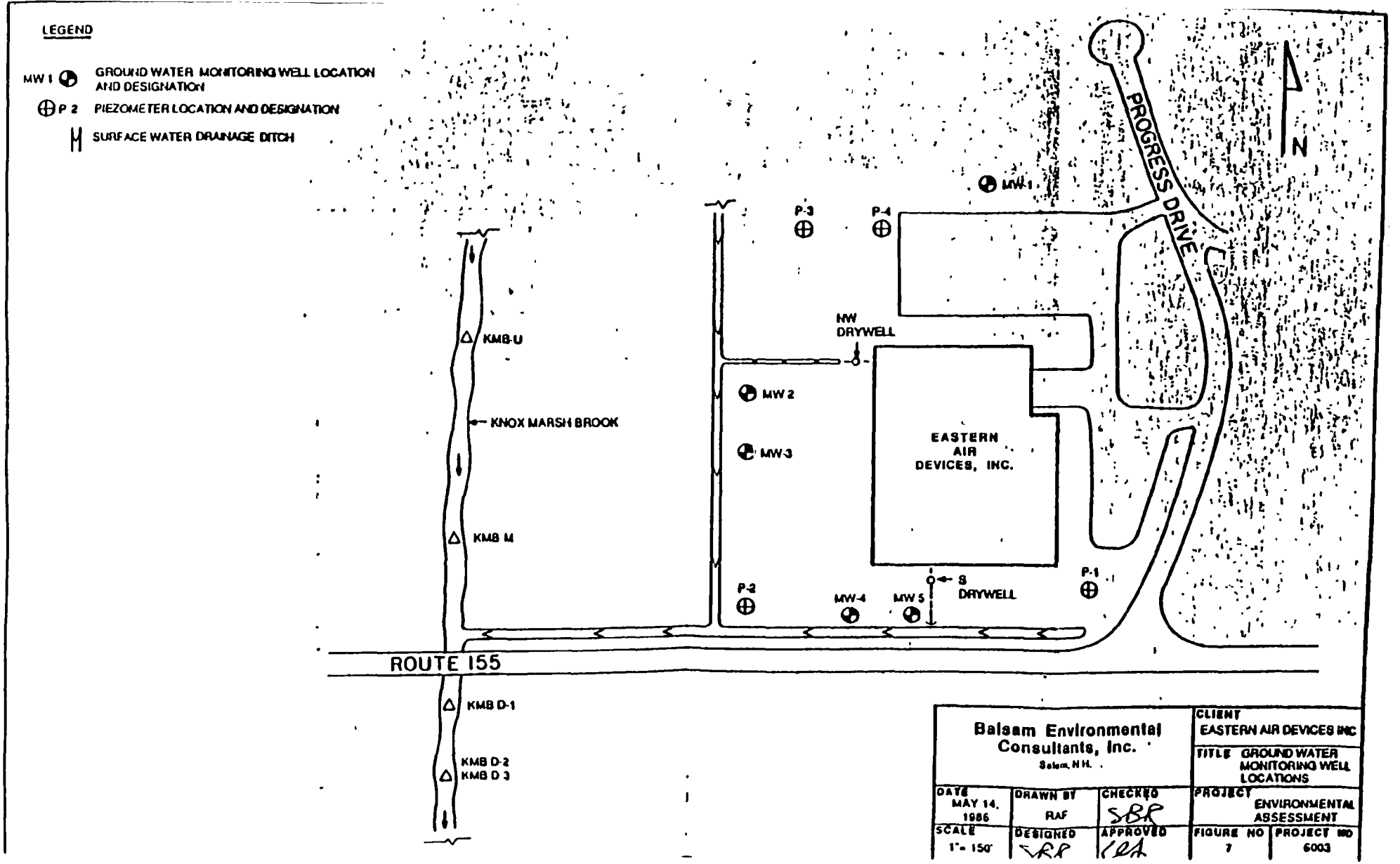

LEGEND
P 2 ( ) PIEZOMETER LOCATION AND DESIGNATION (AND GROUND WATER ELEVATION)
KMB M SURFACE WATER SAMPLING LOCATION AND DESIGNATION
SURFACE WATER DRAINAGE DITCH
- 98 - POTENTIOMETRIC CONTOUR
( ) SURFACE WATER MEASUREMENT LOCATION (AND ELEVATION)
NOTES
1) KMB D2 AND KMB-D3 ARE DUPLICATE SAMPLES FROM ONE LOCATION
2) WATER ELEVATION SHOWN MEASURED MAY 1, 1986
3) ALL ELEVATIONS ARE IN FEET, PLANT DATUM
PROGRESS DRIVE
N
(98.3) P-3
(98.3) P-4
98
NW DRYWELL
EASTERN AIR DEVICES, INC.
KMB-U
KNOX MARSH BROOK
KMB-M
P 2 (94.9)
S DRYWELL
P-1 (98.4)
ROUTE 155
KMB D-1
KMB D-2
KMB D-3
Balsam Environmental Consultants, Inc.
Salem, NH
CLIENT EASTERN AIR DEVICES INC.
TITLE POTENTIOMETRIC CONTOUR MAP MAY 1, 1986
PROJECT ENVIRONMENTAL ASSESSMENT
DATE MAY 14, 1986
DRAWN BY RAF
CHECKED SBK
SCALE 1" = 150'
DESIGNED SBK
APPROVED
FIGURE NO. 4
PROJECT NO. 6000

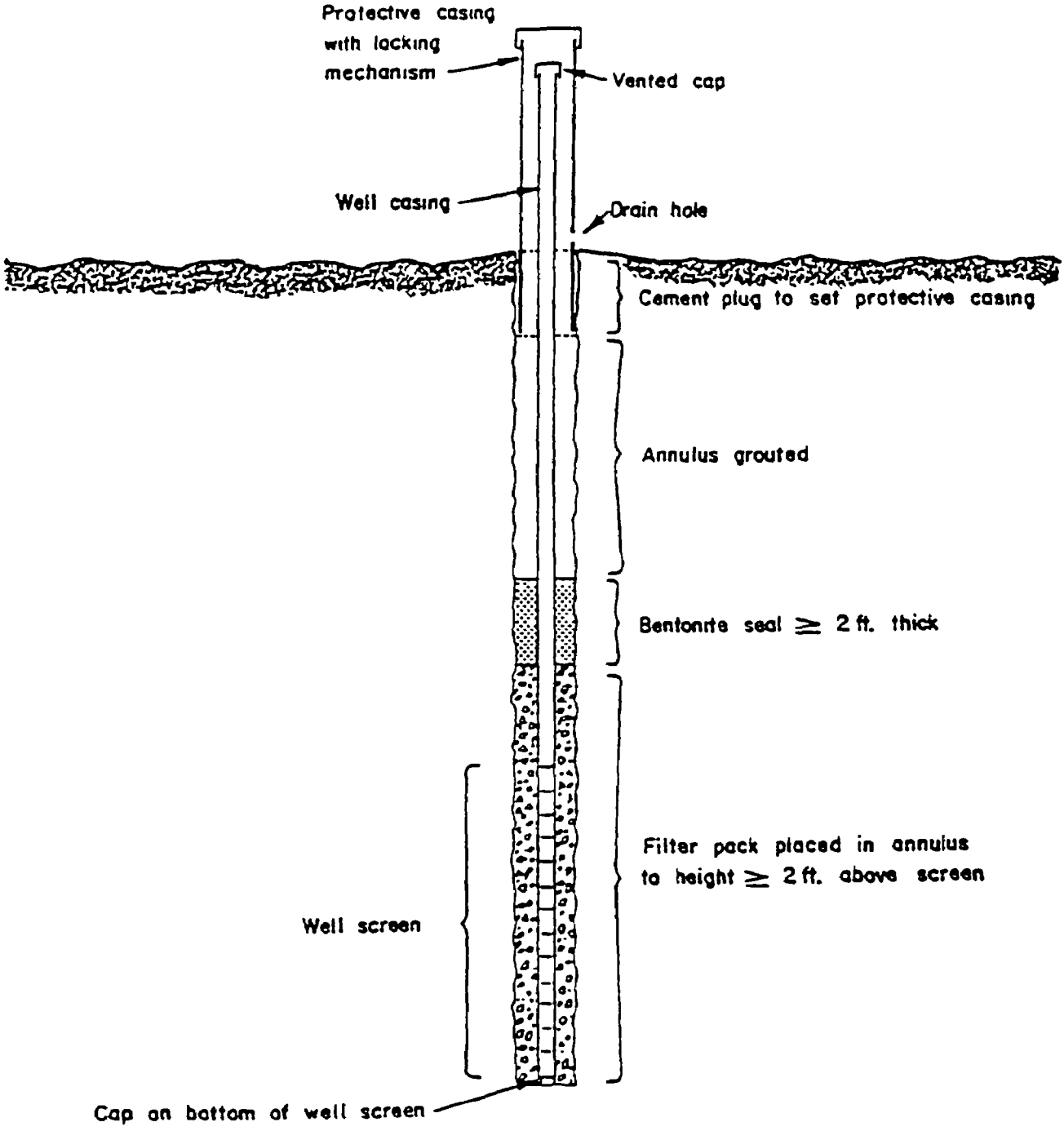
[28-9]


LEGEND
⊕ P 2 PIEZOMETER LOCATION AND DESIGNATION
△ KMB M SURFACE WATER SAMPLING LOCATION AND DESIGNATION
SURFACE WATER DRAINAGE DITCH
ND NOT DETECTED (AT THE INDICATED DETECTION LEVEL)
Cr-ND (0 01) - CONCENTRATION OF CHROMIUM
Zn - ND (0 005) - CONCENTRATION OF ZINC
NOTES
1) KMB-02 AND KMB-03 ARE DUPLICATE SAMPLES FROM ONE LOCATION
2) SURFACE WATER SAMPLES COLLECTED ON FEBRUARY 25, 1986
3) ALL RESULTS EXPRESSED AS MILLIGRAMS / LITER
PROGRESS DRIVE
N
P-3
P-4
NW DRYWELL
KMB-U Cr-ND (0 01) Zn-ND (0 005)
KNOX MARSH BROOK
EASTERN AIR DEVICES, INC.
KMB-M Cr-ND (0 01) Zn-ND (0 005)
P 2
S DRYWELL
P 1
ROUTE 155
KMB D-1 Cr-ND (0 01) Zn-ND (0 005)
KMB D 2 Cr-ND (0 01) Zn ND (0 005)
KMB D-3 Cr-ND (0 01) Zn-ND (0 005)
Balsam Ehvironmental Consultants, Inc.
Salem NH
CLIENT EASTERN AIR DEVICES INC.
TITLE METAL CONCENTRATIONS SURFACE WATER SAMPLES
PROJECT ENVIRONMENTAL ASSESSMENT
DATE MAY 14, 1986
DRAWN BY RAF
CHECKED SRP
SCALE 1" = 150'
DESIGNED SRP
APPROVED
FIGURE NO. 6
PROJECT NO. 6003


LEGEND
P 2 PIEZOMETER LOCATION AND DESIGNATION
KMB M SURFACE WATER SAMPLING LOCATION AND DESIGNATION
SURFACE WATER DRAINAGE DITCH
(ND) NOT DETECTED
NOTES
1) KMB D2 AND KMB-D3 ARE DUPLICATE SAMPLES FROM ONE LOCATION
2) SURFACE WATER SAMPLES COLLECTED ON FEBRUARY 25, 1986
3) ALL SAMPLES WERE ANALYZED FOR THE 38 HAZARDOUS SUBSTANCES LIST VOLITILE ORGANIC COMPOUNDS AND DID NOT CONTAIN DETECTABLE LEVELS OF THESE COMPOUNDS AT THE METHOD DETECTION LIMIT
PROGRESS DRIVE
P-3
P-4
NW DRYWELL
KMB-U (ND)
KNOX MARSH BROOK
EASTERN AIR DEVICES, INC.
KMB-M (ND)
P 2
S DRYWELL
P 1
ROUTE 155
KMB D-1 (ND)
KMB D 2 (ND)
KMB D 3 (ND)
Balsam Environmental Consultants, Inc.
Salem, N H
CLIENT
EASTERN AIR DEVICES INC
TITLE VOLATILE ORGANIC COMPOUND CONCENTRATIONS SURFACE WATER SAMPLES
PROJECT
ENVIRONMENTAL ASSESSMENT
DATE MAY 14, 1986
DRAWN BY RAF
CHECKED SBR
SCALE 1" = 150'
DESIGNED SBR
APPROVED
FIGURE NO 6
PROJECT NO 6003

68-9]


LEGEND
MW 1 GROUND WATER MONITORING WELL LOCATION AND DESIGNATION
P 2 PIEZOMETER LOCATION AND DESIGNATION
SURFACE WATER DRAINAGE DITCH
N
PROGRESS DRIVE
MW 1
P-3
P-4
NW DRYWELL
KMB-U
MW 2
KNOX MARSH BROOK
MW-3
EASTERN AIR DEVICES, INC.
KMB M
P-2
MW-4
MW 5
S DRYWELL
P-1
ROUTE 155
KMB D-1
KMB D-2
KMB D 3
Balsam Environmental Consultants, Inc.
Salem, N.H.
CLIENT EASTERN AIR DEVICES INC
TITLE GROUND WATER MONITORING WELL LOCATIONS
PROJECT ENVIRONMENTAL ASSESSMENT
DATE MAY 14, 1986
DRAWN BY RAF
CHECKED SBR
SCALE 1" = 150'
DESIGNED VRP
APPROVED RA
FIGURE NO 7
PROJECT NO 6003



NOT TO SCALE

Balsam Environmental Consultants, Inc. Salem, N H	BALSAM PROJECT NO. 6003
	DRAWN BY RAF
	CHECKED BY
TITLE TYPICAL MONITORING WELL	FIGURE NO 8

APPENDIX A

EAD
EASTERN AIR DEVICES

1 Progress Drive
Dover, New Hampshire 03820
(603) 742-3330 • TWX: (510) 297-4454

January 6, 1986

Lee Thomas, Administrator
United States Environmental
Protection Agency
401 M. Street, S.W.
Washington, D.C. 20460

Re: Notification of Site Where Hazardous Waste
May Have Been Deposited in the Past

Dear Mr. Thomas:

Eastern Air Devices, Inc. ("EAD") is a small electric motor manufacturer located in Dover, New Hampshire. EAD has hired an engineering firm to assist it in performing an environmental compliance audit, and in reviewing its current and past waste handling and waste management practices, including manifesting, record keeping and reporting, contingency planning, and worker training programming.

During the course of this review, EAD became aware of the presence of two dry wells located on its property which had been used previously for disposal of some aqueous waste streams from the plant. As part of EAD's waste management review program, our environmental engineer advised us to open and evaluate these dry wells and remove any waste residues, should they be present.

When the two dry wells were recently opened, it appeared that they each contained approximately two feet of water, and up to two feet of loose sediment and debris. Each dry well consisted of a 4-foot diameter concrete stand pipe approximately four feet in depth, which had been placed on end over a layer of gravel. Because the soils in this area are mostly clay and do not drain well, each dry well also contained an outflow line to an adjacent surface drainage ditch. EAD has terminated flow through these two dry wells and has cleaned them out.

At the time we opened the dry wells, the water in each dry well was checked using a volatile organic vapor analyzer (HNU), and no volatile organics were detected at that time. However, during our clean-out of the two dry wells, we detected some volatile organic compounds with the HNU in the materials from the lower levels of the dry wells. EAD collected all material (water, sediment, and gravel) removed from the two dry wells in 33 steel, 55-gallon drums and submitted samples from the drums for chemical analysis to determine proper disposal methods for

the contents removed from the two dry wells. We recently received results of these analyses, which indicate that some organic compounds are present. The primary constituent appears to be tetrachloroethylene (PCE). EAD discontinued the use of PCE at our plant in 1984. Prior to that time, waste PCE was handled and disposed of in accordance with RCRA or sold to a recycler for reuse.

Our environmental engineer advises us that the soils surrounding the two dry wells are dense clay material with bedrock underneath going down to a depth of about 20 feet. The engineer indicates that based on a visual inspection of the soil and the minimal groundwater recharge into the two dry wells during their clean-out, it appears that the soils around the wells are relatively impermeable. We believe that little of the contents of the two dry wells has leached into the groundwater.

EAD has cleaned out from the two dry wells virtually all of the wastes and waste residues contained in them, and believes that the dry wells do not present a significant source of PCE to the groundwater. Nevertheless, EAD has initiated an environmental assessment of our plant to evaluate the situation. This assessment includes determination of the direction and rate of groundwater movement, further evaluation of the geology at the plant site, and sampling and analysis to provide additional data. EAD does not know of anyone in the vicinity of our plant currently using groundwater as a drinking water supply.

You will note that we are sending copies of this letter to the appropriate New Hampshire regulatory agencies. At the completion of the assessment, EAD will transmit information to these agencies for their review.

Sincerely,

EASTERN AIR DEVICES

James Burtelow
Vice President, Manufacturing

cc: New Hampshire Water Supply &
Pollution Control Commission

State of New Hampshire
Office of Waste Management
Bureau of Hazardous Waste
Compliance and Enforcement
Division of Public Health Services

APPENDIX B

Balsam Environmental Consultants, Inc.

ENGINEERING, ENVIRONMENTAL SCIENCE & INDUSTRIAL HYGIENE

5 Manor Parkway
The Rollins Building
Salem, NH 03079
(603) 893-0616

4 Gray Birch Lane
Wayland, MA 01778
(617) 358-2363

February 11, 1986

State of New Hampshire
Office of Waste Management
6 Hazen Drive
Concord, New Hampshire 03301

Attention: Mr. Kenneth Marschner

Re: Description of Eastern Air Devices, Inc.
Dry Well Clean-Out
Dover, New Hampshire

Dear Mr. Marschner:

Based on my recent discussions with Mr. James Burtelow of Eastern Air Devices, Inc. (EAD), it is my understanding that you have requested a description of the dry well clean-out program performed at EAD, as well as the environmental assessment of the facility currently in progress. As Mr. Burtelow explained, this assessment program is being used to evaluate potential impacts from the two retired dry wells at EAD's facility.

EAD TANK CLEAN-OUT PROGRAM

Our review of current waste management practices indicated that there were two dry wells located at EAD. After evaluating these dry wells, including past and present uses, we recommended that the dry wells be opened and inspected, and if wastes were present in the dry wells, that they be cleaned out. Through careful planning with EAD, we designed a thorough clean-out program that would successfully clean these dry wells of liquids and sludges present.

During this dry well clean-out, a trash pump was used to initially remove all pumpable liquids/sludges from the dry wells. To remove sludge and gravel, we shoveled and scooped this material into 55-gallon steel drums to complete the clean-out. All materials collected from the dry wells were either pumped directly or shoveleled into 55-gallon steel drums for storage until appropriate disposal could be found.

Both dry wells are concrete and are four feet in diameter by four feet deep. The dry wells are open on the bottom and packed in a very coarse gravel. Each dry well contained approximately two feet of liquid, or approximately 200 gallons. One dry well, located at the northwest (NW) corner of EAD's facility, contained one foot of sludge/sediment above the gravel bed while

the other dry well, located on the southern (S) end of EAD, did not possess a sludge layer below the liquid layer.

The total liquid volume of each dry well was calculated to be approximately 240 gallons. In order to accomplish a thorough clean-out, over three times this volume of liquid was pumped into 55-gallon steel drums from the interior of the dry wells, the gravel bed below the dry wells, and the excavation around the dry wells. Specifically, 14 drums from the NW dry well and 15 drums from the S dry well were filled during this pumping process. Minimal ground water recharge was observed into the dry well excavations following the completion of pumping. Approximately one foot of sludge and one foot of gravel were removed from the NW dry well and two feet of gravel from the S dry well. All of this material was stored in 55-gallon steel drums.

After all the materials from both dry wells were drummed for storage, composite samples of the liquid, sludge, and gravel were submitted for analysis and the wastes characterized for disposal. North East Solvents of North Andover, Massachusetts has accepted these wastes and transported them off-site for appropriate disposal. A copy of the manifest for these wastes is included as Attachment 1.

EAD ENVIRONMENTAL FACILITY ASSESSMENT

In order to evaluate potential effects from the two dry wells, EAD decided to implement an environmental assessment program for their facility. This program was designed to provide sufficient data to determine direction of ground water movement, estimate the rate and volume of ground water flow, and evaluate potential impacts on any receptors that might be identified.

HYDROGEOLOGIC MODEL

The initial step of the environmental assessment was to develop a site specific hydrogeologic model for the EAD facility. To develop this model, a thorough review of existing information was performed to identify information which would provide detailed data describing site conditions. Based on a review of existing topographic maps and field inspections, surface water drainage was observed to be to the west toward Knox Marsh Brook, which appears to be a gaining stream. Topographic relief in the vicinity of EAD is slight, averaging less than 2 percent. Based on the vegetation present, the area due west of EAD appears to be a seasonal lowland.

To evaluate subsurface stratigraphy at the site, available literature including the "Geology and Ground-Water Resources of Southern New Hampshire, Geological Survey Water-Supply Paper 1965" and the Late Wisconsinan Glaciation of New England, Larson, G.J. and Steve, B.D. (1980) were reviewed. Based on these documents, it appeared that the EAD facility is underlain by marine deposits, followed by slate or quartzite bedrock (the Merrimack group). The marine deposits are described by the Geological

Survey as being "divided into two zones: an upper zone of olive-drab to gray sand silt and clay, and a lower zone of bluish-gray silt and clay." The thickness of the upper zone ranges from a fraction of an inch to about 2 feet, whereas the lower zone ranges in thickness from 1 to 50 feet. The Geological Survey further states that "Because the marine deposits are fine grained, they are relatively impermeable and have a very small specific yield." For these reasons, the marine deposits are not considered an aquifer in southeastern New Hampshire. In the Dover area, these marine deposits are known to act effectively as an aquiclude in preventing salt water intrusion into fresh water well fields.

To supplement and verify these regional data, site specific data were also obtained. Of particular value were logs of borings performed in 1969 adjacent to the EAD property. These borings generally indicated a profile of a shallow topsoil layer underlain by brown and gray silts and clays to a depth of 10 to 17 feet. The borings met refusal on bedrock, and were not extended into bedrock. However, based on observations of the lower most cuttings from the borings, bedrock was described as shale. It is highly likely that the shale represents surficial weathering of the expected slate bedrock. Subsurface conditions encountered in these borings were consistent with EAD plant personnel observations of subsurface soils at the EAD facility, and are consistent with the regional geologic mapping of the area.

Thus, in summary, the subsurface stratigraphy at the EAD facility is believed to consist of a shallow (one foot) layer of topsoil followed by 10 to 17 feet of low permeability silts and/or clays, underlain by slate bedrock of the Merrimack group.

Regarding ground water flow in the unconsolidated materials, the direction of flow typically parallels surficial topography toward the nearest ground water receptor. At the EAD facility, surface topography slopes to the west, and the closest potential ground water receptor was judged to be Knox Marsh Brook, located less than one-quarter mile from the EAD facility. The hydraulic gradient toward the brook is expected to be very flat, and the hydraulic conductivity of the soil is expected to be low (in the range of 10^{-5} cm/sec to 10^{-7} cm/sec). This estimate of hydraulic conductivity is based on data contained in the Geological Survey paper and on-site observations.

HYDROGEOLOGIC ASSESSMENT

In order to confirm the hydrogeologic model prepared for the EAD facility, five small diameter steel piezometers have been installed at EAD. These piezometers, installed to a depth of up to 10 feet, will provide the necessary data to confirm the direction of ground water flow at the site and to calculate hydraulic gradient(s) at the site. Sufficient on-site excavation has been performed to confirm subsurface stratigraphy present at the site.

These data should allow calculation of the direction, rate and amount of ground water movement at the site.

RECEPTOR MONITORING

Once the direction of ground water flow has been confirmed, receptor monitoring will be performed. Because the nearest expected ground water receptor is Knox Marsh Brook, the brook was selected as the monitoring point. Water samples will be obtained at four locations in the brook; upstream of EAD, mid-stream of EAD, and at two locations downstream of EAD. These surface water samples will be analyzed for Priority Pollutant volatile organic compounds (VOC's) and for selected heavy metals. Samples will be obtained, preserved and transported in accordance with established EPA protocol. One trip blank and one duplicate sample will also be submitted with the four surface water samples to allow quality control (QC) evaluation of laboratory performance.

Should analyses of any of the surface water samples indicate the presence of heavy metals or VOC's above New Hampshire ground water protection standards, a second set of samples will be obtained to verify the initial analyses.

DATA ASSESSMENT

Based on the data collected during the environmental assessment, Balsam Environmental Consultants, Inc. (Balsam) will perform an evaluation of environmental conditions at the EAD facility. Included in this evaluation will be an estimate of risk presented to the environment by EAD, if any, and possible receptors of this risk. Additional investigatory work, if required, will also be discussed. Copies of this assessment will be submitted to both the New Hampshire Bureau of Waste Management Engineering and Water Supply and Pollution Control Commission for their review.

Please feel free to contact us should you have any questions regarding our approach to this assessment or the associated scope of work.

Sincerely,

BALSAM ENVIRONMENTAL CONSULTANTS, INC.

Stephen B. Ransom
Project Engineer

Leonard C. Sarapas, P.E.
Project Manager

cc: J. Burtelow, EAD
W. Evans, NH WSPCC

ATTACHMENT 1

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING
DIVISION OF HAZARDOUS WASTE
One Winter Street
Boston, Massachusetts 02108

6483

UNIFORM HAZARDOUS WASTE MANIFEST

NHD 0 0 0 4 7 9 3 0 3 | Page 1 of 1

4 Generator's Phone: 603 742-3330

5 Transporter 1 Company Name: Northeast Solvents

6 US EPA ID Number: MAD 0 0 0 6 0 4 4 4 7

7 Transporter 2 Company Name:

8 US EPA ID Number:

9 Designated Facility Name and Site Address: Northeast Solvents, 300 Canal Street, Lawrence, MA

10 US EPA ID Number: MAD 0 0 0 6 0 4 4 4 7

Eastern Air Devices
1 Progress Drive
Dover, NH 03820

State Manifest Document Number: MA-8073165

B State Gen ID: Same

C State Trans ID: MA 8027

D Transporter's Phone: 617 683-1002

E State Trans ID:

F Transporter's Phone:

G State Facility's ID: Not Required

H Facility's Phone: 617 683-1002

11 US DOT Description Including Proper Shipping Name, Hazard Class, and ID Number	12 Containers No.	Type	13 Total Quantity	14 Unit Wt/Vol	I Waste No.
a Hazardous Waste Liquid, N.O.S. ORM-E NA 9189	001	DM	1812	P	F001
b Hazardous Waste Solid, N.O.S. ORM-E NA 9189	003	DM	2436	P	F001
c Hazardous Waste Liquid, N.O.S. ORM-E NA 8189	029	DM	14442	P	F001
d					

J Additional Descriptions for Materials Listed Above: mud & H_2O, Organics & Metals from dry well clean-out - Gravel & Mud, Organics from dry well clean-out; H_2O & Organics from dry well clean-out

K Handling Codes for Wastes Listed Above: SOL; SOL; SOL

15 Special Handling Instructions and Additional Information

16 GENERATOR'S CERTIFICATION: I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked and labeled/placarded, and are in all respects in proper condition for transport by highway according to applicable international and national government regulations and all applicable State regulations.

Printed/Typed Name: J. Burtelow — Signature — Date: 9/22/86

17 Transporter 1 Acknowledgement of Receipt of Materials — Printed/Typed Name: Fred Ash — Signature: Fred Ash — Date: 9/22/86

18 Transporter 2 Acknowledgement of Receipt of Materials — Printed/Typed Name — Signature — Date

19 Discrepancy Indication Space

20 Facility Owner or Operator: Certification of receipt of hazardous materials covered by this manifest except as noted in Item 19.

Printed/Typed Name: CARL Muzio — Signature: Carl Muzio — Date: 9/22/86

MA 8073165 COPY>3: GENERATOR-MAILED BY TSDF

[6-101]

COPY 3: GENERATOR-MAILED BY TSDF

APPENDIX C

RAI

Resource Analysts, Incorporated
Box 4778 Hampton, NH 03842
(603) 926-7777

TO:

Mr. Steve Ransom
Balsam Environmental
5 Manor Parkway, Rollins Building
Salem, NH 03079

PO # KMB

Date Received: 2-25-86 (1705)

Lab Number: 6296

Date Reported: 3-14-86

Please find attached results for Volatile Organic Compounds, Chromium and Zinc.

Date 3/14/86

Technical Director

Parameter: Chromium, recoverable (mg/L) matrix: water
Method: 303A Reference: 1 date analyzed: 2-27-86

Laboratory Number	Field Identification	Concentration
6296-7	KMB-M	<0.01
6296-8	KMB-U	<0.01
6296-9	KMB-D1	<0.01
6296-10	KMB-D2	<0.01
6296-11	KMB-D3	<0.01
6296-12	Trip Blank	<0.01

Parameter: Zinc, recoverable (mg/L) matrix: water
Method: 303A Reference: 1 date analyzed: 2-27-86

Laboratory Number	Field Identification	Concentration
6296-7	KMB-M	<0.005
6296-8	KMB-U	<0.005
6296-9	KMB-D1	<0.005
6296-10	KMB-D2	<0.005
6296-11	KMB-D3	<0.005
6296-12	Trip Blank	<0.005

Reference 1: Standard Methods, 16th Edition

Lab Number:	6296-1
Sample Designation:	KMB-M
Date analyzed:	3-7-86

VOLATILE ORGANICS	CONCENTRATION (ug/L)	DETECTION LIMIT (ug/L)
CHLOROMETHANE	BDL	10
VINYL CHLORIDE	BDL	10
CHLOROETHANE	BDL	5
BROMOMETHANE	BDL	10
METHYLENE CHLORIDE	BDL	5
1,1-DICHLOROETHYLENE	BDL	5
1,1-DICHLOROETHANE	BDL	5
1,2-trans-DICHLOROETHYLENE	BDL	5
CHLOROFORM	BDL	5
1,2-DICHLOROETHANE	BDL	5
1,1,1-TRICHLOROETHANE	BDL	5
CARBON TETRACHLORIDE	BDL	5
VINYL ACETATE	BDL	10
BROMODICHLOROMETHANE	BDL	5
1,2-DICHLOROPROPANE	BDL	5
1,3-trans-DICHLOROPROPENE	BDL	5
TRICHLOROETHYLENE	BDL	5
BENZENE	BDL	5
1,3-cis-DICHLOROPROPENE	BDL	5
1,1,2-TRICHLOROETHANE	BDL	5
2-CHLOROETHYL VINYL ETHER	BDL	5
DIBROMOCHLOROMETHANE	BDL	5
BROMOFORM	BDL	5
TETRACHLOROETHYLENE	BDL	5
1,1,2,2-TETRACHLOROETHANE	BDL	5
TOLUENE	BDL	5
CHLOROBENZENE	BDL	5
ETHYLBENZENE	BDL	5
ACETONE	BDL	25
CARBON DISULFIDE	BDL	5
THF	BDL	25
MEK	BDL	25
MIBK	BDL	25
2-HEXANONE	BDL	25
STYRENE	BDL	5
XYLENES	BDL	5

Resource Analysts, Incorporated

BDL = BELOW DETECTION LIMIT
METHOD REFERENCE: EPA 600/4-82-057 METHOD 624

Lab Number: 6296-2
Sample Designation: KMB-U
Date analyzed: 3-7-86

VOLATILE ORGANICS	CONCENTRATION (ug/L)	DETECTION LIMIT (ug/L)
CHLOROMETHANE	BDL	10
VINYL CHLORIDE	BDL	10
CHLOROETHANE	BDL	5
BROMOMETHANE	BDL	10
METHYLENE CHLORIDE	BDL	5
1,1-DICHLOROETHYLENE	BDL	5
1,1-DICHLOROETHANE	BDL	5
1,2-trans-DICHLOROETHYLENE	BDL	5
CHLOROFORM	BDL	5
1,2-DICHLOROETHANE	BDL	5
1,1,1-TRICHLOROETHANE	BDL	5
CARBON TETRACHLORIDE	BDL	5
VINYL ACETATE	BDL	10
BROMODICHLOROMETHANE	BDL	5
1,2-DICHLOROPROPANE	BDL	5
1,3-trans-DICHLOROPROPENE	BDL	5
TRICHLOROETHYLENE	BDL	5
BENZENE	BDL	5
1,3-cis-DICHLOROPROPENE	BDL	5
1,1,2-TRICHLOROETHANE	BDL	5
2-CHLOROETHYL VINYL ETHER	BDL	5
DIBROMOCHLOROMETHANE	BDL	5
BROMOFORM	BDL	5
TETRACHLOROETHYLENE	BDL	5
1,1,2,2-TETRACHLOROETHANE	BDL	5
TOLUENE	BDL	5
CHLOROBENZENE	BDL	5
ETHYLBENZENE	BDL	5
ACETONE	BDL	25
CARBON DISULFIDE	BDL	5
THF	BDL	25
MEK	BDL	25
MIBK	BDL	25
2-HEXANONE	BDL	25
STYRENE	BDL	5
XYLENES	BDL	5

Resource Analysts, Incorporated

BDL = BELOW DETECTION LIMIT
METHOD REFERENCE: EPA 600/4-82-057 METHOD 624

Lab Number:	6296-3
Sample Designation:	KMB-D1
Date analyzed:	3-7-86

VOLATILE ORGANICS	CONCENTRATION (ug/L)	DETECTION LIMIT (ug/L)
CHLOROMETHANE	BDL	10
VINYL CHLORIDE	BDL	10
CHLOROETHANE	BDL	5
BROMOMETHANE	BDL	10
METHYLENE CHLORIDE	BDL	5
1,1-DICHLOROETHYLENE	BDL	5
1,1-DICHLOROETHANE	BDL	5
1,2-trans-DICHLOROETHYLENE	BDL	5
CHLOROFORM	BDL	5
1,2-DICHLOROETHANE	BDL	5
1,1,1-TRICHLOROETHANE	BDL	5
CARBON TETRACHLORIDE	BDL	5
VINYL ACETATE	BDL	10
BROMODICHLOROMETHANE	BDL	5
1,2-DICHLOROPROPANE	BDL	5
1,3-trans-DICHLOROPROPENE	BDL	5
TRICHLOROETHYLENE	BDL	5
BENZENE	BDL	5
1,3-cis-DICHLOROPROPENE	BDL	5
1,1,2-TRICHLOROETHANE	BDL	5
2-CHLOROETHYL VINYL ETHER	BDL	5
DIBROMOCHLOROMETHANE	BDL	5
BROMOFORM	BDL	5
TETRACHLOROETHYLENE	BDL	5
1,1,2,2-TETRACHLOROETHANE	BDL	5
TOLUENE	BDL	5
CHLOROBENZENE	BDL	5
ETHYLBENZENE	BDL	5
ACETONE	BDL	25
CARBON DISULFIDE	BDL	5
THF	BDL	25
MEK	BDL	25
MIBK	BDL	25
2-HEXANONE	BDL	25
STYRENE	BDL	5
XYLENES	BDL	5

BDL = BELOW DETECTION LIMIT
METHOD REFERENCE: EPA 600/4-82-057 METHOD 624

Lab Number: 6296-4
Sample Designation: KMB-D2
Date analyzed: 3-7-86

VOLATILE ORGANICS	CONCENTRATION (ug/L)	DETECTION LIMIT (ug/L)
CHLOROMETHANE	BDL	10
VINYL CHLORIDE	BDL	10
CHLOROETHANE	BDL	5
BROMOMETHANE	BDL	10
METHYLENE CHLORIDE	BDL	5
1,1-DICHLOROETHYLENE	BDL	5
1,1-DICHLOROETHANE	BDL	5
1,2-trans-DICHLOROETHYLENE	BDL	5
CHLOROFORM	BDL	5
1,2-DICHLOROETHANE	BDL	5
1,1,1-TRICHLOROETHANE	BDL	5
CARBON TETRACHLORIDE	BDL	5
VINYL ACETATE	BDL	10
BROMODICHLOROMETHANE	BDL	5
1,2-DICHLOROPROPANE	BDL	5
1,3-trans-DICHLOROPROPENE	BDL	5
TRICHLOROETHYLENE	BDL	5
BENZENE	BDL	5
1,3-cis-DICHLOROPROPENE	BDL	5
1,1,2-TRICHLOROETHANE	BDL	5
2-CHLOROETHYL VINYL ETHER	BDL	5
DIBROMOCHLOROMETHANE	BDL	5
BROMOFORM	BDL	5
TETRACHLOROETHYLENE	BDL	5
1,1,2,2-TETRACHLOROETHANE	BDL	5
TOLUENE	BDL	5
CHLOROBENZENE	BDL	5
ETHYLBENZENE	BDL	5
ACETONE	BDL	25
CARBON DISULFIDE	BDL	5
THF	BDL	25
MEK	BDL	25
MIBK	BDL	25
2-HEXANONE	BDL	25
STYRENE	BDL	5
XYLENES	BDL	5

BDL = BELOW DETECTION LIMIT
METHOD REFERENCE: EPA 600/4-82-057 METHOD 624

Lab Number:	6296-5
Sample Designation:	KMB-D3
Date analyzed:	3-7-86

VOLATILE ORGANICS	CONCENTRATION (ug/L)	DETECTION LIMIT (ug/L)
CHLOROMETHANE	BDL	10
VINYL CHLORIDE	BDL	10
CHLOROETHANE	BDL	5
BROMOMETHANE	BDL	10
METHYLENE CHLORIDE	BDL	5
1,1-DICHLOROETHYLENE	BDL	5
1,1-DICHLOROETHANE	BDL	5
1,2-trans-DICHLOROETHYLENE	BDL	5
CHLOROFORM	BDL	5
1,2-DICHLOROETHANE	BDL	5
1,1,1-TRICHLOROETHANE	BDL	5
CARBON TETRACHLORIDE	BDL	5
VINYL ACETATE	BDL	10
BROMODICHLOROMETHANE	BDL	5
1,2-DICHLOROPROPANE	BDL	5
1,3-trans-DICHLOROPROPENE	BDL	5
TRICHLOROETHYLENE	BDL	5
BENZENE	BDL	5
1,3-cis-DICHLOROPROPENE	BDL	5
1,1,2-TRICHLOROETHANE	BDL	5
2-CHLOROETHYL VINYL ETHER	BDL	5
DIBROMOCHLOROMETHANE	BDL	5
BROMOFORM	BDL	5
TETRACHLOROETHYLENE	BDL	5
1,1,2,2-TETRACHLOROETHANE	BDL	5
TOLUENE	BDL	5
CHLOROBENZENE	BDL	5
ETHYLBENZENE	BDL	5
ACETONE	BDL	25
CARBON DISULFIDE	BDL	5
THF	BDL	25
MEK	BDL	25
MIBK	BDL	25
2-HEXANONE	BDL	25
STYRENE	BDL	5
XYLENES	BDL	5

BDL = BELOW DETECTION LIMIT
METHOD REFERENCE: EPA 600/4-82-057 METHOD 624

Resource Analysts, Incorporated

Lab Number: 6296-6
Sample Designation: TRIP BLANK
Date analyzed: 3-7-86

VOLATILE ORGANICS	CONCENTRATION (ug/L)	DETECTION LIMIT (ug/L)
CHLOROMETHANE	BDL	10
VINYL CHLORIDE	BDL	10
CHLOROETHANE	BDL	5
BROMOMETHANE	BDL	10
METHYLENE CHLORIDE	BDL	5
1,1-DICHLOROETHYLENE	BDL	5
1,1-DICHLOROETHANE	BDL	5
1,2-trans-DICHLOROETHYLENE	BDL	5
CHLOROFORM	BDL	5
1,2-DICHLOROETHANE	BDL	5
1,1,1-TRICHLOROETHANE	BDL	5
CARBON TETRACHLORIDE	BDL	5
VINYL ACETATE	BDL	10
BROMODICHLOROMETHANE	BDL	5
1,2-DICHLOROPROPANE	BDL	5
1,3-trans-DICHLOROPROPENE	BDL	5
TRICHLOROETHYLENE	BDL	5
BENZENE	BDL	5
1,3-cis-DICHLOROPROPENE	BDL	5
1,1,2-TRICHLOROETHANE	BDL	5
2-CHLOROETHYL VINYL ETHER	BDL	5
DIBROMOCHLOROMETHANE	BDL	5
BROMOFORM	BDL	5
TETRACHLOROETHYLENE	BDL	5
1,1,2,2-TETRACHLOROETHANE	BDL	5
TOLUENE	BDL	5
CHLOROBENZENE	BDL	5
ETHYLBENZENE	BDL	5
ACETONE	BDL	25
CARBON DISULFIDE	BDL	5
THF	BDL	25
MEK	BDL	25
MIBK	BDL	25
2-HEXANONE	BDL	25
STYRENE	BDL	5
XYLENES	BDL	5

BDL = BELOW DETECTION LIMIT
METHOD REFERENCE: EPA 600/4-82-057 METHOD 624

Resource Analysts, Incorporated

CHAIN OF CUSTODY RECORD

SAMPLERS: Stephen R. Ransom / [illegible]

STATION NUMBER	STATION LOCATION	DATE	TIME	SAMPLE TYPE: Comp.	SAMPLE TYPE: Grab	SAMPLE TYPE: Air	MO. NO.	NO. OF CONTAINERS	ANALYSIS REQUIRED
KMB-M	—	2/25/86			✓			3	VOC's / Cr + Zn
KMB-U	—	2/25/86			✓			3	VOC's / Cr + Zn
KMB-D1	—	2/25/86			✓			3	VOC's / Cr + Zn
KMB-D2	—	2/25/86			✓			3	VOC's / Cr + Zn
KMB-D3	—	2/25/86			✓			3	VOC's / Cr + Zn
TRIP BLANK	—	2/25/86			✓			2	VOC's / Cr + Zn

Relinquished by: Stephen R. Ransom	Received by:	Date/Time 2/25 17:20
Relinquished by:	Relinquished by:	Date/Time
Relinquished by:	Received by:	Date/Time
Received by:	Received by Mobile Laboratory for field analysis:	Date/Time
Dispatched by:	Date/Time: Received for Laboratory by: [signature]	Date/Time 2/25 1720
Method of Shipment:		

Distribution: Orig.–Accompany Shipment
1 Copy–Sample Coordinator Field Files

unf

sa

Resource Analysts, Incorporated

Section 6.2.5

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Inspection Report No. 3 From Report on Inventory and Assessment of Class V Injection Wells in Puerto Rico.
AUTHOR: **(or INVESTIGATOR)**	Engineering Enterprises, Inc.
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Viscase Puerto Rico Corporation (Formerly Union Carbide Films-Packaging, Inc.)
NATURE OF BUSINESS:	Food Casing Manufacturer
BRIEF SUMMARY/NOTES:	Process wastewater, ancillary cooling water, power house water, and filter backwashes were neutralized in concrete basins, filtered through anthracite filters, and then injected. Wells were plugged after approximately 10 years of use.

INSPECTION 3

Name: Viscase Puerto Rico Corporation
(Formerly Union Carbide Films-Packaging, Inc.)
Address: Corr. 2, Km 59, Barceloneta, P.R.
Number of Wells:

4 (2 abandoned)

Classes of Wells:

(1) 5W20 (abandoned; plugged)
(2) 5W20 (abandoned; plugged)
(3) 5D2 (closed)
(4) 5D2 (closed)

General Description of Wells

Two natural sinkholes are within the facility grounds. They receive all runoff from roofs and paved and unpaved areas. During the team inspection visit, some grading was being done to eliminate these sinkholes. Once this work is completed, runoff water will not reach groundwater through these sinkholes.

Process wastewater resulting from the manufacture of food casings (regenerated cellulose) by the viscose process as well as ancillary cooling water, power house water and filter backwashes was neutralized in concrete basins, filtered through anthracite filters, and then injected through an injection well. This operation was performed from September 1969 (Plant Start-up) until August 1979 when the plant started discharging its wastewater effluent to the Barceloneta Plant. The injection system consisted of two injection/extraction wells which were designed to allow fresh water extraction and deep well injection within the same well either concurrently or separately. The two wells were drilled to a depth below 2000 feet. The waste disposal zone was between 1545 and 2000 feet, in the Lares limestone. These wells were plugged in 1984 and 1985, after being unused for a period of 5 years.

General Description of Industry

This industry is dedicated to the manufacture of food casings (regenerated cellulose) by the viscose process.

Description of Wastewater Injected

Runoff water is the only liquid presently flowing into the sinkholes. Water quality information was not available at the time of the inspection; this was not requested because the sinkholes were being covered up. A laboratory test report of the effluent wastewater that was injected in the past is presented below.

2)

Underground Sources of Drinking Water

Several municipal and industrial water supply wells are located in the area surrounding Viskase. Groundwater depth varies from 17 ft. to 259 ft. depending on the location of the wells. Groundwater is hard to moderately hard, with low to slightly high dissolved solids.

The abandoned wells and closed sinkholes do not appear to constitute a threat to groundwater.

The prinicpal aquifers of this region are the Aymamon Limestone (Aquada Limestone (water table); the Montibello Limestone (artesian); and the Lares Limestone (artesian).

V(3)

TABLE 1

LABORATORY TEST REPORT ON A WASTEWATER SAMPLE TAKEN JUNE 28, 1985.

PARAMETERS	RESULTS	UNIT
Oil & Grease	<5.0	mg/L
Color	30	PtCoCU
Chemical Oxygen Demand	153	mg/L
Phenol	0.034	mg/L
Total Organic Carbon	17	mg/L
Turbidity	27	NTU
Settleable Solids	0.2	ml/L
Volatile Suspended Solids	21	mg/L
Total Solids	6,707	mg/L
Ammonia-N	200	mg/L
Nitrite-N	1.68	mg/L
Nitrate + Nitrite-N	2.05	mg/L
Chloride	454	mg/L
Total Cyanide	<0.02	mg/L
Sulfate	4,283	mg/L
Sulfide	0.120	mg/L
Total Arsenic	3.6	ug/L
Total Cadmium	14	ug/L
Chromium Hexavalent	<20	ug/L
Total Chromium	<20	ug/L
Total Iron	1,053	ug/L
Total Lead	<50	ug/L
Total Manganese	25	ug/L
Total Mercury	41.1	ug/L
Total Nickel	90	ug/L
Total Selenium	<2.0	ug/L
Total Silver	11	ug/L
Total Zinc	116	ug/L
Fluoride	0.48	mg/L

Source: Information provided by VISCASE Puerto Rico Corp.

TABLE 3

WATER QUALITY DATE OF WATER SAMPLES
TAKEN FROM WELLS IN THE VICINITY OF THE
VISCASE PUERTO RICO CORPORATION
PLANT SITE, PUERTO RICO

Analysis

Parts per million	27-66.32-1 Barceloneta Well	25-66.31-1 Plant Site No. 1
Silica (SiO_2)	9.5	10
Iron (Fe)	.0	0
Calcium (Ca)	124	88
Magnesium (Mg)	15	5.8
Sodium (Na)		
Potassium (K)	81	22
Carbonate (CO_3)	0	0
Bicarbonate (HCO_3)	266	236
Sulfate (SO_4)	23	53
Chloride (Cl)	216	22
Fluoride (F)	.8	0
Nitrate (NO_3)	.2	16
Dissolved solids	600	390
Hardness as $CaCO_3$:		
Total	371	244
Noncarbonate	153	
Color	1	0
pH	7.1	7.5
Turbidity	0	8
Date of collection	3-3-59	5-1-67

Source: Water Resources Bulletin, No. 2, USGS, Public Water Supplies in Puerto Rico, T. Arnow and J.W. Crooks, 1960.

Section 6.2.6

TITLE OF STUDY: (or **SOURCE OF INFORMATION**)	Inspection Report No. 5 From Report on Inventory and Assessment of Class V Injection Wells in Puerto Rico
AUTHOR: (or **INVESTIGATOR**)	Engineering Enterprises, Inc.
DATE:	December, 1986
FACILITY NAME AND LOCATION:	RCA del Caribe, Inc. Barceloneta, Puerto Rico USEPA Region II
NATURE OF BUSINESS:	Aperture Mask Manufacturer
BRIEF SUMMARY/NOTES:	Wastewater contains acids, alkalis, ferric chloride, ferrous chloride, organic materials, and chromium. Discharge violates several limits imposed by Environmental Quality Board. Closer monitoring is recommended.

Name: RCA del Caribe, Inc.
Address: Hwy. No. 2, Km 59, Barceloneta, P.R.
Number of Injection Wells:

One

Classification of well:

Class V, Type 5W20

General Description of Well:

Improved sinkhole with 10 feet of 60-inch concrete pipe installed in throat.

General Description of Industry:

This facility is dedicated to the manufacture of aperture masks which are specially prepared metal screens used in cathode-ray tubes to direct the electron beam to the screen. This industry began operation in 1971.

General Description of Waste Injected

The industrial wastewater produced contains acids, alkalies, ferric chloride, ferrous chloride, organic material, and chromium. These wastes are treated by neutralization and clarification prior to being discharged to a sinkhole at a rate of 295 gpm. Tables 1 and 2 present information on the quality of the effluent being injected. This discharge violates some of the recommended limits imposed by EQB, such as iron, cadmium, hexavalent chromium, zinc, phenols, chlorides and total dissolved solids.

Sanitary wastes are discharged into a separate sewer line connected to the Barceloneta Regional Wastewater Plant.

General Geological/Hydrogeological Setting

The entire region is underlain by strata of tertiary limestone tilting gently downward toward the north (seaward). The upper strata (termed Aymamon and Aquada limestone) are very pure limestone, generally hard in the upper and lower layers and soft in the middle layer. The hardness yields the very rugged topography of the Karst Outcrop Region with sinks and steep mogotes. These strata are cavernous, particularly within the upper (Aymamon) stratum. Their thickness is estimated to be 300-400 meters at the coast, pinching out inland until they disappear at the south edge of the region.

The plant site is located on a plain which is characteristic of the north coastal area of Puerto Rico. The area is characterized

(2)

by haystacks, consisting largely of limestone rock with no agricultural value, although dense in vegetation. These haystacks are characteristics of Puerto Rico's north area from Barceloneta to Quebradillas. These are close to the RCA plant, but there are none in the area occupied by the plant.

The surface drainage of the site is affected by the topography and by the geology of the area. Studies made of rock formations by the U.S. Geological Survey in San Juan indicate that the rocks consist mainly of Aymamon Limestone, Aguada Limestone, Cibao formation (which is interbedded marl, chalk, and limestone).

Underlying USDW's

The water table aquifer is known as the Aymamon/Aquada.

The artesian formations are the Montibello Limestone (of the Cibao formation) and the Lares Limestone.

Plant water is supplied from a deep well which draws from an artesian limestone aquifer. Information on chemical quality of water from a shallow well owned by RCA (Table 3), shows that it is of good quality. Water supply wells in a 1-mile radius are those used by industries such as Pfizer, Abbott, Cyanamid, and Upjohn. There are 2 municipal wells - one at Cruce Davila and one at Tiburones.

To further assess the impact on water quality from the injection operation, additional information on nearby wells is needed, especially those wells located in the same formation. The present monitoring program being conducted by RCA is not appropriate, since some of the monitoring wells are far away from the injection well, and some others are not in the same aquifer.

VI(3)

TABLE 1

PHYSICAL AND CHEMICAL ANALYSIS OF WASTEWATER (1)
RCA DEL CARIBE, INC.

Parameter	Concentration in mg/l
Barium	0.1
Iron	0.34-0.11 (2)
Cadmium	0.0075
Chromium $^{+6}$	0.06
Chromium $^{+3}$	0.01
Copper	0.02
Cyanide	0.02
Zinc	0.347
Phenols	0.015
BOD	6
COD	35
pH, SU	8.1
Hardness	180
Calcium ($CaCO_3$)	136
Magnesium ($CaCO_3$)	44
Chlorides	370
Sulphates	26
Specific Conductance	1600
Total Dissolved Solids	1200
Silica	1.6
Carbon Dioxide	30
Color, SU	0
Turbidity, SU	0

(1) Sample collected on October 9, 1984.
(2) Two samples

(4)

TABLE 2

CHEMICAL ANALYSIS OF WASTEWATER DISCHARGE
RCA DEL CARIBE, PUERTO RICO

	WWTP Effluent (mg/l)
Cyanide	<0.05
Phenols	0.004
Boron	0.26
Arsenic	<0.01
Barium	<0.05
Cadmium	<0.001
Copper	0.008
Lead	<0.008
Mercury	<0.002
Nickel	<0.006
Selenium	<0.01
Zinc	0.03

Sample Date: 4/17/85
Source: Data provided by Ramon Guzman and Associates

TABLE 3

CHEMICAL QUALITY OF SHALLOW WATER WELL AT
RCA DEL CARIBE - 8/9/81

Parameter	Concentration
pH (Electrometric)	7.7
Hardness. Total as $CaCO_3$, ppm	186
(a) Calcium as $CaCO_3$, ppm	170
(b) Magnesium as $CaCO_3$, ppm	16
(c) Iron as Fe, ppm	.01
P. Alkalinity as $CaCO_3$, ppm	zero
Total as $CaCO_3$, ppm	186
Chlorides as Cl, ppm	46
Sulphate as SO_4, ppm	15.3
Phosphates as PO_4, ppm	--
Sulphite as SO_3, ppm	--
Specific Conductance-Micromhos	320
Dissolved solids, ppm	240
Silica as SiO_2, ppm	6.1
Carbon Dioxide as CO_2, ppm	20
Turbidity, ppm	zero
Color	zero

Source: Data given by Ramon Guzman and Associates

Section 6.2.7

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Inspection Report No. 10 From Report on Inventory and Assessment of Class V Injection Wells in Puerto Rico
AUTHOR: **(or INVESTIGATOR)**	Engineering Enterprises, Inc.
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Glamourette Fashion Mills, Inc. Quebradillas, Puerto Rico USEPA Region II
NATURE OF BUSINESS:	Apparel Manufacturer
BRIEF SUMMARY/NOTES:	The U.S. EPA considers certain dyes to be hazardous. The company declined to provide information on the kinds, quantities, and concentrations of dyes in the injectate. Matter is under investigation by EPA, Region II.

Name: Glamourette Fashion Mills, Inc.

Address: Road 113, Km 10.8, Quebradillas, P.R.

Number of Injection Wells:

One

Classification of Well:

Class V, Type 5W20

General Description of Injection Well:

This is an undeveloped sinkhole that receives plant process waste water via a pipe and gravity flow.

General Description of Industry:

This industry has manufactured apparel since 1956. It employs 750 people.

The dying operation is the main source of wastes. Dye wastes without any treatment are discharged directly into a sinkhole located on company property.

General Description of Waste Injected:

Literature sources characterize such wastes generally as colored, highly alkaline, high in BOD and suspended solids, and high in temperature. The U.S. Environmental Protection Agency considers certain dyes to be hazardous. The company declined to provide information on the kinds or quantities of chemicals and dyes used and the concentrations found in the injectate, alleging that the sinkhole is not a well as defined in 40 CFR 144 (see attached letter). This case is, at this writing, being studied by EPA Region II, New York.

General Geological/Hydrogeological Setting:

Karst topography - decomposed limestone (Aymamon and Cibao) with solution channels, caverns, marl, chalk, sands and clays. Sinkholes common to the area.

Underlying USDW's:

The Cibao formation with water table aquifer. Deeper artesian aquifers: Montibello Limestone and Lares Limestone.

The Cibao yields "small to moderate" amounts of water to wells.

(2)

Two water supply wells are located in the vicinity of the injection facility - the Glamourette well and the Del Rey well. The Glamourette well is 580 feet deep and yields 200 gpm; static water level is at 400 feet.

The Del Rey well serves as a backup supply source for Quebradillas, a town of 27,000. This well is 610 feet deep and is pumped at 120 gpm; static water level is reported to be at 420 feet.

Those responsible for the UIC program should follow up on this potential problem - both because of the unknown toxicity of the dyes, and because of the proximity to public water supply wells.

Section 6.2.8

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Inspection Report No. 19 From Report on Inventory and Assessment of Class V Injection Wells in Puerto Rico
AUTHOR: **(or INVESTIGATOR)**	Engineering Enterprises, Inc.
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Lotus (Land Authority of Puerto Rico-Pineapple Division) Barceloneta, Puerto Rico USEPA Region II
NATURE OF BUSINESS:	Tropical Fruit Processing and Canning
BRIEF SUMMARY/NOTES:	Industrial wastes come from the cooling process, pineapple washing, and pineapple extraction. The organic waste is higher than that of typical domestic sewage. Recommended limits for phenol, total dissolved solids, and surfactants are exceeded. Monitoring program is recommended.

Name: Lotus (Land Authority of Puerto Rico-Pineapple Div.)

Address: Hwy. No. 2, Km 56.3, Barceloneta, P.R.

Classification of Wells:

(1) Class V. Type 5W20 (sinkhole)
(2) Class V, Type 5W20 (sinkhole)

General Description of Wells

The wells are unimproved sinkholes - irregular depressions that are overgrown by dense vegetation that must be periodically cleaned out to prevent damming of suspended materials. The sinkholes drain into the Aymamon Limestone and the water table aquifer.

General Description of Industry

Lotus, owned by the Puerto Rico Land Authority, started operations in 1956. It is dedicated to the processing and canning of tropical fruits, such as pineapple, oranges, guava, pears, peaches, apricots and bananas.

Industrial wastes come from the cooling process, pineapple washing and pineapple extraction. The amount of waste injected is estimated to be about 122,900 gpd. The quality of this waste is presented in Table 1. The organic strength of this waste is higher than that of a typical domestic sewage. The recommended limits on phenol, total dissolved solids and surfactants are exceeded.

This plant does not have operating permits for its two sinkholes. The two sinkholes receive raw industrial waste.

General Geological/Hydrogeological Setting

The geology is typical of the north coastal region and similar to that described for the UIF's above. The decomposed Aymamon Limestone with its Karst topography has numerous sinkholes that accept water rapidly. There is no known competent barrier between these superficial cavernous formations and the water table aquifer -- the Aymamon/Aquada formation.

Underlying USDW's

Two water supply wells are used by Lotus. One is a water table well drilled to 450 feet and the other an artesian well with a depth of 1200 feet. Information on water quality of the shallow

well was not available, but it is expected to be similar in general quality to that for the shallow aquifer in this area. Groundwater quality from the artesian well is good (see Table 7). Depth of the shallow water table was reported to be around 100 feet.

No nearby wells, except for the one owned by Lotus, exist in the area, so no reports of groundwater pollution caused by this operation have been reported.

It is obvious that this discharge has to affect the quality of fresh groundwater in the area. Further development of groundwater resources in the area may be limited by this operation.

To further assess the impact of these wells on groundwater quality, a monitoring program would have to be adopted. Some additional monitoring wells would perhaps have to be constructed.

TABLE 1

Chemical Quality of Wastewater Produced at Lotus and Recommended Limits

Parameter	Concentration (mg/l)	Recommended Limit (mg/l)
Phenol	1.7	0.001
Ammonia	0.68	--
Nitrate	1.01	10
Phosphorus, Total	0.84	1.0
Orthophosphorus	0.76	--
Iron	0.28	0.30
BOD_5	445	--
COD	5294	--
TSS	1359	--
TDS	5539	500
SeS	138	--
TKN	2.47	--
Surfactants	0.72	0.10

Source: EQB Files

Section 6.2.9

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Inspection Report No. 23 From Report on Inventory and Assessment of Class V Injection Wells in Puerto Rico
AUTHOR: **(or INVESTIGATOR)**	Engineering Enterprises, Inc.
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Kendall McGaw Laboratories, Inc. Sabana Grande, Puerto Rico USEPA Region II
NATURE OF BUSINESS:	Parenteral Medical Accessories
BRIEF SUMMARY/NOTES:	Septic tank receives sanitary wastes (71%) process water (24%), and washing water (5%).

INSPECTION 23

Name: Kendall McGaw Laboratories, Inc. Plant No. 1

Address: Road No. 2, Km 215.8, Sabana Grande, P.R.

Number of Injection Wells:

One

Classification of Wells:

Class V, Type 5W20

General Description of Wells:

There are 4 cesspools connected in series by an 8-inch pipe; they receive the discharge from a septic tank.

General Description of Industry:

This industry manufactures parenteral medical accessories.

Description of Waste Injected:

The septic tank receives sanitary wastes (71%), process water (24%), and cleaning and washing water (5%) by gravity flow. The process water is boiler blow-down and water-softener regenerant water. Volume applied is 4,200 gallons per day.

General Geological/Hydrogeological Setting:

Alluvium-erosion products of tuffaceous sandstone, siltstone, breccia and lava.

Underlying USDW's:

Water table conditions in river alluvium, with high water table. Materials may be very coarse and permeable.

There is a PRASA water supply well about 1,000 meters to the southwest.

Section 6.2.10

TITLE OF STUDY: (or SOURCE OF INFORMATION)	New York Automobile Dealer Inspection Trip Report
AUTHOR: (or INVESTIGATOR)	USEPA Region II
DATE:	October, 1986
FACILITY NAME AND LOCATION:	Various Automobile Dealers Long Island, New York USEPA Region II
NATURE OF BUSINESS:	Car Dealers and Car Washes
BRIEF SUMMARY/NOTES:	The NJDEP found a Toyota dealer removing cosmolene from automobiles with formula R-E-L (87% Petroleum Hydrocarbons, 11% trichloroethane, 4% Detergents) and washing it into a dry well. Several other car dealers in New York were observed using hydrocarbons to remove cosmolene.

TRIP REPORT

Travelers: Leon Lazarus, Leslie Zawacki (October 23, only)

Dates: October 23-24, 1986

Location: Long Island

Summary: The NJDEP recently found a Toyota dealer removing cosmolene from automobiles with formula R-E-L (87% Petroleum Hydrocarbons, 11% trichloroethane, 4% Detergents), and washing the R-E-L into a dry well. We inspected car dealers on Long Island to see if they were using chlorinated hydrocarbons to remove cosmolene. We did not observe any auto dealers that used chlorinated solvents, but several used hydrocarbons to remove cosmolene. We observed 12 auto dealers that injected auto wash water into UIC wells that should be permitted. We also inspected two car washes that recycle their wash water. These facilities should not be permitted.

Date/Time	Name/Address	Contact	Number of Drains	Comments
10/23/86 10:00 AM	Huntington Hyundai, Inc. 1221 East Jericho Tpke Huntington, NY 11743	Francis X. Johnson	6 Surface Drains	Cosmolene removed with Afta cleaning fluid (Petroleum distillate)
10:30 AM	Habberstad Datsun-BMW	James Borrelli	6 Surface Drains	Autos are decosmolened at port
11:30 AM	Stevens Toyota 1030 E. Jericho Tpke Huntington Station, NY 11746	Pat Fallon	1 Floor Drain in repair area 40' x 1/2' 1 Drain under car wash bay 3 Surface Drains	The water in the floor drain was very greasy and dirty Cosmolene removed with kerosene
1:00 PM	Metric Auto Sales 1767 E. Jericho Tpke Huntington, NY 11743	Bob Johnson	1 Drain under car wash bay 2 Surface Drains	Cars do not have Cosmolene
1:20 PM	Huntington Honda	June Watcher	1 Floor Drain repair area 1 Drain under car wash bay	Cosmolene removed with Ardex Cosmolene Remover (contains petroleum hydrocarbons). Possibly fined previously by the County for using floor drains without authorization.
1:50 PM	J&M Car Wash 1977 Jericho Tpke E. Northport, NY 11731	John Cinque	4 Surface Drains	All wash water recycled. One drain receives some car wash fluid. One drain receives wash water from cleaning mats. This facility should not be permitted.

Date/Time	Name/Address	Contact	Number of Drains	Comments
10/23/86 2:20 PM	Mohawk Brushless Car Wash 1102 Jericho Tpke Commack, NY 11725	Marvin Endelson	6 Surface drains	Car washes that recirculate their wash waters should not be permitted.
2:50 PM	Smithtown Toyota 360 E. Jericho Tpke Smithtown, NY 11787	Joe Martorano	1 Floor drain in repair area 1 Car wash drain	Cosmolene taken off at port. Antifreeze dumped down car wash drain
3:15 PM	Smithtown Subaru 400 E. Jericho Tpke Smithtown, NY 11787	Vic Bable	Car wash goes to surface area drain, which appears to connect to storm sewer	Cosmolene removed with Afta cleaner fluid
3:45 PM	Smithhaven Mazda 463 Jerich Tpke Smithtown, NY 11787	Jim Kincaid	2 Floor drains in repair 2 Surface drains receive car wash fluids	Autos have no cosmolene
10/24/86 8:30 AM	Hagstron Buick 305 W. Jericho Tpke Huntington, NY 11743	Ken Gordad	1 Floor drain in repair area 1 drain under car wash bay "Reception Area" has 2 indoor drains - no repairs in this area 3 surface drains	Antifreeze dumped down dry well. Parts cleaner mixed with waste oil
9:00 AM	Mitchell Cadillac 275 W. Jericho Tpke Huntington Station, NY 11746	Dick Walters	5 floor drains in repair area 1 drain under car wash bay	
9:45 AM	Mitchell Oldsmobile 670 E. Jericho Tpke Huntington Station, NY 11746	Harry Sara	1 Floor drain in repair area 5 Surface drains	
10:00 AM	Mitchell Dodge 660 E. Jericho Tpke Huntington Station, NY 11746	Jerry Jacobson	3 Floor drains in repair area 1 car wash drain 1 surface drain	

Date/Time	Name/Addresss	Contact	Number of Drains	Comments
10:30 AM	AMC/Jeep/Renault of Huntington 1220 E. Jericho Tpke Huntington, NY 11743	Bob Storck	1 Floor drain in repair area 1 Surface drain	Antifreeze dumped in parking lot, parts cleaner never changed
11:00 AM	Sportique Motors 1249 E. Jericho Tpke Huntington, NY 11743	Thomas Lederer	1 Floor drain in repair area 1 Car wash drain under garage door	
11:45 AM	Deacon Ford Truck Sales 1600 Route 110 Farmingdale, NY 11735	Sal Battaglia	1 Surface drain	
1:30 PM	Wantagh Mazda 3460 Sunrise Highway Wantagh, NY 11793	Jerry Kincaid	1 Floor drain in repair area 1 Outdoor drain for car wash 1 Other surface drain	Cosmolene removed at port
2:00 PM	Wantagh Mitsubishi 3460 Sunrise Highway Wantagh, NY 11793	Sal De Franco	3 Floor drains in repair area (two receive car wash waters) 6 Surface drains	Will mail us parts cleaner manifest
2:30 PM	Stern Motors of Freeport 146 West Sunrise Highway Freeport, NY 11520	Vic Surico	1 Floor drain in repair area (receives car wash waters) 1 Surface drain	

Section 6.2.11

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Summary of New York State Department of Environmental Conservation, SPDES Permit Compliance System Data, "Limits and Measurement Data for Nassau and Suffolk Facilities Which Discharge to Groundwater."
AUTHOR: **(or INVESTIGATOR)**	Engineering Enterprises, Inc. and USEPA Region II
DATE:	November, 1986
STUDY AREA NAME AND LOCATION:	Nassau and Suffolk Counties, Long Island, New York USEPA Region II
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	Includes descriptions and volumes of fluids permitted (by NYSDEC) for injection into industrial waste disposal wells in Nassau and Suffolk Counties. Please refer to the Report to Congress for discussion and evaluation.

KEY TO TABLE OF PCS SUMMARY

TEMP	TEMPERATURE
TDS	SOLIDS, TOTAL DISSOLVED
TSS	SOLIDS, TOTAL SUSPENDED
Sttl.Slds	SOLIDS, SETTLEABLE
Cr(T)	CHROMIUM, TOTAL
Cr(H)	CHROMIUM, HEXAVALENT
MEK	METHYLETHYLKETONE
TCE	TRICHLOROETHYLENE
TTCE	TETRACHLOROETHYLENE
TCFM	TRICHLOROFLURO-METHANE
1,1-DCA	1,1-DICHLORO- ETHANE
1,1-DCE	1,1-DICHLOROETHYLENE
1,1,1-TCA	1,1,1-TRICHLORO- ETHANE
1,2-Trans	1,2-TRANS-DICHLORO-ETHYLENE
T O C	TOTAL ORGANIC CARBON
O & G	OIL AND GREASE
BOD(C)	BOD, CARBONACEOUS
COD	CHEMICAL OXYGEN DEMAND
OD(C)	CARBONACEOUS OXYGEN DEMAND

TABLE SUMMARY OF PERMIT COMPLIANCE SYSTEM (PCS) DATA TITLED "LIMITS AND MEASUREMENT DATA FOR NASSAU AND SUFFLOK FACILITIES DISCHARGE TO GROUND WATER", MAINTAINED FOR THE SPDES PROGRAM IN NEW YORK.

PERMIT #	FACILITY NAME & ADDRESS	DISCHARGE RATE AVG, GPD	DISCHARGE RATE MAX, GPD	Color Pt-Co Ut	TEMP DEG. C	pH min su	pH max su	Spec.Cond u mhos/cm	TDS mg/l	TSS mg/l	Sttl.Slds mg/l	Chloride mg/l	Fluoride mg/l	Nitrogen(T) mg/l	Sulfate(T) mg/l	Sulfide mg/l
NY0088447	Allstate Regional HQ , Farmingdale, NY 11735	23500	128125	NA	NA	6.6	7.4	NA	7.1	32.5	0.37	NA	NA	5.3	NA	NA
NY0108049	American Institute of Physics, New York, NY 10017	856	1060	NA	NA	6.6	7.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0081698	Arkay Packaging Corp, Hauppauge, NY 11767	7812	19586	51	NA	5.9	8.1	NA	751	NA	NA	NA	NA	6E	NA	NA
NY0074764	Astro Electroplating Inc , Farmingdale, NY 11735	1500	1500	NA	NA	6.7	7.6	NA	65	NA	NA	NA	NA	1	7	NA
NY0101834	CW Post College Wastewater Plt, Greenvale NY 11548	108767	146000	NA	NA	5.4	6.7	NA	NA	2.6	NA	NA	NA	NA	NA	NA
NY0100871	Call Data Long Island, Woodbury, NY 11797	857	1242	NA	NA	7.1	8.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0074713	Cardwell Condenser Corp, Lindenhurst, NY 11757	ERR	ERR	NA	NA	7	7.1	NA	243	NA	NA	25	NA	1.4	25	NA
NY0075591	Deutch Relays Inc, East Northport, NY 11731	1851	11280	NA	NA	7.15	8.75	NA	2440	NA	NA	NA	7.85	29.67	NA	NA
NY0108090	Dover Finding Inc, St James, NY 11780	ERR	ERR	NA	NA	6.53	7.04	NA	183.1	NA	NA	NA	NA	NA	NA	NA
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	6446	17145	NA	NA	7.1	7.9	NA	485	11	NA	NA	1	10	NA	NA
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	706177	850000	NA	NA	6.1	6.7	171	NA	NA	NA	NA	NA	NA	NA	NA
NY0076155	Fairchild Weston Systems Inc, Syosset, NY 11791	ERR	ERR	NA	NA	7.1	7.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106038	Font Manufacturing, Hauppauge, NY 11788	2196	2625	ERR	ERR	7.1	7.1	NA	NA	NA	NA	NA	NA	10.3	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	2190	5520	NA	NA	6.5	6.5	NA	140	NA	NA	NA	7	11	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	1333	1500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	33	65	NA	NA	6.2	6.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	5000	5000	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	5000	5000	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	85	1000	NA	NA	6.6	8.2	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	1500	1500	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	1800000	3200000	ERR	ERR	6.9	7.3	NA	NA	NA	NA	NA	0.1	ERR	ERR	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	2900000	4200000	NA	NA	6.4	6.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	1700000	3000000	ERR	ERR	6.2	6.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	ERR	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	ERR	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	100000	500000	NA	NA	6.4	6.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	1000	1000	NA	NA	6.9	7.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	587000	1620000	NA	NA	6.4	6.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109916	H C M Graphics Inc, Hauppauge, NY 11789	207	1000	NA	NA	6.7	6.7	NA	NA	NA	NA	NA	NA	18.7	NA	NA
NY0066028	Hauppauge Country Center S T P, Hauppauge, NY 1178	95000	95000	NA	ERR	6.7	7.4	NA	NA	NA	NA	NA	NA	10	NA	NA
NY0084859	Hauppauge Record MFG Ltd, Hauppauge, NY 11787	10	10	NA	NA	6.7	6.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075744	Hazeltine Research Lab, Greenlawn, NY 11740	ERR	ERR	NA	NA	7.6	7.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0091090	Holbrook S982, Hauppauge, NY 11788	120000	760000	NA	ERR	7	7.4	NA	NA	ERR	ERR	NA	NA	45	NA	NA
NY0106470	Huntington (T) Incinerator, Huntington, NY 11743	ERR	ERR	NA	NA	6	c	NA	1900	ERR	NA	NA	3	15	200	NA
NY0081540	Janeco Industries Inc, Wyandanch, NY 11798	ERR	ERR	NA	NA	6.2	7.4	NA	2795	NA	NA	NA	5	24	NA	NA
NY0081540	Janeco Industries Inc, Wyandanch, NY 11798	ERR	ERR	NA	NA	6.2	7.4	NA	2795	NA	NA	NA	5	20	NA	NA
NY0075957	Kollmorgen Corp-Additive Prod., Aquebogue, NY 1193	1002723	1801007	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075957	Kollmorgen Corp-Additive Prod., Aquebogue, NY 1193	8407	18751	NA	NA	6.7	6.3	NA	NA	1	NA	NA	2	NA	NA	NA
NY1017042	Kortund Dynamics Corporation, Westbury, NY 11590	2600	2600	NA	NA	5.5	5.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	ERR	NA	NA	NA	6.1	6.1	NA	NA	ERR	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	ERR	NA	NA	NA	7	6.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	ERR	NA	NA	NA	7	6.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	ERR	NA	NA	NA	7	6.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075477	Lambda Electric Corp, Melville, NY 11746	216	216	NA	NA	6.6	7.3	NA	238	NA	NA	NA	NA	5	17	NA
NY0100731	Lewis Oil Company, Port Washington, NY 11050	ERR	ERR	NA	NA	6.3	6.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0100731	Lewis Oil Company, Port Washington, NY 11050	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

ERR - No Data Available
NA - Not Applicable

TABLE CONTINUED

PERMIT #	FACILITY NAME & ADDRESS	DISCHARGE RATE AVG, GPD	DISCHARGE RATE MAX, GPD	Color Pt-Co Ut	TEMP DEG, C	pH min su	pH max su	Spec.Cond u mhos/cm	TDS mg/l	TSS mg/l	Sttl Slds mg/l	Chloride mg/l	Fluoride mg/l	Nitrogen(Ti mg/l	Sulfate(Ti mg/l	Sulfide mg/l
NY0081558	Lincoln Graphic Arts Inc, Farmingdale, NY 11735	ERR	ERR	103	NA	5 1	6.5	NA	613.9	NA	NA	NA	NA	32 1	NA	NA
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	5000	9000	NA	NA	6.2	7	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	7900	7900	NA	NA	5.1	9 8	NA	372	NA	NA	104	NA	NA	58	NA
NY0140112	MCC Powers-Fiat Corp, Plainview, NY 11803	12	18	NA	NA	6 9	8	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0140112	MCC Powers-Fiat Corp, Plainview, NY 11803	7	15	NA	NA	7 1	8.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0079906	Norden Systems, Melville, NY 11747	3856	3850	NA	NA	7	7 8	NA	212	NA	NA	NA	3	4	49	NA
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	123	230000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	128	66207	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0199401	Numax Electronics, Hauppauge, NY11789	ERR	NA	NA	NA	7	6 9	NA	58	NA	NA	NA	0.5	0 4	NA	1
NY0101826	NY INST Of TECH. Plant, Old Westbury, NY 11568	10000	19000	NA	NA	6 5	6.8	NA	NA	15	NA	NA	NA	NA	NA	NA
NY0070106	Oak Tree Farm Dairy Inc, E Northport, NY 11731	80000	80000	NA	NA	7 3	7.7	NA	NA	190	0.2	NA	NA	NA	NA	NA
NY0108626	P C V Technology, Melville, NY 11747	6796710	16300	NA	NA	6 9	7 5	NA	615	NA	NA	NA	1	7	NA	NA
NY0107824	P R D Eletronics Inc, Syosset, NY 11791	ERR	ERR	NA	NA	6 6	6 9	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0065358	Parkland SD#14, Hauppage, NY 11788	350000	350000	NA	NA	6 5	7 1	NA	NA	NA	NA	NA	NA	21	NA	NA
NY0075663	Peerless Photo Products, Shoreham, NY 11786	36844	260000	NA	NA	7.1	8	NA	1088	24	NA	476	NA	22	463	NA
NY0085537	R F I Corp, Bayshore, NY 11706	380	400	NA	NA	7	7	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0078221	R S M Electron Power Inc, Deer Park, NY 11729	ERR	NA	NA	NA	NA	NA	NA	157	NA	NA	NA	NA	3	NA	NA
NY0078221	R S M Electron Power Inc, Deer Park, NY 11729	2819	2925	NA	NA	6 7	7 7	NA	NA	NA	NA	NA	1	NA	NA	NA
NY0108154	R A I Research Corp, Hauppauge, NY 11787	3429	7000	NA	NA	7.8	7.8	NA	2108	NA	NA	NA	NA	NA	NA	NA
NY0108006	Regency Creations Inc, Greenvale, NY 11548	1000	1000	NA	NA	7.2	7.5	NA	452	NA	NA	NA	NA	26	NA	NA
NY0199095	RHG Electonics Laboratory, Deer Park, NY 11729	ERR	ERR	NA	NA	6.3	6 3	NA	NA	NA	NA	NA	NA	0.5	NA	NA
NY0109398	Royal Petroleum Corp, New Hyde Park, NY 11040	ERR	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0104388	Ruco Polymer Corpration, Hicksville, NY 11802	10522	10680	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5	NA
NY0079324	Selden SD#11, Hauppauge, NY 11788	1490000	1600000	NA	19	6 7	7.6	NA	NA	NA	NA	NA	NA	33	NA	NA
NY0081655	Seven-Upbrooklyn BTLG Co Inc, Melville, NY 11747	1235	7000	NA	NA	6.1	6 7	NA	705	89	NA	32	NA	NA	5	NA
NY0106241	Slater Electric Inc, Glen Cove, NY 11542	300000	300000	NA	17	6.9	6 9	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109673	Spectragraphic Inc, Commack, NY 11725	ERR	NA	NA	NA	7	7	NA	200 8	NA	NA	NA	NA	4 1	NA	NA
NY0109673	Spectragraphic Inc, Commack, NY 11725	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	11624	26030	NA	NA	3 9	10	NA	3934	NA	NA	NA	75	87	875	NA
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	14161	27720	NA	NA	2 6	9.5	NA	4053	NA	NA	NA	71	62	1626	NA
NY0108359	Stepar Place, Huntington, NY 11746	64	87	NA	NA	6.1	7	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108359	Stepar Place, Huntington, NY 11746	3090	3500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0078247	Stony Brook SD#10, Hauppauge, NY 11789	480000	490000	NA	18	6 6	7.2	NA	NA	NA	NA	NA	NA	18	NA	NA
NY0079391	Strathmore Ridge SD#6, Hauppauge, NY 11786	80000	480000	NA	NA	6 9	7.2	NA	NA	NA	NA	NA	NA	17	NA	NA
NY0032646	Swezey Fuel Co., Inc, Patchogue, NY 11772	ERR	ERR	NA	NA	ERR	ERR	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107760	Tiffen MFG Corp, Hauppauge, NY 11787	ERR	ERR	NA	NA	4 3	4 3	NA	2206	247	NA	NA	NA	NA	NA	NA
NY0107646	Topo Metrics Inc, Central Islap, NY 11722	30	300	NA	NA	7.2	7.6	NA	111	NA	NA	NA	NA	4	NA	NA
NY0080683	Twelve Pines, Medford SD#7, Hauppauge, NY 11786	600000	600000	NA	19	6 9	7 7	NA	NA	NA	NA	NA	NA	8	NA	NA
NY0109258	United Parcel Service Pkg Dist, Uniondale, NY11553	ERR	ERR	NA	NA	6 9	6 0	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109258	United Parcel Service Pkg Dist, Uniondale, NY11553	ERR	ERR	NA	NA	6 5	6 7	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107174	US Components, Inc, Bohemia, NY 11716	ERR	ERR	NA	NA	6.5	7.4	NA	164	NA	NA	NA	1	NA	NA	NA
NY0085481	Wall-Mate Vinyls Inc, Coram, NY 11727	4557	7300	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0085481	Wall-Mate Vinyls Inc, Coram, NY 11727	101	160	NA	NA	6 9	7 7	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0076988	Woodside, Medford, SD#7, Hauppauge, NY 11788	231000	250000	NA	17	7 1	7 5	NA	NA	NA	NA	NA	NA	20	NA	NA
NY0085693	Yapnani County Center STF, Hauppauge, NY 11788	60000	70000	NA	16	6.6	7 2	NA	NA	NA	NA	NA	NA	13	NA	NA

DISCHARGE RATE AVG, MGD	DISCHARGE RATE MAX, MGD	Color Pt-Co Ut	TEMP DEG, C	pH min su	pH max su	Spec Cond u mhos/cm	TDS kg/min	TSS kg/min	Sttl Slds ag/min	Chloride ag/min	Fluoride ag/min	Nitrogen(Ti ag/min	Sulfate(Ti ag/min	Sulfide ag/min
19.78	21.33						190 83	0.766	1 086	805.67	390 591	5878.779	2233 9743	NA

ERR - No Data Available
NA - Not Applicable

TABLE CONTINUED

PERMIT #	FACILITY NAME & ADDRESS	Sulfite mg/l	Arsenic mg/l	Aluminum mg/l	Barium mg/l	Cadmium mg/l	Cr(T) mg/l	Cr(H) mg/l	Copper mg/l	Cyanide mg/l	Gold mg/l	Iron mg/l	Lead mg/l	Manganese mg/l	Mercury mg/l	Nickel mg/l	Selenium mg/l	Silver mg/l
NY0088447	Allstate Regional HQ , Farmingdale, NY 11738	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108049	American Institute of Physics, New York, NY 10017	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.06
NY0081698	Arkay Packaging Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2 7	NA	NA	NA	NA	NA	0.02
NY0074764	Astro Electroplating Inc , Farmingdale, NY 11735	NA	NA	NA	NA	NA	0.21	0.07	1 61	NA	NA	NA	NA	NA	NA	0 26	NA	NA
NY0101834	CW Post College Wastewater Plt, Greenvale NY 11548	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106871	Call Data Long Island, Woodbury, NY 11797	NA	NA	NA	NA	NA	NA	0.01	NA	0 01	NA	0 15	NA	NA	NA	NA	NA	0 45
NY0074713	Carowell Condenser Corp, Lindenhurst, NY 11757	NA	NA	0.26	NA	0 01	0.01	0 01	0 09	0.01	NA	NA	NA	NA	NA	0 07	NA	0 01
NY0075591	Deutch Relays Inc, East Northport, NY 11731	NA	NA	NA	NA	NA	NA	NA	1 83	0 03	NA	NA	NA	NA	NA	20.11	NA	0.12
NY0108090	Dover Finding Inc, St James, NY 11780	NA	NA	NA	NA	NA	0 187	0.02	0.2	0.01	NA	0.5	0.04	NA	NA	0.2	NA	0.04
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	NA	NA	NA	NA	0 002	0.1	0.01	0 2	0.01	NA	0 1	0 03	NA	NA	0 3	NA	0.005
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0076155	Fairchild Weston Systems Inc, Syosset, NY 11791	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106038	Font Manufacturing, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	0 5	0 01	NA	NA	NA	NA	NA	NA	NA	0.003
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	0.2	0.01	1	0 01	NA	0.1	0 09	NA	NA	0.6	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	0.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.02
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	NA	ERR	NA	ERR	ERR	ERR	ERR	ERR	NA	ERR	ERR	NA	NA	ERR	NA	ERR
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	NA	ERR	NA	ERR	ERR	ERR	ERR	ERR	NA	ERR	ERR	NA	NA	ERR	NA	ERR
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	NA	ERR	NA	ERR	0.03	0.03	NA	0.03	NA	NA	NA	NA	NA	NA	NA	0.04
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	NA	ERR	NA	ERR	ERR	ERR	ERR	ERR	NA	ERR	ERR	NA	NA	ERR	NA	ERR
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	ERR	NA	ERR	NA	ERR	0 01	0 05	0 05	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109916	H C M Graphics Inc, Hauppauge, NY 11789	NA	0 01	NA	NA	0.01	0 2	0 01	NA	NA	NA	NA	NA	0.001	NA	NA	NA	0.02
NY0066028	Hauppauge Country Center S T P, Hauppauge, NY 1178	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0084859	Hauppauge Record MFG Ltd, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075744	Hazeltine Research Lab, Greenlawn, NY 11740	NA	NA	6	NA	NA	NA	NA	ERR	NA	NA	NA	NA	NA	NA	NA	NA	0.2
NY0091090	Holbrook SD#2, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106470	Huntington (T) Incinerator, Huntington, NY 11743	200	0.2	37	1	0.2	ERR	0 03	0 4	0 01	NA	4	2	4	0 01	0.1	0.01	0.01
NY0081540	Jaeco Industries Inc, Wyandanch, NY 11798	NA	NA	NA	NA	NA	0 3	0 03	0 2	0 04	NA	0.1	0 02	NA	NA	1	NA	NA
NY0081540	Jaeco Industries Inc, Wyandanch, NY 11798	NA	NA	NA	NA	NA	0.3	0 03	0 2	0.04	NA	0 1	0.02	NA	NA	1	NA	NA
NY0075957	Kollmorgen Corp-Additive Prod , Aquebogue, NY 1193	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075957	Kollmorgen Corp-Additive Prod , Aquebogue, NY 1193	NA	NA	NA	NA	NA	0.04	0.002	0.2	NA	NA	0 12	0.03	NA	NA	0 04	NA	NA
NY1017042	Korfund Dynamics Corporation, Westbury, NY 11590	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075477	Lamboa Electric Corp, Melville, NY 11746	NA	NA	NA	NA	NA	0 01	0 01	0 1	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0100731	Lewis Oil Company, Port Washington, NY 11050	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0100731	Lewis Oil Company, Port Washington, NY 11050	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

ERR- Data Not Available
NA - Not Applicable

TABLE CONTINUED

PERMIT #	FACILITY NAME & ADDRESS	Sulfite mg/l	Arsenic mg/l	Aluminum mg/l	Barium mg/l	Cadmium mg/l	Cr(T) mg/l	Cr(H) mg/l	Copper mg/l	Cyanide mg/l	Gold mg/l	Iron mg/l	Lead mg/l	Manganese mg/l	Mercury mg/l	Nickel mg/l	Selenium mg/l	Silver mg/l
NY0081558	Lincoln Graphic Arts Inc, Farmingdale, NY 11735	NA	NA	NA	NA	0.03	NA	NA	NA	NA	NA	6.2	NA	NA	NA	NA	NA	1
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0140112	MCC Powers-Flat Corp, Plainview, NY 11803	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0140112	MCC Powers-Flat Corp, Plainview, NY 11803	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075906	Norden Systems, Melville, NY 11747	NA	NA	0.1	NA	NA	NA	NA	1	NA	0.2	0.1	0.01	NA	NA	1	NA	0.005
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0199401	Numax Electronics, Hauppauge, NY11788	NA	NA	NA	NA	NA	NA	0.1	NA	0.1	NA	0.1	NA	NA	NA	NA	NA	0.03
NY0101826	NY INST Of TECH Plant, Old Westbury, NY 11568	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0070106	Oak Tree Farm Dairy Inc, E Northport, NY 11731	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108626	P C B Technology, Melville, NY 11747	NA	NA	0.2	NA	NA	0.01	0.01	0.4	NA	NA	0.4	0.01	0.1	NA	0.5	NA	NA
NY0107824	P P D Eletronics Inc, Syosset, NY 11791	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0065358	Parkland SD#14, Hauppage, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075663	Peerless Photo Products, Shoreham, NY 11786	NA	NA	NA	NA	0.03	NA	NA	0.1	0.1	NA	0.74	0.04	NA	NA	NA	NA	0.6
NY0085537	R F I Corp, Baysnore, NY 11706	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0078221	R S M Electron Power Inc, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0078221	P S M Electron Power Inc, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	0.1	NA	NA	NA	0.03	NA	NA	NA	NA	NA
NY0108154	R A I Research Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108006	Regency Creations Inc, Greenvale, NY 11548	NA	NA	NA	NA	NA	NA	NA	NA	0.1	0.3	ERR	0.1	NA	NA	NA	NA	0.1
NY0199095	RHG Electonics Laboratory, Deer Park, NY 11729	NA	NA	NA	NA	NA	0.2	0.005	0.1	NA	NA	NA	0.03	NA	NA	ERR	NA	NA
NY0109398	Royal Petroleum Corp, New Hyde Park, NY 11040	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0104386	Ruco Polymer Corpration, Hicksville, NY 11802	NA	NA	NA	NA	NA	NA	NA	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0079324	Selden SD#11, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0081655	Seven-Upbrooklyn BTLG Co Inc, Melville, NY 11747	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	11.2	NA	NA	NA	NA	NA	NA
NY0106241	Slater Electric Inc, Glen Cove, NY 11542	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.5	NA	NA	NA	NA	NA	NA
NY0109673	Spectragraphic Inc, Commack, NY 11725	NA	NA	NA	NA	NA	NA	NA	0.2	NA	NA	0.1	NA	NA	NA	NA	NA	0.2
NY0109673	Spectragraphic Inc, Commack, NY 11725	NA	NA	NA	NA	NA	NA	NA	NA	0.0005	NA	NA	NA	NA	NA	NA	NA	NA
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	0.8	1	NA	NA	NA	NA	NA	NA	NA	NA	0.3
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	0.4	1.5	NA	NA	NA	NA	NA	NA	NA	NA	0.2
NY0108359	Stepar Place, Huntington, NY 11746	NA	NA	NA	NA	NA	NA	NA	NA	0.05	0.1	NA	NA	NA	NA	3	NA	NA
NY0108359	Stepar Place, Huntington, NY 11746	NA	NA	NA	NA	NA	NA	NA	NA	0.2	0.7	NA	NA	NA	NA	1	NA	NA
NY0078247	Stony Brook SD#10, Hauppauge, NY 11789	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0079391	Strathmore Ridge SD#8, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0032646	Swezey Fuel Co., Inc, Patchogue, NY 11772	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107760	Tiffen MFG Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.55	0.01	NA	NA	NA	NA	NA
NY0107646	Topo Metrics Inc, Central Islap, NY 11722	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.03
NY0080683	Twelve Pines, Medford SD#7, Hauppauge, NY 11786	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109258	United Parcel Service PKG Dist, Uniondale, NY11553	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109258	United Parcel Service PKG Dist, Uniondale, NY11553	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107174	US Components, Inc, Bohemia, NY 11716	NA	NA	0.4	NA	0.35	0.04	0.01	0.2	0.04	NA	NA	NA	NA	NA	1	NA	1
NY0085481	Wall-Mate Vinyls Inc, Coram, NY 11727	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0085481	Wall-Mate Vinyls Inc, Coram, NY 11727	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0076988	Woodside, Medford, SD#7, Hauppauge, NY 11786	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0095693	Yaphank County Center STP, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Sulfite kg/min	Arsenic kg/min	Aluminum kg/min	Barium kg/min	Cadmium kg/min	Cr(T) kg/min	Cr(H) kg/min	Copper kg/min	Cyanide kg/min	Gold kg/min	Iron kg/min	Lead kg/min	Mn kg/min	Mercury kg/min	Nickel kg/min	Selenium kg/min	Silver kg/min
		NA	0.00009	59.5565	NA	0.04907	3.843	7.589	125.341	0.201	0.142	128.477	3.079	29.769	0.000009	150.965	NA	1.282

ERR - No Data Available
NA - Not Applicable

TABLE CONTINUED

PERMIT #	FACILITY NAME & ADDRESS	Tin ug/l	Zinc ug/l	Metals(T) ug/l	Benzene ug/l	Chloroform ug/l	Toluene ug/l	Methylene Chloride	M E K ug/l	TCE ug/l	TTCE ug/l	TCFM ug/l	1,1-DCA ug/l	1,1-DCE ug/l	1,1,1-TCA ug/l
NY0088447	Allstate Regional HQ , Farmingdale, NY 11735	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108049	American Institute of Physics, New York, NY 10017	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0081698	Arkay Packaging Corp, Hauppauge, NY 11787	NA	3.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0074764	Astro Electroplating Inc., Farmingdale, NY 11735	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0101834	CW Post College Wastewater Plt, Greenvale NY 11548	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0100871	Call Data Long Island, Woodbur,, NY 11797	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0074713	Cardwell Condenser Corp, Lindenhurst, NY 11757	NA	0.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075561	Deutch Relays Inc, East Northport, NY 11731	0.4	NA	NA	NA	NA	NA	ERR	NA	NA	NA	NA	NA	NA	ERR
NY0108090	Dover Finding Inc, St James, NY 11780	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	NA	0.03	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0076155	Fairchild Weston Systems Inc, Syosset, NY 11791	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106038	Font Manufacturing, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	0.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	ERR	NA	ERR	ERR	ERR	ERR	NA	ERR	ERR	ERR	ERR	ERR	ERR
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	ERR	NA	ERR	ERR	ERR	ERR	NA	ERR	ERR	ERR	ERR	ERR	ERR
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	ERR	NA	ERR	ERR	ERR	ERR	NA	ERR	ERR	ERR	ERR	ERR	ERR
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	0.003	0.001	NA	0.001	ERR	ERR	NA	ERR	NA	ERR
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	0.005	0.004	NA	0.003	ERR	ERR	NA	ERR	NA	ERR
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	0.005	0.001	NA	0.003	ERR	ERR	ERR	NA	ERR	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	0.004	0.1	NA	0.001	ERR	ERR	NA	NA	ERR	ERR
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	0.005	0.003	ERR	0.017	ERR	ERR	NA	NA	ERR	ERR
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	N
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	0.005	0.003	NA	0.001	0.002	0.004	NA	NA	0.002	0.004
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	0.001	0.004	NA	0.003	ERR	ERR	NA	NA	ERR	ERR
NY0109910	H C M Graphics Inc, Hauppauge, NY 11789	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0066028	Hauppauge Country Center S T P, Hauppauge, NY 1178	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0084855	Hauppauge Record MFG Ltd, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075744	Hazeltine Research Lab, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	0.001	NA	NA	NA	NA	NA	NA	NA
NY0091090	Holbrook SD#2, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106470	Huntington (T) Incinerator, Huntington, NY 11743	NA	7	6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0081540	Jameco Industries Inc, Wyandanch, NY 11798	NA	0.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0081540	Jameco Industries Inc, Wyandanch, NY 11798	NA	0.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075957	Kollmorgen Corp-Additive Prod., Aquebogue, NY 1193	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075957	Kollmorgen Corp-Additive Prod , Aquebogue, NY 1193	0.12	NA	NA	NA	NA	NA	190	NA	NA	NA	NA	NA	0.03	1847.2
NY1017042	Kortund Dynamics Corporation, Westbury, NY 11590	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	0.0005	NA	0.0005	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	0.0005	NA	0.0005	NA	NA	NA	NA	NA	NA	NA	NA
NY0075477	Lambda Electric Corp, Melville, NY 11746	NA	NA	NA	NA	NA	0.001	0.0005	NA	NA	NA	NA	0.002	0.011	
NY0100731	Lewis Oil Company, Port Washington, NY 11050	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0100731	Lewis Oil Company, Port Washington, NY 11050	NA	NA	NA	0.002	ERR	0.003	NA	NA	NA	NA	NA	NA	NA	NA

ERR - No Data Available
NA - Not Applicable

TABLE CONTINUED

PERMIT #	FACILITY NAME & ADDRESS	Tin ug/l	Zinc ug/l	Metals(T) ug/l	Benzene ug/l	Chloroform ug/l	Toluene ug/l	Methylene Chloride	M E K ug/l	TCE ug/l	TTCE ug/l	TCFM ug/l	1,1-DCA ug/l	1,1-DCE ug/l	1,1,1-TCA ug/l
NY0081558	Lincoln Graphic Arts Inc, Farmingdale, NY 11735	NA	0.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0140112	MCC Powers-Fiat Corp, Plainview, Ny 11803	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0140112	MCC Powers-Fiat Corp, Plainview, Ny 11803	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075906	Norden Systems, Melville, NY 11747	0.2	0 04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0199401	Numax Electronics, Hauppauge, NY11789	NA	0.03	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0101826	NY INST Of TECH Plant, Old Westbury, NY 11568	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0070106	Oak Tree Farm Dairy Inc, E Northport, NY 11731	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108626	P C B Technology, Melville, NY 11747	0 2	0.0045	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107824	P R D Eletronics Inc, Sydsset, NY 11791	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0065358	Parkland SD#14, Hauppage, Ny 11786	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075663	Peerless Photo Products, Shoreham, NY 11786	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0085537	R F I Corp, Bayshore, NY 11706	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0078221	R S M Electron Power Inc, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0078221	R S M Electron Power Inc, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108154	R A I Research Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	0 4	0 05	NA	NA	NA	NA	NA	NA	NA
NY0108066	Regency Creations Inc, Greenvale, NY 11548	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0199095	RHG Electonics Laboratory, Deer Park, NY 11729	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109398	Royal Petroleum Corp, New Hyde Park, NY 11040	NA	NA	NA	0 3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0104388	Ruco Polymer Corpration, Hicksville, NY 11802	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0079324	Selden SD#11, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0081655	Seven-Upbrooklyn BTLG Co Inc, Melville, NY 11747	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106241	Slater Electric Inc, Glen Cove, NY 11542	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109073	Spectragraphic Inc, Commack, NY 11725	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109673	Spectragraphic Inc, Commack, NY 11725	NA	0 04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108359	Stepar Place, Huntington, NY 11746	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108359	Stepar Place, Huntington, NY 11746	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0078247	Stony Brook SD#10, Hauppauge, NY 11789	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0079391	Strathmore Ridge SD#6, Hauppauge, NY 11786	NA	NA	NA	NA	12	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0032646	Swezey Fuel Co., Inc, Patchogue, NY 11772	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107769	Tiffen MFG Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107646	Topo Metrics Inc, Central Islap, NY 11722	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0080683	Twelve Pines, Medford SD#7, Hauppauge, NY 11786	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109258	United Parcel Service PKG Dist, Uniondale, NY11553	NA	NA	NA	0.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109258	United Parcel Service PKG Dist, Uniondale, NY11553	NA	NA	NA	0 5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107174	US Components, Inc, Bohemia, NY 11716	NA	0.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0085481	Wall-Mate Vinyls Inc, Coram, NY 11727	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0085481	Wall-Mate Vinyls Inc, Coram, NY 11727	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0076968	Woodside, Medford, SD#7, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0085693	Yaphank County Center STP, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Tin kg/min	Zinc kg/min	Metals(T) kg/min	Benzene kg/min	Chloroform kg/min	Toluene kg/min	Methylene Chloride, kg/l	M E K kg/min	TCE kg/min	TTCE kg/min	TCFM kg/min	1,1-DCA kg/min	1,1-DCE kg/min	1,1,1-TCA kg/min
		59 669	2.45	NA	NA	41.645	0.121	69 97E	NA	NA	NA	NA	NA	0.0121	680.188

ERR - No Data Available
NA - Not Applicable

TABLE CONTINUED

PERMIT #	FACILITY NAME & ADDRESS	1,2-Trans DCE, ug/l	Vinyl Chl. ug/l	Xylene ug/l	Haloo.Org ug/l	Furq.Halc carb, ug/l	Benzlocacids (T), ug/l	PAA acid ug/l	Guatensin ug/l	Niacinamide ug/l	Theophylline ug/l	Paraben(M&P) ug/l	Surfactant ug/l	T O C ug/l	Chlorine(T) ug/l
NY0088447	Allstate Regional HQ , Farmingdale, NY 11735	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ERR
NY0108049	American Institute of Physics, New York, NY 10017	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0081698	Arkay Packaging Corp. Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0074764	Astro Electroplating Inc., Farmingdale, NY 11735	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0101834	C W Post College Wastewater Plt, Greenvale NY 11548	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.6
NY0100871	Call Data Long Island, Woodbury, NY 11797	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	62	NA
NY0074713	Carowell Condenser Corp, Lindenhurst, NY 11757	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.05	NA	NA
NY0075591	Deutch Relays Inc, East Northport, NY 11731	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108090	Dover Finding Inc, St James, NY 11780	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1	NA	NA
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4	NA	NA
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0076155	Fairchild Weston Systems Inc, Syosset, NY 11791	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106038	Font Manufacturing, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	NA	ERR	NA	ERR	NA	NA	NA	NA	NA	NA	ERR	ERR	ERR
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	NA	ERR	NA	ERR	NA	NA	NA	NA	NA	NA	ERR	ERR	ERR
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	NA	ERR	NA	ERR	NA	NA	NA	NA	NA	NA	ERR	ERR	ERR
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	0.001	0.001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	0.002	0.002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	0.002	0.002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	0.001	0.001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	0.001	0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	0.005	0.004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0096792	Grumman Aerospace Corp, Bethpage, NY 11714	NA	0.004	0.002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109916	H C M Graphics Inc, Hauppauge, NY 11789	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1	27.9	NA
NY0066028	Hauppauge Country Center S T P, Hauppauge, NY 1178	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.9
NY0084859	Hauppauge Record MFG Ltd, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075744	Hazeltine Research Lab, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0091090	Holbrook SD#2, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106470	Huntington (T) Incinerator, Huntington, NY 11743	NA	NA	NA	0.002	NA	NA	NA	NA	NA	NA	NA	0.1	34	NA
NY0081540	Jameco Industries Inc. Wyandanch, NY 11798	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4	NA	NA
NY0081540	Jameco Industries Inc, Wyandanch, NY 11798	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4	NA	NA
NY0075957	Kollmorgen Corp-Additive Prod , Aquebogue, NY 1193	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075957	Kollmorgen Corp-Additive Prod , Aquebogue, NY 1193	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY1017042	Kortund Dynamics Corporation, Westbury, NY 11590	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	0.0005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	0.0005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075477	Lambda Electric Corp. Melville, NY 11746	NA	NA	0.0005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0100731	Lewis Oil Company, Port Washington, NY 11050	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0100731	Lewis Oil Company, Port Washington, NY 11050	NA	NA	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

ERR - Data Not Available
NA - Not Applicable

TABLE CONTINUED

PERMIT #	FACILITY NAME & ADDRESS	1,2-Trans DCE, ug/l	Vinyl Chl ug/l	Xylene ug/l	Halog.Org Purg ug/l	Halo carb, ug/l	Benzolcacids (T), ug/l	PNA acid ug/l	Guaifensin ug/l	Niacinamide ug/l	Theophylline ug/l	Paraben(M&P) ug/l	Surfactant ug/l	T O C ug/l	Chlorine(T) ug/l
NY0081558	Lincoln Graphic Arts Inc, Farmingdale, NY 11735	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	NA	NA	NA	NA	NA	12	NA	19 313	2.15e	3.2e	0 15	NA	NA	NA
NY0140112	MCC Powers-Fiat Corp, Plainview, NY 11803	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0140112	MCC Powers-Fiat Corp, Plainview, NY 11803	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075906	Norden Systems, Melville, NY 11747	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1	NA	NA
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0199401	Numax Electronics, Hauppauge, NY11789	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01	68 4	NA
NY0101826	NY INST Of TECT Plant, Old Westbury, NY 11568	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
NY0070106	Oak Tree Farm Dairy Inc, E Northport, NY 11731	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106626	P C P Technology, Melville, NY 11747	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107824	P R D Eletronics Inc, Sydsset, NY 11791	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0065358	Parkland SD#14, Hauppage, NY 11786	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1 1
NY0075663	Peerless Photo Products, Shoreham, NY 11786	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0 6	NA	NA
NY0085537	R F I Corp, Bayshore, NY 11706	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0078221	R S M Electron Power Inc, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1	NA	NA
NY0078221	R S M Electron Power Inc, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108154	R & I Research Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	143 67	NA	NA	NA	NA	26.5	463 e	NA
NY0108006	Regency Creations Inc, Greenvale, NY 11548	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0 4	NA	NA
NY0109095	RHB Electonics Laboratory, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109398	Royal Petroleum Corp, New Hyde Park, NY 11040	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0104388	Ruco Polymer Corpration, Hicksville, NY 11802	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0079324	Selden SD#11, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1 6
NY0081655	Seven-Upbrooklyn BTLG Co Inc, Melville, NY 11747	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0106241	Slater Electric Inc, Glen Cove, NY 11542	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109673	Spectragraphic Inc, Commack, NY 11725	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109673	Spectragraphic Inc, Commack, NY 11725	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108359	Stepar Place, Huntington, NY 11746	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0108359	Stepar Place, Huntington, NY 11746	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0078247	Stony Brook SD#10, Hauppauge, NY 11789	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2
NY0079391	Strathmore Ridge SD#6, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
NY0032640	Swezey Fuel Co., Inc, Patchogue, NY 11772	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107760	Tilten MFG Corp, Hauppauge, NY 11767	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107646	Topo Metrics Inc, Central Islap, NY 11722	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	38	NA
NY0080683	Twelve Pines, Medford SD#7, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
NY0109258	United Parcel Service PKG Dist, Uniondale, NY11553	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0109258	United Parcel Service PKG Dist, Uniondale, NY11553	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0107174	US Coaponents, Inc, Boheaia, NY 11716	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0085481	Wall-Rate Vinyls Inc, Coram, NY 11727	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0085481	Wall-Rate Vinyls Inc, Coram, NY 11727	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NY0076988	Woodside, Medford, SD#7, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
NY0085693	raphank County Center STF, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.5

	1,2-Trans DCE, ag/min	Vinyl Chl ag/min	Xylene ag/min	Halog.Org Purg ag/min	Halo carb, ag/min(T)	Benzoicacids , ag/min	PNA acid ag/min	Guaifensin ag/min	Niacinamide ag/min	Theophylline ag/min	Paraben M&P ag/min	Surfactant ag/min	T O C ag/min	Chlorine(T) ag/min
	NA	NA 0 000004		NA	NA	4.15	21 578	o 68	6 74	1 138	0 05	9.687	141 88o	194 768

ERR - Data Not Available
NA - Not Applicable

TABLE CONTINUED

PERMIT #	FACILITY NAME & ADDRESS	Freon mg/l	O & G mg/l	Phenol mg/l	Coliform mg/l	BOD(C) mg/l	COD mg/l	OD(C) mg/l	CURRENT STATUS
NY0088447	Allstate Regional HQ , Farmingdale, NY 11735	NA	NA	NA	ERR	ERR	NA	NA	ACTIVE BUT MINOR FACILITY
NY0108049	American Institute of Physics, New York, NY 10017	NA	NA	0.002	77	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0081698	Array Packaging Corp, Hauppauge, NY 11787	NA	NA	0 055	NA	NA	3167	NA	ACTIVE BUT MINOR FACILITY
NY0074764	Astro Electroplating Inc , Farmingdale, NY 11735	NA	NA	Nm	Nm	NA	NA	Nm	ACTIVE BUT MINOR FACILITY
NY0101834	C W Post College Wastewater Plt, Greenvale NY 11548	NA	NA	Nm	2o 7	3.4	NA	NA	ACTIVE BUT MINOR FACILITY
NY0100871	Call Data Long Island, Woodbury, NY 11797	NA	Nm	0 04	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0074713	Cardwell Condenser Corp, Lindenhurst, NY 11757	Nm	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075591	Deutch Relays Inc, East Northport, NY 11731	ERR	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0108040	Dover Finding Inc, St James, NY 11780	NA	NA	Nm	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	NA	NA	0.001	NA	NA	30	NA	ACTIVE BUT MINOR FACILITY
NY0075582	Eaton Corporation A I L Div, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0076155	Fairchild Weston Systems Inc, Syosset, NY 11791	NA	NA	NA	Nm	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0106038	Font Manufacturing, Hauppauge, NY 11788	NA	NA	0 001	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	Nm	Nm	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	0 00o	NA	NA	Nm	NA	ACTIVE BUT MINOR FACILITY
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ACTIVE BUT MINOR FACILITY
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ACTIVE BUT MINOR FACILITY
NY0075752	Government Products Div, Greenlawn, NY 11740	NA	NA	0.005	Nm	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075752	Government Products Div, Greenlawn, NY 11740	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	0 001	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	0 005	NA	ERR	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	Nm	0 001	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	0.009	NA	0 001	NA	NA	Nm	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	0.006	NA	0 00[illegible]	NA	NA	Nm	Nm	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	Nm	Nm	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	0.0025	NA	0 001	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	Nm	Nm	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	0 004	NA	0 003	NA	NA	Nm	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0096792	Grumman Aerospace Corp, Bethpage, NY 117114	0.016	NA	0.002	NA	NA	Nm	NA	ACTIVE BUT MINOR FACILITY
NY0109916	H C M Graphics Inc, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0066028	Hauppauge Country Center S T P, Hauppauge, NY 1178	NA	NA	NA	5 4	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0084859	Hauppauge Record MFG Ltd, Hauppauge, NY 11787	NA	0.08	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075744	Hazeltine Research Lab, Greenlawn, NY 11740	NA	NA	0.007	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0091090	Holbrook SD#2, Hauppauge, NY 11788	NA	NA	NA	NA	ERR	NA	ERR	ACTIVE BUT MINOR FACILITY
NY0106470	Huntington (T) Incinerator, Huntington, NY 11743	NA	NA	0 3	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0081540	Jaeco Industries Inc, Wyandanch, NY 11798	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0081540	Jaeco Industries Inc, Wyandanch, NY 11798	NA	NA	NA	NA	NA	89	NA	ACTIVE BUT MINOR FACILITY
NY0075957	Kollmorgen Corp-Additive Prod., Aquebogue, NY 1193	NA	NA	NA	NA	Nm	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075957	Kollmorgen Corp-Additive Prod., Aquebogue, NY 1193	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY1017042	Kortfund Dynamics Corporation, Westbury, NY 11590	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	1.88	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	Nm	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075892	Koster Keunen Inc, Sayville, NY 11782	NA	NA	NA	NA	NA	Nm	NA	ACTIVE BUT MINOR FACILITY
NY0075477	Lambda Electric Corp, Melville, NY 11748	NA	NA	0 042	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0100731	Lewis Oil Company, Port Washington, NY 11050	NA	3	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0100731	Lewis Oil Company, Port Washington, NY 11050	NA	NA	Nm	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY

ERR - Data Not Available
NA - Not Applicable

TABLE CONTINUED

PERMIT #	FACILITY NAME & ADDRESS	Freon mg/l	O & G mg/l	Phenol mg/l	Coliform mg/l	BOD(C) mg/l	COD mg/l	OD(C) mg/l	CURRENT STATUS
NY0081556	Lincoln Graphic Arts Inc, Farmingdale, NY 11735	NA	NA	0.131	NA	NA	807 7	NA	ACTIVE BUT MINOR FACILITY
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	NA	2	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0109550	Luitpold Pharmaceuticals, Shirley, Ny11967	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0140112	MCC Powers-Fiat Corp, Plainview, NY 11803	NA	7	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0140112	MCC Powers-Fiat Corp, Plainview, NY 11803	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075905	Norden Systems, Melville, NY 11747	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	NA	4	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0032760	North Ville Industries Corp, Riverhead, NY 11901	NA	4	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0199401	Numax Electronics, Hauppauge, NY11789	NA	NA	0 001	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0101826	NY INST Of TECT Plant, Old Westbury, NY 11568	NA	NA	NA	16	5	NA	NA	ACTIVE BUT MINOR FACILITY
NY0070106	Oak Tree Farm Dairy Inc, E Northport, NY 11731	NA	NA	NA	NA	98	NA	NA	ACTIVE BUT MINOR FACILITY
NY0108626	P C I Technology, Melville, NY 11747	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0107824	P R D Eletronics Inc, Syosset, NY 11791	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0065358	Parkland SD#14, Hauppage, NY 11788	NA	NA	NA	4	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075663	Peerless Photo Products, Shoreham, NY 11786	NA	NA	0 002	NA	NA	45	NA	ACTIVE BUT MINOR FACILITY
NY0085537	R F I Corp, Bayshore, NY 11706	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0078221	P S M Electron Power Inc, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0078221	P S M Electron Power Inc, Deer Park, NY 11729	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0108154	R & I Research Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0108005	Regency Creations Inc, Greenvale, NY 11548	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0199695	RHG Electonics Laboratory, Deer Park, NY 11729	NA	NA	0.005	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0109398	Royal Petroleum Corp, New Hyde Park, NY 11040	NA	5	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0104388	Ruco Polymer Corpration, Hicksville, NY 11802	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0079324	Selden SD#11, Hauppauge, NY 11788	NA	NA	NA	165	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0081655	Seven-Upbrooklyn BTLG Co Inc, Melville, NY 11747	NA	NA	NA	NA	1553	NA	NA	ACTIVE BUT MINOR FACILITY
NY0106241	Slater Electric Inc, Glen Cove, NY 11542	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0109673	Spectragraphic Inc, Commack, NY 11725	NA	NA	0.01	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0109673	Spectragraphic Inc, Commack, NY 11725	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	NA	NA	0.35	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0075833	Standard Microsystems Corp, Hauppauge, NY 11787	NA	NA	0 1	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0108359	Stepar Place, Huntington, NY 11746	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0108359	Stepar Place, Huntington, NY 11746	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0078247	Stony Brook SD#10, Hauppauge, NY 11789	NA	NA	NA	35	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0079351	Strathmore Ridge SD#8, Hauppauge, NY 11788	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0032646	Swezey Fuel Co , Inc. Patchogue, NY 11772	NA	0.03	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0107760	Tiffen MFG Corp, Hauppauge, NY 11787	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0107646	Topo Metrics Inc, Central Islap, NY 11722	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0080683	Twelve Pines, Medford SD#7, Hauppauge, NY 11788	NA	NA	NA	42	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0109258	United Parcel Service PAG Dist, Uniondale, NY11553	NA	6	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0109258	United Parcel Service PAG Dist, Uniondale, NY11553	NA	36	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0107174	US Components, Inc, Bohemia, NY 11716	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0085481	Wall-Mate Vinyls Inc, Coram, NY 11727	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0085481	Wall-Mate Vinyls Inc, Coram, NY 11727	NA	NA	NA	NA	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0078985	Woodside, Medford, SD#7, Hauppauge, NY 11786	NA	NA	NA	7	NA	NA	NA	ACTIVE BUT MINOR FACILITY
NY0085693	Yaphank County Center STF, Hauppauge, NY 11788	NA	NA	NA	4	NA	NA	NA	ACTIVE BUT MINOR FACILITY

Freon mg/min	O & G mg/min	Phenol mg/min	Coliform mg/min	BOD(C) mg/min	COD mg/min	OD(C) mg/min	CURRENT STATUS
NA	0.486	0.343	13015 16	447 536	1164.73	NA	

ERR - Data Not Available
NA - Not Applicable

Section 6.2.12

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Assessment of Lehigh Portland Cement Co. From State of Maryland Class V Injection Well Inventory and Assessment
AUTHOR: **(or INVESTIGATOR)**	(Not Available)
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Lehigh Portland Cement Co. Woodsboro, Maryland USEPA Region III
NATURE OF BUSINESS:	Mining and Crushing for Cement Aggregate
BRIEF SUMMARY/NOTES:	Disposal well receives storm water runoff and wash water that is used to rinse rock crushing dust from the outside of trucks.

UIC Facility Identification Number	MDS0215W0010
Well Type	5W20 Industrial Process and Waste Disposal Well
Permit Information	State Discharge Permit 85-DP-0457
Owner & Location	Lehigh Portland Cement Company 10642 Woodsboro Road, Route 550 Woodsboro
County	Fredrick
Nature of Facility	Mining and crushing for cement aggregate.
Contact	Randy Boone, Office Supervisor
Date Visited	May 16, 1986
Number of Wells	1
Construction Features	Unknown, blue prints of dry well not located
Source of Injected Fluid	Truck washwater and parking lot runoff water
Volume of Injected Fluid	Approximately 110 gpd of truck washwater
Operational Status	Active
Date of Construction	Unknown
Monitoring Wells	
Number of Wells	2
Installation Date	Nov 1986
Construction Features	2 inch diameter, PVC casing 10 foot screens, gravel pack Bentonite Seal Bentonite clay and Cement Grout
Drilling Method	Mud Rotary
Date Sampled	---

(2)

Facility Discription

The Lehigh Portland Cement facility is located along Route 550 as shown in Figure 9. The facility is á quarry and crushing operation that produces a lightweight aggregate for cement. The Class V disposal well receives parking lot/loading area stormwater runoff and truck washwater.

Contamination Potential

The wastewater which is disposed of via the Class V well is stormwater runoff and washwater that is used to rinse rock crushing dust from the outside of trucks. Properly used, the potential for groundwater contamination is low.

XII(3)

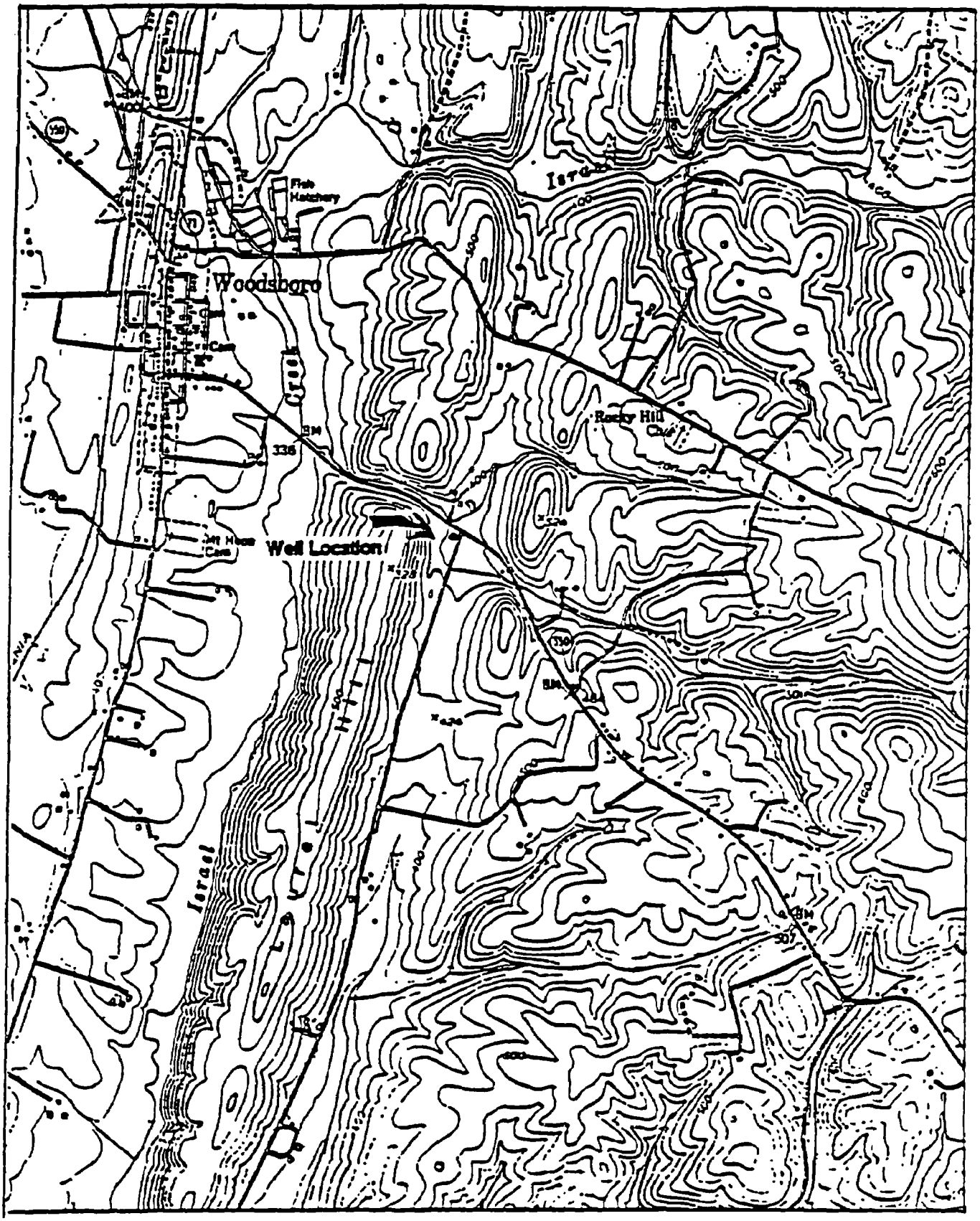


FIGURE 9 LOCATION OF LEHIGH PORTLAND CEMENT

SCALE 1:24000

1 0 1 MILE

Section 6.2.13

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Assessment of Applied Electro-Mechanics, Inc. From State of Maryland Class V Injection Well Inventory and Assessment
AUTHOR: **(or INVESTIGATOR)**	(Not Available)
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Applied Electro-Mechanics, Inc. Point of Rocks, Maryland USEPA Region III
NATURE OF BUSINESS:	Manufacturer of Public Address Systems
BRIEF SUMMARY/NOTES:	Well used for disposal of rinse water from the metal irridite and annodizing process. Drainfield used for disposal of rinsewater from the printed circuit and photo-graphic processes.

UIC Facility Identification Number	MDS0215W0009
Well Type	5W20 Industrial Process Water and Waste Disposal Well
Permit Information	State Discharge Permit 83-DP-2066
Owner & Location	Applied Electro-Mechanics, Incorporated Route 28 & Rock Hall Road Point of Rocks
County	Fredrick
Nature of Facility	Manufacture of public address systems
Contact	Charles Cook, Plant Production Consultant
Date Visited	May 19, 1986
Number of Wells	1
Construction Features	Unknown, dimensions of drywell not on blueprints
Source of Injected Fluid	Rinsewater from metal iridite and annodizing process
Volume of Injected Fluid	180 gpd
Operation Status	Active
Date of Construction	Unknown
Monitoring Wells	
Number of Wells	3
Installation Date	June, 1986
Construction Features	4 inch diameter, PVC casing 10 foot screens, gravel packed Bentonite seal Bentonite-cement grout
Drilling Method	Solid Stem Auger
Date Sampled	August 5, 1986

11(2)

Facility Description

Applied Electro Mechanics (AEM) manufactures public address systems. The facility is located near Point of Rocks as shown in Figure 10. The manufacturing process includes design, printed circuit board production. machining of metals and plastic, metal finishing and final assembly. AEM operates two small metal finishing lines in an auxilary building behind the main plant. All of the base metal used here is aluminum. The first line, aluminum coating, consists of an etch bath (caustic), spray rinse, oxidizer (acid), spray rinse and irridite bath (chromate). The second line, anodizing, consists of a sulphuric acid dip, immersion rinse, spray rise, brown olive drab dye dip, immersion rinse, black dye dip, fixer bath, and hot water dip. The lines are only used intermittently. The Class V well is used for disposal of rinse water from the metal irridite and anodizing processes. There is also a drainfield in the northwest corner of the property that is used for disposal of rinsewater from the printed circuit and photographic processes.

Contamination Potential

Properly used, the potential for contamination is low. However, the first set of samples showed an elevated level of copper, indicating possible missue of the disposal systems. This facility will continue to be monitored.

XIII (3)

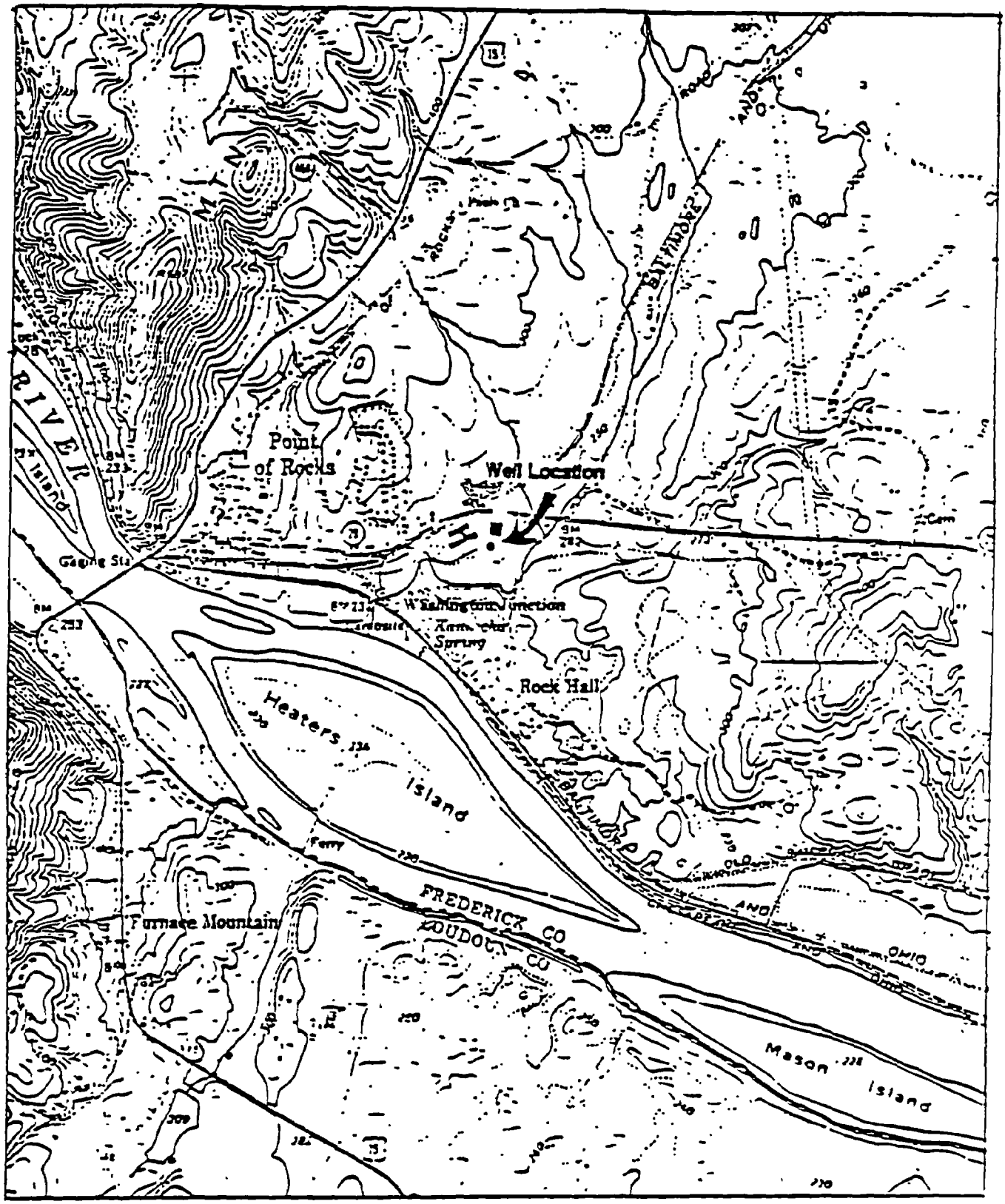


FIGURE 10 LOCATION OF APPLIED ELECTRO MECHANICS, INCORPORATED

SCALE 1:24000

Section 6.2.14

TITLE OF STUDY: (or **SOURCE OF INFORMATION**)	Assessment of Hammermill Paper Co. From Underground Injection Control Program Class V Well Assessment
AUTHOR: (or **INVESTIGATOR**)	USEPA Region III
DATE:	January, 1987
FACILITY NAME AND LOCATION:	Hammermill Paper Co. Erie, Pennsylvania USEPA Region III
NATURE OF BUSINESS:	Pulp and Paper Mill
BRIEF SUMMARY/NOTES:	During seven and one half years of operation, over one billion gallons of waste pulping liquors were injected. Wells were plugged when a new process for making paper was developed.

HAMMERMILL PAPER COMPANY

Hammermill Paper Company operates a pulp and paper mill at Erie, Pennsylvania which produces bleached hardwood pulp and fine grade writing and printing paper. Waste disposal had been a problem for this company because of no proven process that could economically treat spent pulping liquor. The State Sanitary Water Board ordered this company to abate discharge of its pulping wastes into Lake Erie by the end of 1965.

Dow Industrial Services, a division of The Dow Chemical Company, contacted Hammermill and was authorized to conduct a study on deep well disposal. A test well was drilled to determine the characteristics of the subsurface strata and the possibility of using injection wells as a possible solution to the waste problem. Drilling began in January 1963, and was completed in March to a depth of 2,302 feet. Preliminary studies indicated that three limestone formations might be suitable for injection zones: the Bass Island at 1,600 feet below the surface, the Lockport at 2,100 feet, and the Gatesburg at 5,000 feet.

Further tests were conducted including well logging, acidizing, and water injection. The Lockport was found to be unsuitable and the well was plugged between this formation and the Bass Island. Injection tests demonstrated that the Bass Island limestone was the most suitable because it lies between impermeable strata and would accept fluids at an acceptable rate. The well was completed to be used for waste disposal and an application was made to the Pennsylvania Sanitary Water Board.

The State issued a permit for Hammermill to dispose of pulping liquors by underground injection on August 14, 1963. Before any of this waste could be injected, the particulate that would plug the formation pores had to be removed by surface treatment. Studies were conducted by Hammermill and Dow Industrial Service to find the best means of preparing the spent pulping liquor for injection.

Surface treatment operations were begun, the well was equipped with injection pumps, and the injection of wastes began on April 24, 1964. Injection pressures were maintained at 1,220 psig at 194 gpm and 1,330 psig at 388 gpm with only minor fluctuations. After the apparent success of Well No. 1, drilling was begun on the No. 2 well in July 1964.

Well No. 2 was drilled to a depth of 5,972 feet where the Gatesburg Limestone Formation was encountered. Injection tests determined it to be unsuitable for disposal, but a Precambrian metamorphic schist was found just below which readily accepted fluids. The well was completed in the Bass Island and down to the Precambrian schist with a capacity approximately double that of Well No. 1. A permit was applied for and was granted on July 30, 1965.

During this time Hammermill considered deep well injection the best solution to the spent pulping liquor problem. The company did not consider it to be the ultimate method because of the great amount of unrecoverable waste products. Research was being done for a process that would economically recover some of the chemicals that were being thrown away.

On April 14, 1968, Well No. 1 failed. The injection casing ruptured at approximately the 880 foot depth; and the back pressure forced the string of casing 30 feet into the air. Waste fluids flowed back out of the formation, up the well, and onto the surface at a rate of 200 gpm. It was two days until the well could be sealed. The system was repaired and on May 17, 1968 an application was made for Well No. 1 to return to service.

Well No. 3 was drilled 625 feet west of Well No. 2 to provide additional facilities for disposing of waste fluids. In May 1968, an application was made for deep well disposal. On September 9, 1968, Well No. 3 was placed into service and injection began into the Bass Island at 1,620 feet. The total pumping capacity for the three wells was 1,219 gpm which was more than sufficient to handle all pulping liquor wastes.

By June 1971, Hammermill had perfected a new process for making paper from hardwood pulp. After October their patented "Neutracel II" process was in full operation and the waste disposal wells were no longer used. The State required Hammermill to hire a consultant and have its three wells plugged in an approved manner. Plugging was completed on September 12, 1972. During the seven and one half years of operation over one billion gallons of waste pulping liquors were injected into the Bass Island Formation.

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HAMMERMILL PAPER COMPANY - DEEP WELL INJECTION

(Summary of Significant Dates)

DATE	ACTION
January, 1963	Well #1 drilled to Bass Island Limestone Formation (1,620' - 1,670')
March, 1963	Well #1 was tested for suitability for injections by the Dow Industrial Service. Bass Island Formation was found suitable.
August 14, 1963	Permit was issued for deep well disposal of pulping liquors. Injected waste from Pulp Mill, Neutracel I process.
April 24, 1964	Injection of pulping liquor began into Well #1.
July 26, 1964	Drilling began on Well #2.
June 17, 1965	Application for Well #2 was made. Bass Island Limestone Formation at 1,620' to 1,710'.
July 30, 1965	Permit for Well #2 was granted by the Sanitary Water Board.
September 5, 1965	Well #2 was placed into operation.
(After) January, 1966	All hardwood was used for pulp production by their patented NEUTRACEL I process.

April 14, 1968	Well #1 failed.
May 17, 1968	Application for Well #1 to return to service.
May 24, 1968	Application was made for Well #3.
September 9, 1968	Well #3 placed in service. Bass Island Limestone Formation at 1,620' to 1,720'.
June, 1971	The Neutracel II process was being placed in operation to replace the Neutracel I process.
(By) October, 1971	Neutracel II is in full operation and Neutracel I has been phased out. Deep well injection was no longer used.
September 6, 1972	Wells No. 1, 2, and 3 are plugged.

Section 6.2.15

TITLE OF STUDY: (or **SOURCE OF INFORMATION**)	Assessment of Rodale (Square D) From Underground Injection Control Program Class V Well Assessment
AUTHOR: (or **INVESTIGATOR**)	USEPA Region III
DATE:	January, 1987
FACILITY NAME AND LOCATION:	Rodale Manufacturing Company Plant (Square D) Emmaus Burrough, Pennsylvania USEPA Region III
NATURE OF BUSINESS:	Electric Products Manufacturing Plant
BRIEF SUMMARY/NOTES:	Approximately 3,000 gallons per day of electroplating waste containing up to 118.4 ppm cyanide were illegally dumped into 3 injection wells. Area wells (serving 10,000 people) have been sampled and no contamination found.

RODALE (SQUARE D)

Rodale Manufacturing Company Plant is located in Emmaus Borough, Lehigh County.

The geology of the area consists of the Hardystown formation (quartzite) and the Tomstown formation (limestone). Ground-water movement is from the north and northeast, from the Hardystown formation and an underlying gneiss to the Tomstown formation.

From the time period of 1961 to 1965, approximately 3000 gallons per day of electroplating waste containing up to 118.4 ppm cyanide were illegally dumped into three injection wells on the premises of Rodale Manufacturing Company.

The Rodale firm and borough officials were first notified of the illegal dumping in 1961. A letter from the Department of Health was sent, stating the disposal was in violation of The Clean Streams Law and must be abated or the waste treated.

Sometime after 1965, the company began treating the waste and discharging it into the public sanitary sewer. At that time, borough officials were told the dumping could have contaminated the borough's seven water supply wells, the closest one being located about four blocks from the Rodale injection wells. The disposal wells were last used in the early 1970's.

In 1975 the Square D. Co. purchased the electrical products manufacturing plant. At that time a private drilling contractor was hired to make test bores near the injection well to determine the extent of the underground contamination. Two of the wells were sampled and the sludge was removed.

Concern continued to exist over the long term threat posed by this large volume of to the seven public water supply wells serving approximately 10,000 people. By December 1981, the remaining well had been pumped out. DER is presently attempting to locate an environmentally suitable disposal site for the 2000 gallons of this waste recovered. Area wells have been sampled and no contamination found.

Section 6.2.16

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Assessment of National Wood Preservers, Inc. From Underground Injection Control Program Class V Well Assessment
AUTHOR: **(or INVESTIGATOR)**	USEPA Region III
DATE:	January, 1987
FACILITY NAME AND LOCATION:	National Wood Preservers, Inc. Haverford Township, Pennsylvania USEPA Region III
NATURE OF BUSINESS:	Wood Treatment and Preservation
BRIEF SUMMARY/NOTES:	Pentachlorophenol (PCP) and fuel oil were discharged into disposal well. Subsequently, PCP and fuel oil migrated to the top of the water table and flowed downgradient, killing or heavily depressing aquatic life for 5-1/2 miles downstream.

NATIONAL WOOD PRESERVERS

National Wood Preservers, Inc. (NWP) and their predecessors have facilities for the preservation and treatment of wood located adjacent to Naylor's Run at the intersection of Lawrence and West Eagle Roads in Haverford Township, Delaware county. The plant and storage area for wood are in an abandoned borrow pit at an elevation of approximately 310 feet above sea level on the Lansdowne 7-1/2 minute quadrangle.

Bedrock in the area consists of the Wissahickon Formation, primarily a hornblende gneiss and granite. Locally, a veneer of Bryn Mawr deposits are found at the site which are high level terrace deposits composed of sands and gravels in silt or clay. Local drainage is into Naylor's Run and ground water in the area of the facility is at the depth of 15 to 20 feet.

In the past, the facility collected stormwater/wastewater and discharged it into a disposal well. This well, approximately 42 feet deep, was located where a Shell station is now located, a corner of the property in what appears to be the lowest elevation.

Clifford and Virginia Rogers have owned the property since 1947. In 1947, they leased it to Samuel T. Jacoby and C. David Jacobs, who then assigned the lease to National Wood Preservers. This company conducted their wood preservation business on the parcel between 1947 and 1963. During this period, the company used the chemical pentachlorophenol (PCP). PCP is a fungicide, herbicide and a wood preservative. It is a highly toxic chemical and in certain concentrations is lethal to aquatic life. The PCP, along with fuel oil, was subsequently discharged into the disposal well which drained into the ground water beneath the premises. In 1963 Jacoby sold NWP to the Goldsteins, who have continued to operate NWP on the property. Discharge to the disposal well was stopped at that time and a Shell Service Station was constructed over the site.

Unfortunately, by this time the fuel oil and PCP had migrated to the top of the water table and flowed down-gradient under Eagle Road and the property of Philadelphia Chewing Gum Company (PCG). Here the PCP/oil was intercepted by a storm sewer which discharged into Naylor's Run on property owned by Haverford Township. Aquatic life was destroyed in the vicinity of the discharge and heavily depressed for 5-1/2 miles downstream. It is

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estimated that approximately 80,000 gallons of PCP-laden fuel oil is still in the ground water.

In June of 1972, in response to numerous complaints, the Department of Environmental Resources (DER) initiated its investigation of an oily substance found in Naylor's Run. The investigation eventually established that PCP mixed with fuel oil was found in ground water on the properties owned or occupied by Rogers, NWP, Shell and PCG. DER drilled several shallow wells into the area and found up to 3-1/2 feet of oil/PCP. None of these wells drilled by DER now exist.

Such contamination constituted pollution within the meaning of the Clean Streams Law. On July 12, 1973, DER issued administrative orders to NWP, PCG, Shell and the Rogers, requiring them to take action to correct the pollution condition on its premises. The orders required the defendants to determine the extent of pollution and develop a ground-water renovation plan. All four parties filed appeals of the order with the Environmental Hearing Board (EHB), the quasi-judicial body which adjudicates apeals from DER actions.

In 1976, DER notified the Environmental Protection Agency (EPA) of the situation and a response team was sent to the site. EPA removed a portion of the PCP/oil mixture by means of four large diameter recovery wells and sand-activated carbon filters in Naylor's Run. EPA determined that this was a satisfactory method for short-term handling of the pollution problem.

In July of 1976, the EHB sustained in part and modified DER's orders against NWP, PCG, Shell, and the Rogers. The EHB adjudication was appealed to Commonwealth Court where it was affirmed in 1978. The Pennsylvania Supreme Court granted a petition for allowance of appeal of the Commonwealth Court's decision and affirmed the decision in 1980. The Supreme Court of the United States refused to grant certiorari in the matter.

As of December 1981, there was still a significant amount of oil/PCP on Naylor's Run in the area below Eagle Road. It appears that there is a continuing discharge of oil/PCP from the stormwater pipe which intersects the water table.

EPA, NWP and Rodgers obtained consultants in 1981 to drill test wells in the area with the intent of determining the extent of ground-water pollution and providing an effective recovery program. EPA maintains filter fences of absorbent material in Naylor's Run to protect downstream water quality.

As of December 1981, seventeen observation wells have been drilled over the dispersion plume. A report on the study findings is anticipated in January 1982 which will be implemented to recover PCP and oil from ground-water.

Section 6.2.17

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Assessment of Highway Auto Service From Underground Injection Control Program Class V Well Assessment
AUTHOR: **(or INVESTIGATOR)**	USEPA Region III
DATE:	January, 1987
FACILITY NAME AND LOCATION:	Highway Auto Service Station Butler Mine Tunnel Pittstown Township, Pennsylvania USEPA Region III
NATURE OF BUSINESS:	Auto service station
BRIEF SUMMARY/NOTES:	Petrochemicals, cyanides, 2,2 dichlorobenzene, and a host of other known and unknown carcinogenic, teratogenic, mutagenic, and toxic chemicals were present in discharge from a mine tunnel to the Susquehanna River. Sampling analysis indicated pollution.

BUTLER MINE TUNNEL (Highway Auto Service)

Introduction

The Highway Auto Service Station is located on Route 315 just off Route 81 South, in Pittston Township, Luzerne County (Pittston 7½' quadrangle). Owned and operated by Elmo "Tony" Scatena, the business involved general auto repairs and service. It is at this site that one of Pennsylvania's worst pollution incidents involving underground injection occurred.

Geology

The station is located within the confines of the Lackawanna Syncline. The underlying geologic environment consists of the Llewellan Formation. This sequence consists of fine to coarsely grained sandstones, siltstones, and shales. Mineable anthracite coals occur throughout the formation. Directly below the service station are voids remaining after the Butler Mine was abandoned. Five coal seams were worked during the operation of the Butler Mine. The upper seams collapsed after their support "roof" pillars were mined-out. Remaining below the collapsed zone, is the lower, or fifth zone which is a void approximately 400' by 400'. This void drains directly to the Butler Mine tunnel. This tunnel is a mine underdrain which discharges directly to the north branch of the Susquehanna River.

Investigation

In July, 1979, DER staff were alerted to an oil discharge occurring at the Butler Mine tunnel portal on the Susquehanna River. Analysis revealed that petrochemicals, cyanides, 2,2 dichlorobenzene, and a host of other known and unknown carcinogenic, teratogenic, mutagenic and toxic chemicals were present in the discharge.

An investigation located a borehole on the Scatena property, previously used to discharge sewage. Samples taken from the well had a chemical profile which matched the mine tunnel's discharge (confirmed by gas chromatograph). Elmo "Tony" Scatena the Hudson Oil Refining Co., Ag-Met, Inc., and the Newtown Refining Co. allegedly disposed of hazardous materials via the borehole to the mine voids and had caused the pollution incident. It was contended by DER in subsequent legal actions that the mentioned New York

and New Jersey firms had paid Mr. Scatena to inject materials from tanker-type trucks into the borehole on the Highway Service Station property between May and August, 1979.

Damages

Damage to both the ground and surface water of the Pittston area is extensive. It is estimated that more than 4.3 billion gallons of fresh ground and surface water was contaminated. Susquehanna River biota was damaged, and the City of Danville installed extra capacity charcoal filtration devices to remove the carcinogenic chemical 2,2 dichlorobenzene. Potentially lethal cyanide vapors were released due to the wastes interaction with acid mine waters. A significant risk of fire and explosion from accumulated gases occurred.

Current Status

Scatena was convicted of misdemeanor violations of the Clean Streams Law and risking a catastrophe under the Crimog Code in the Luzerne County Court of Common Pleas in 1981. Officials and employees of Hudson Oil have been charged with similar criminal violations and are awaiting trial in Luzerne County. Extensive clean-up and monitoring efforts by DER and EPA staff have continued. Public clean-up and monitoring costs are expected to be in excess of 2.3 million dollars.

A permanent robot monitoring system was installed at the mine pool outflow. This system activates an answering service which then alerts field personnel to the problem who in turn respond by recovering the accumulated product.

Section 6.2.18

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Assessment of Franklin A. Holland & Son From Assessment of Selected Class V Wells in the State of Virginia
AUTHOR: (or INVESTIGATOR)	CH2M Hill
DATE:	April, 1983
FACILITY NAME AND LOCATION:	Franklin A. Holland & Son New Church, Virginia USEPA Region III
NATURE OF BUSINESS:	Chicken Farm
BRIEF SUMMARY/NOTES:	Pit was constructed to dispose of fowl that die prior to being sold. Increased nitrate, organic, and bacteriological levels could be expected, but no information on nature of the liquid waste that enters the water table is available. One pit probably does not constitute high contamination potential; however, if many pits are utilized in one area, evaluation of quality and quantity of leachate may be required.

4.8 FACILITY NO. VAS 001 5W 0001

4.8.1 GENERAL INFORMATION AND DESCRIPTION

Well Number	-	VAS 001 5W 0001
Owner/Location	-	Franklin A. Holland & Son Star Route, Box 53 New Church, VA 23415
Source of Information	-	Franklin Holland
Nature of Business or Facility	-	Chicken Farm
Number of Wells	-	1 (pit)
Construction Features:		
Depth	-	12 feet deep; 6 feet wide
Casing (diameter-depth)	-	Not applicable
Construction Method	-	Dug
Grout	-	None
Special Features	-	Pit with no bottom
Use of Well	-	Pit used to dispose of dead chickens
Source of Injected Fluid	-	N/A
Volume of Injected Fluid	-	N/A
Operation Status	-	Active
Operation Period	-	10 + years
Driller	-	None
Consultant	-	State Agriculture Department
Data Available	-	None additional
Date Visited	-	August 17, 1982

The location of this pit is shown on Figure 4-5.

This pit was installed under the direction of the State Agriculture Department in the early 1970's. A typical problem experienced by the numerous poultry farms in this area is the disposal of fowl that die prior to being sold to the commercial processing plants.

In order to attempt to halt the dumping of these carcasses in the undeveloped wooded areas and avoid potential health hazards the State Agriculture Department required that the

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poultry farms install an anaerobic digester pit or an incinerator at the farm as per State specifications.

The pit is constructed with walls and a top but has no bottom. The bottom of this pit is above the normal water level of the water table in this area.

4.8.2 HYDROGEOLOGY

This pit is located in the Atlantic Coastal Plain in northern Accomack County. The pit is constructed in the formation designated as the Pleistocene Aquifer in the Columbia Group of Pleistocene Age which overlies the Yorktown Formation. The lithology is chiefly yellow sand, sandy clay, and minor lenses of gravel. This water-table aquifer is not extensively developed but is considered as a good source of water supply with generally poorer quality than the deeper Yorktown and St. Marys Aquifers.

The Pleistocene Aquifer is reported to have higher nitrate concentrations that are attributed to surface contamination such as septic tanks, feedlots, and fertilizers.

The pit is located in a rural setting where most ground-water withdrawals are for domestic and small farming uses.

4.8.3 CONTAMINATION POTENTIAL

Contamination in the form of increased nitrate, organic, and bacteriological levels could be expected from this facility. Due to the fact that the pit is constructed and discharges into the sands above the zone of saturation, the quality of any liquid waste discharging from the pit should be considerably improved as a result of the attenuation capabilities of the sands. However, no information is available to assess the expected nature of the liquid waste that enters the water-table aquifer.

The level of contamination is expected to be localized due to the low quantities of liquid waste that would be generated from this facility and the limited amount of ground-water withdrawals in this area.

4.8.4 CORRECTIVE MEASURES

The only viable alternative for the disposal of these carcasses is to replace the disposal pit with an incinerator.

4.8.5 REMEDIAL ACTIONS

The isolated existence of one pit as discussed in this section does not warrant further study or concern. However, if many pits are utilized throughout the area, evaluation of

the quantity and quality of the leachate from these anaerobic digestion pits and determination of ground-water quality in the immediate vicinity of the pits may be required.

As discussed earlier, contamination of the shallow aquifer has been reported in Accomack County. A detailed inventory of the potential sources of contamination is advisable.

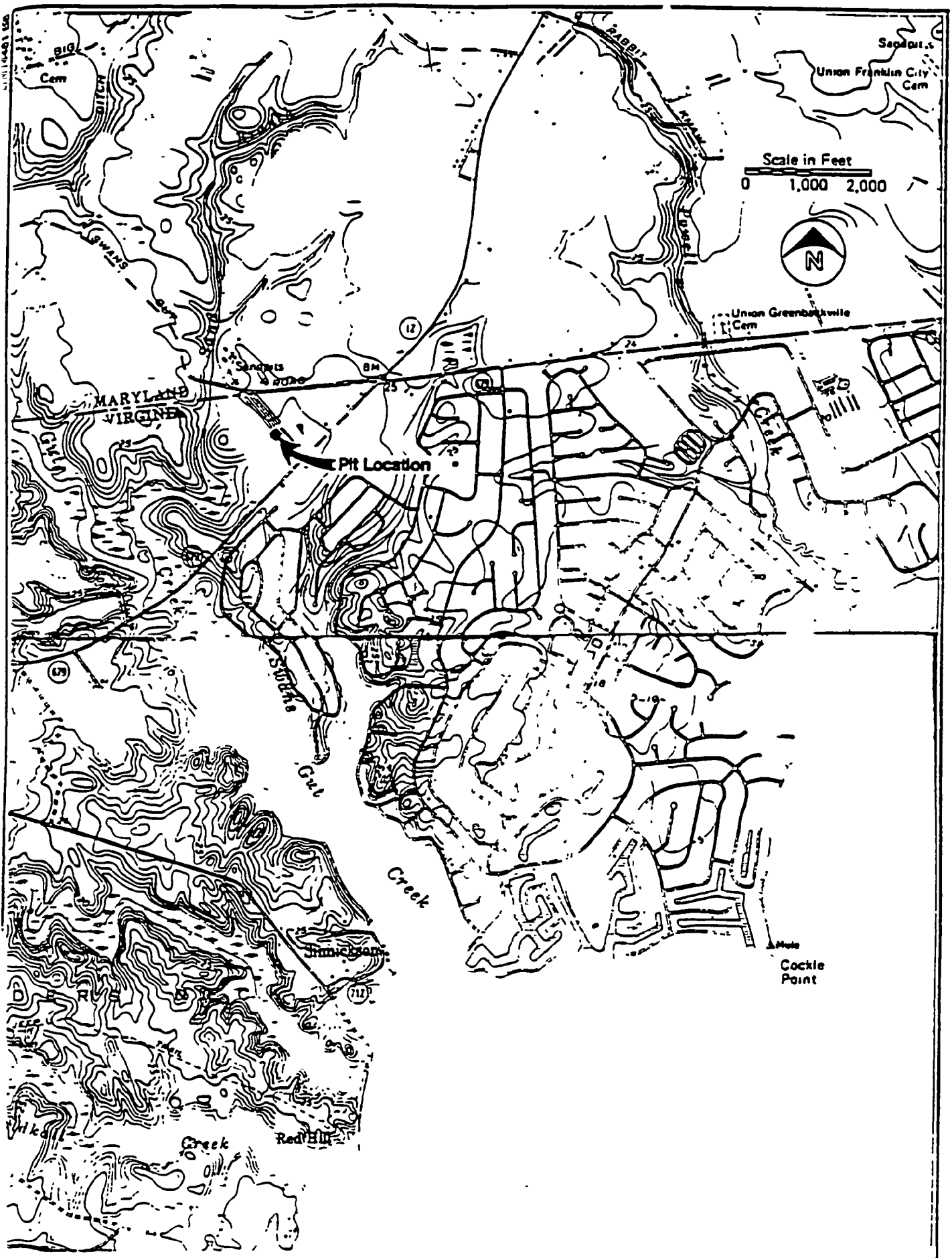

FIGURE 4-5.
Location of Facility No. VAS 001 5W 0001
Franklin A. Holland & Son.

CH2M HILL

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Section 6.2.19

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	"Reverse Osmosis Brine Wells" From Florida Underground Injection Control Class V Well Inventory and Assessment Report
AUTHOR: **(or INVESTIGATOR)**	Bureau of Groundwater Protection, Florida Department of Environmental Regulation
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Various facilities, Florida, USEPA Region IV
NATURE OF BUSINESS:	Reverse Osmosis Processes
BRIEF SUMMARY/NOTES:	Some Class V wells in Florida are used to dispose of reject water (brine) from water treatment plants using membrane technology (reverse osmosis) to render poor quality groundwater potable. Of particular interest are the high levels of radionuclides.

DRAFT

REVERSE OSMOSIS BRINE WELLS

INTRODUCTION

Some Class V wells in Florida are used to dispose of reject water (brine) from water treatment plants using membrane technology (reverse osmosis) to render poor quality ground water potable. At present these "RO reject" wells are only located in Charlotte County in southwest Florida and the Florida Keys.

WELL DISTRIBUTION

At present there are six Class V reverse osmosis reject water wells located at two facilities in Charlotte County. The remaining ten wells are located at three facilities in the middle and upper Florida Keys. (Florida Department of Environmental Regulation GMS data base, 1986).

The potential exists for using reverse osmosis reject wells throughout the coastal areas of the state and in much of south Florida. In many of these areas reverse osmosis water treatment plants have already been constructed and reject waters are being discharged either to surface water bodies, percolation ponds or into drain fields. In recent months however much concern has been expressed over these methods of disposal and the possibility of their polluting surface waters or shallow water-table aquifers. At three inland facilities where reverse osmosis reject water is disposed through injection wells, the wells that were constructed are Class I wells.

WELL CONSTRUCTION

Construction techniques vary somewhat for the various Class V reverse osmosis reject water injection wells. The wells located in Charlotte County are typically approximately 70 feet deep and are cased to approximately 60 feet in depth. These wells are cased with four inch inside diameter PVC pipe (Fig. III.I.1) as the reject waters tend to be corrosive to steel casings. The Charlotte County wells are very low capacity, and only inject waste water at a maximum rate of about 15 gallons per minute (Missimer and Associates, 1983).

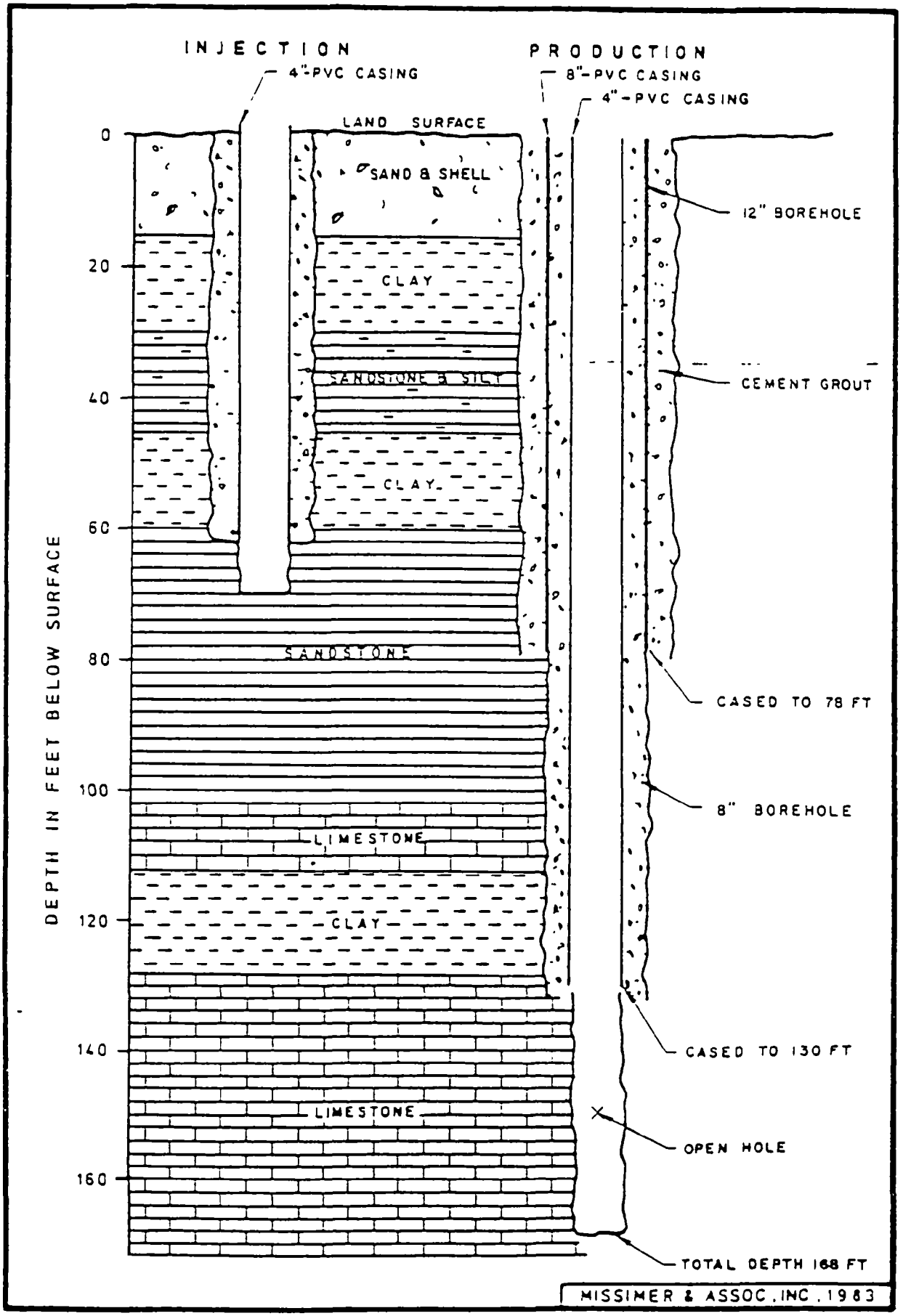

Figure III.I.1 DIAGRAM SHOWING CONSTRUCTION DETAILS OF THE PALM ISLAND VILLAGE PRODUCTION & INJECTION WELLS AND THEIR RELATIONSHIP TO THE ON-SITE GEOLOGICAL SECTION.

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XIX

Reverse osmosis reject water wells in the Florida Keys generally have a much larger open hole section compared to the wells in Charlotte County and are usually only cased to a depth of 20 to 30 feet below land surface as there is either a very thin fresh water lens (Big Pine Key) or no USDW present beneath the facility. There are eight RO reject water wells in the Florida Keys with an eight-inch diameter casing and two wells with a four-inch diameter casing. These wells are higher capacity wells than those in Charlotte County and each are used to dispose of 30,000 to 250,000 gallons per day of RO reject water.

QUALITY OF THE INJECTED FLUID

The quality of reverse osmosis reject water is dependent on two factors. These are the quality of the supply water and the efficiency of the reverse osmosis membrane. As a rule-of-thumb, the concentrations of constituents in the reject water will be from two to five times that of the supply (feed) water. Table III.I.1 shows the expected quality of the reject water at a reverse osmosis facility using a Class I well and located about 20 miles northeast of the Charlotte County facilities. As noted from these data, all primary and secondary drinking water parameters are exceeded.

Of particular interest are the high levels of radionuclides. Radium concentration (Ra 226 + Ra 228) ranges from 75-87 picocuries/liter (pCi/L) and Gross Alpha radiation ranges from 130-150 pCi/L. This is due to the relatively high concentration of radionuclides in the feed water which is withdrawn from aquifers within the Hawthorn Formation. The high radionuclide levels are typical of those for reverse osmosis plants located in Sarasota and Charlotte county area of southwest Florida which use aquifers within the Hawthorn Formation for supply water. At other locations, radionuclide levels should be much lower as the levels in the supply water will be much lower.

PERMITTING

Class V reverse osmosis wells are not specifically designated in the Florida UIC rule (Chapter 17-28, FAC). They can either be permitted as industrial wells (Group 4) or as "other" wells in Group 6. In practice, owners of these wells are required to obtain an operation permit which may require monitoring of the injected fluid's physical and chemical parameters, in addition to monitoring the water quality in overlying aquifers. To date, none of the Class V reverse osmosis reject water wells have been permitted to inject into a USDW due to the high radionuclide levels. Under the current regulations, these wells cannot be permitted to inject into a USDW unless a zone within the USDW contains radionuclide levels as high as those of the injected fluid. Even if this were to occur, the permittee would have to demonstrate that the injected fluids would stay within the injection zone.

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Table III.I.1 Estimated Quality of Reverse Osmosis Reject Water at the Plantation and Englewood Sites in Southwest Sarasota County, Florida.

Parameter	Concentration*
Plantation	
Total Hardness (as $CaCO_3$)	3,600 - 5,000
Chloride	1,200 - 2,000
Fluoride	2.0 - 3.5
Silica	75 - 120
Sulfate	2,100 - 3,500
Total Dissolved Solids	6,500 - 9,000
Hydrogen Sulfide	2.5 - 4.5
Calcium	450 - 750
Conductivity	7,500 - 11,000 umhos/cm
Englewood	
Total Dissolved Solids	11,750 - 13,630
pH	6.0 - 6.5
Conductivity	16,800 - 19,500 umhos/cm
Sodium	2,870 - 3,320
Chloride	6,200 - 7,200
Sulfate	1,060 - 1,230
Phosphate (as total Phosphorus)	3.75 - 4.35
Hydrogen Sulfide	3.0 - 4.0
Radium (Ra^{226} and Ra^{228})	75 - 87 picocuries/L
Gross Alpha Radiation	130 - 150 picicuries/L

*mg/L except pH or where noted

Source: Post, Buckley, Schuh and Jernigan, 1982
CH2M Hill, 1981

From : DER, 1983

XIX

Since there are many reverse osmosis plants which generate reject waters that do not have excessively high radionuclide levels, they could be permitted to inject fluids into a confined portion of the USDW. The state regulations require the injected fluid to be as good or better in quality than the ambient water quality of the injection zone or any zone affected by injection. Many reverse osmosis facilities should be able to meet this requirement provided they construct a well which injects fluids into a zone near the base of the USDW.

GEOLOGY AND HYDROGEOLOGY

The existing wells are only considered Class V wells because aquifers containing less than 10,000 mg/L TDS are found beneath the injection zone. In some cases they are considered Class V because there is a USDW which lies both above and below the injection zone.

In Charlotte County the water quality of the injection zone is that of sea water (Table III.I.2). These facilities are located on barrier islands where a fresh water lens up to twelve feet thick is present in the unconsolidated surficial sands. (Missimer and Associates, 1983).

The Charlotte County facilities are unique in that the injection zone is located above the water supply zone. This is because injection is into a confined saline water zone (30,000 mg/L TDS) located between the fresh water lense above and the supply zone below. Water quality of the supply zone is given in Table III.I.3. The potentionmetric surface of the supply zone is above land surface. This allowed the test supply well to flow at about 40 gpm at the facility. The injection zone water will not flow under ambient conditions. Under these conditions, injected fluids should not migrate into the zone used for the reverse osmosis supply water.

The injection zone is a sandy limestone with good primary and secondary porosity (Missimer and Associates, 1983). This zone is about 20 feet thick and is confined above and below by clay units within the Hawthorn Formation.

RECOMMENDATIONS

Class V RO reject water wells should be permitted using extreme caution. The supply water should be analysed for primary and secondary water quality parameters and a projection should be made as to the expected reject water quality before a well is permitted. If the projected reject water is of very poor quality only a Class I well should be permitted. If the projected reject water quality is as good or better than the ambient water quality in injection zone, a Class V well may be permitted if the applicant can demonstrate that the injected fluids will remain in the injection zone.

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Table III.I.2. Injection Zone Water Quality

Source: Missimer and Associates, 1983

Orlando Laboratories, Inc.

P. O. Box 19127 • Orlando, Florida 32814 • 305/896-6645

ROUTINE WATER ANALYIS

Missimer & Associates, Inc.
Route 8, Box 625-D
Cape Coral, Florida 33909

Report #: 29006 (1371)
Sampled by: Client
Date Sampled:
Date Received: 05-09-83
Date Reported: 05-23-83

IDENTIFICATION: Knight Island.

METHODS

This water was analyzed according to "Standard Methods for the Examination of Water and Wastewater," Latest Edition, APHA, AWWA and WPCF.

RESULTS

Total Dissolved Solids, TDS	30,532	Total Hardness, $CaCO_3$	5,600
Phenolphthalein Alkalinity, $CaCO_3$	0	Calcium Hardness, $CaCO_3$	2,000
Total Alkalinity, $CaCO_3$	138	Magnesium Hardness, $CaCO_3$	3,600
Carbonate Alkalinity, $CaCO_3$	0	Calcium, Ca	800
Bicarbonate Alkalinity, $CaCO_3$	138	Magnesium, Mg	874
Carbonates, $CaCO_3$	0	Sodium, Na	11,888
Bicarbonates, HCO_3	168	Iron, Fe	<0.05
Hydroxides, as OH	0	Manganese, Mn	<0.05
Carbon Dioxide, CO_2	12	Copper, Cu	<0.01
Chloride, Cl	15,811	Silica, SiO_2	4.0
Sulfate, SO_4	2,350	Potassium, K	368
Fluoride, F	0.18	Hydrogen Sulfide, H_2S (F-F)	<0.01
pH (Laboratory)	7.4		
pHs	6.4		
Stability Index	5.4		
Saturation Index (corrosivity)	1.0		
Color, PCU	0		
Odor Threshold	0		
Turbidity, NTU	0.69		

Our Florida Department of Health & Rehabilitative Services Identification Number is 83141.

Signed: C Keyes / /
Chemist/Biologist Chemist/Biologist Chemist/Biologist

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Table III.I.3 Supply-Zone Water Quality.

ROUTINE WATER ANALYSIS REPORT

Orlando Laboratories, Inc.

P. O. Box 19127 • Orlando, Florida 32814 • 305/ 896-6845

Report to: Missimer & Associates, Inc. Appearance: Clear

Date: 22 March 1983 Sampled by: Client

Report Number: 28480 (923) Identification: Knight Island Feed

METHODS

This water was analyzed according to "Standard Methods for the Examination of Water and Wastewater," Latest Edition, APHA, AWWA and WPCF

RESULTS

Determination	Data Significance	mg/l	Determination	Data Significance	mg/l
Total Dissolved Solids	x	3700	Total Hardness, as $CaCO_3$	x	834
Phenolphthalein Alkalinity, as $CaCO_3$	x	0	Calcium Hardness, as $CaCO_3$	x	434
Total Alkalinity, as $CaCO_3$	x	138	Magnesium Hardness, as $CaCO_3$	x	400
Carbonate Alkalinity, as $CaCO_3$	x	0	Calcium, as Ca	x	173
Bicarbonate Alkalinity, as $CaCO_3$	x	138	Magnesium, as Mg	x	97
Carbonates, as CO_3	x	0	Sodium, as Na	x	630
Bicarbonates, as HCO_3	x	168	Iron, as Fe	x	<0.05
Hydroxides, as OH	x	0	Manganese, as Mn	x	<0.05
Carbon Dioxide, as CO_2	x	30	Copper, as Cu	x	<0.01
Chloride, as Cl	x	1235	Silica, as SiO_2	x	0.2
Sulfate, as SO_4	x	60	Potassium, as K	x	16
Fluoride, as F	x	0.56	Hydrogen Sulfide, H_2S (Field fixed)		0.12
pH (Laboratory)	x	7.0			
LSI	x	7.2			
Stability Index	x	7.4			
Saturation Index	x	-0.2			
Color, PCU	x	0			
Odor Threshold	x	0			
Turbidity, NTU	x	2.8			

Signed: C Keyser
Chemist

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C

On-site monitor wells should always be required as part of the permitted Class V well system unless a USDW is not present above the injection zone. Key parameters should be monitored monthly and reported along with other injection parameters such as flow, pressure, ect. Other requirements, such as mechanical integrity testing, should be placed on these Class V systems depending on various local factors such as proximity of drinking water wells, quality of water in overlying aquifers and well construction, among others.

REFERENCES

Florida Department of Environmental Regulation, 1986, Ground Water Management System data base, provided by the Bureau of Information Systems.

Missimer and Associates, 1983, Knight Island geohydrologic investigation.

Section 6.2.20

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Technical Evaluation for American Cyanamid Company Injection Well Nos. 1 and 2
AUTHOR: (or INVESTIGATOR)	Engineering Enterprises, Inc.
DATE:	January, 1984
FACILITY NAME AND LOCATION:	American Cyanamid Co. Michigan City, Indiana USEPA Region V
NATURE OF BUSINESS:	Catalyst Manufacturer
BRIEF SUMMARY/NOTES:	Injected waste generally contains high levels of total solids, Na, and SO_4. The injection zone lies between two USDW. The upper USDW is currently a source of drinking water, and the lower zone is a potential source of drinking water. It is recommended that these wells be phased out. (Note: Recommendations and conclusions indicated that this facility should consider these to be Class IV wells. Further study suggests that these are actually Class V wells because the injectates do not contain "hazardous" wastes.)

ENGINEERING Enterprises, Inc.

CONSULTANTS SPECIALIZING IN
Civil and Sanitary Engineering, Ground Water Geology, Oil Recovery, and Irrigated Agriculture

1225 West Main, Suite 215 Norman, Oklahoma 73069 Phone (405) 329-8300

January 13, 1984

Mr. Mark Vendl
U. S. Environmental Protection Agency
Region V
230 South Dearborn Street
Chicago, Illinois 60604

Re: "Technical Evaluation for American Cyanamid Company Injection Well Nos. 1 and 2"

Dear MarK:

Enclosed please find the above titled report on the American Cyanamid Company waste disposal wells located in Michigan City, Indiana. We concur with the recommendations of Subsurface Data Corporation that the ACC Well Nos. 1 and 2 be reclassified as Class IV wells and be phased out. We also recommend that an alternative Class I well drilled to a deeper horizon, with the intervening strata between the top of the injection zone and the base of the lowermost underground source of drinking water (USDW) having a minimum thickness of 200 feet, be used for disposal purposes in the study area. Results of the study also indicate that the USDW's in the study area should not be granted "aquifer exemption" status.

If you have any questions, please do not hesitate to contact me.

Yours sincerely,

Talib Syed

Talib Syed
Petroleum Engineer

TS/cld

Enclosure

TECHNICAL EVALUATION FOR

AMERICAN CYANAMID COMPANY

INJECTION WELL NOS. 1 & 2

Prepared for:

U.S. Environmental Protection Agency
Region ~~V~~ IV
230 S. Dearborn
Chicago, Illinois

U.S. EPA - UIC Program
Contract No. 68-01-6389
Work Assignment No. ~~11~~ 10

Prepared by:

Engineering Enterprises, Inc.
1225 West Main
Norman, Oklahoma 73069

January, 1984

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INTRODUCTION

There are currently 13 deep injection wells used for the disposal of industrial wastes in Indiana. Of these 13 wells, 11 are completed at depths exceeding several thousand feet with confining intervals in excess of several hundred feet. The remaining two are shallow injection wells completed at depths of 650 and 295 feet respectively. The thickness of the intervening strata (confining interval) between the top of the injection interval and the base of the overlying underground source of drinking water (USDW) is 51 and 72 feet respectively in these two wells. The subject injection wells are operated by the American Cyanamid Company (ACC), located in Michigan City, Indiana. The waste fluids being injected consist of waste from the production of petroleum refining catalysts and intermediates.

The objectives of this study are:

1. To make a technical evaluation of the two shallow injection wells (ACC Well Nos. 1 and 2);

2. To assess the potential for contamination of an underground source of drinking water (USDW) via injection of industrial wastes;

3. To determine whether the USDW's in the study area can be granted "aquifer exemption" status; and

4. To determine whether the thickness of the confining layer is adequate to prevent upward vertical migration

of the injected wastes into the USDW in the study area.

The data used in this study was obtained from the following two reports prepared for the U.S. EPA - Region IV, namely,

1. "Technical Evaluation for American Cyanamid Company No. 1 Well," Subsurface Disposal Corporation, July 1981.

2. "An Aquifer Study for Northwest Indiana," SMC Martin Inc., April 1983.

CONCLUSIONS AND RECOMMENDATIONS

An evaluation of the data available in the reports prepared by Subsurface Disposal Corporation and SMC Martin Inc. has led to the following conclusions and recommendations:

1. The source of the high concentrations of total dissolved solids (TDS), SO_4 and Na in Well No. 002 (Long Beach Country Club) located 1 1/4 miles northeast of the ACC plant and in Well No. 007 located two miles southwest of the ACC plant, cannot be confirmed as originating from the ACC waste disposal wells. Additional ground-water samples from suitable monitoring wells will be needed to track the path of the injected wastes and to confirm the cause of the high concentrations in Well Nos. 002 and 007.

2. The large waste volumes injected at the relatively shallow injection depths (approximately 270 feet), coupled with the fact that the confining layer (Antrim Shale) varies in thickness, is relatively thin in the study area (50 feet in ACC #1 and 72 feet in ACC #2), and may pinch out away from the study area, increases the potential hazard to potable water supplies. The potential for water wells in the area that penetrate the disposal zone to become contaminated by the injected wastes is quite high.

3. The injection zone which consists primarily of limestone and dolomite, may have fractures, vugs and solution channels present. The large volumes of waste being injected at low pressures (13,700 barrels/day at 35 psig) indicates presence of fractures. Vertical fractures may break out of the injection zone and propagate vertically through the confining layer and if the confining layer is not sufficiently thick may lead to vertical migration of injected wastes into a shallow fresh water aquifer. A thickness of at least 200 feet is recommended for injection rates of 1000 BPD and in the study area the confining layer thickness is insufficient for the high injection rates employed.

4. The injection zone (Unit 3) has a concentration of less than 10,000 mg/l TDS and is under artesian pressure. Well No. 007, although originally abandoned, was flowing under artesian pressure. This again indicates a potential danger of the injected wastes migrating upward through inadequately plugged and abandoned wells and contaminating the shallow fresh water aquifers, depending on the pressure in Unit 3.

5. Mr. Stephen Reuter, State of Indiana Environmental Engineer, reported a high TDS value in the Long Beach Country Club Well No. 002 and suspected that the ACC wells were probably the cause of the high

concentrations. However, this could not be confirmed due to conflicting background data of the natural formation fluids in the injection zone of ACC Well No. 1.

6. Mr. Reuter also stated that there are zones beneath the injection zone which contain water with a TDS of less than 10,000 mg/l. If this is true, then the ACC Well Nos. 1 and 2 can no longer be classified as Class I disposal wells, since by definition a Class I well can only inject beneath the deepest underground source of drinking water (USDW).

7. The absence of a downhole packer and the annulus being filled with cement rules out testing of the casing for mechanical integrity in ACC Well No. 1. However, a casing failure having already occurred in 1954, the age of the casing (approximately 33 years) and the corrosive nature of the injected fluids, signal doubts about the integrity of the casing.

8. Considering all the above factors, Engineering Enterprises concurs with the recommendations of Subsurface Data Corporation that the ACC No. 1 and ACC No. 2 wells be reclassified as Class IV wells and be phased out.

9. Considering the volumes of waste to be disposed of, a new Class I well completed in a deeper zone beneath

the lowermost USDW, appears to be the most safe, efficient, and cost-effective alternative.

10. The question of granting an "exempted aquifer" status to the USDW's in the study area can only be answered after a close evaluation of all the criteria needed to qualify for exemption (refer to 40 CFR Sec. 146.04). Based on the available data, it appears that the USDW's in the study area do have a potential for supplying potable water for human consumption and therefore cannot be granted an "exempted aquifer" status.

11. Engineering Enterprises recommends that further investigations be carried out to track the path of the injected wastes and to determine that no degradation of ground water quality in the study area is taking place.

GEOLOGIC CONSIDERATIONS

Location

Michigan City is in LaPorte County in northwestern Indiana, along the shore of Lake Michigan (Figure 1). The American Cyanamid Company (ACC) plant is located in LaPorte County at East Dunes Highway, Route 12, Michigan City, Indiana.

General Geology

A brief description of the geology of LaPorte County is first presented. For a more extensive description, reference can be made to the original report of SMC-Martin.

The current landscape in LaPorte County resulting from the last major glacial phase is subdivided into three physiographic units: The Calumet Lacustrine Plain, the Valparaiso Morainal Area, and the Kankakee Outwash and Lacustrine Plain (Figure 2).

The Calumet Lacustrine Plain was laid down as deposits of lake clay and sand when Lake Chicago (ancestral Lake Michigan) occupied various elevations descending from 640 feet above sea level to the present level of Lake Michigan.

The Valparaiso Moraine is actually a complex of several end moraines composed of loam to silt loam till, each representing a stillstand of the glacier in that area.

During the formation of Lake Chicago, the retreat of a glacial lobe located to the east (the Huron-Saginau) created a massive river of meltwater which cut a swath an average of 8

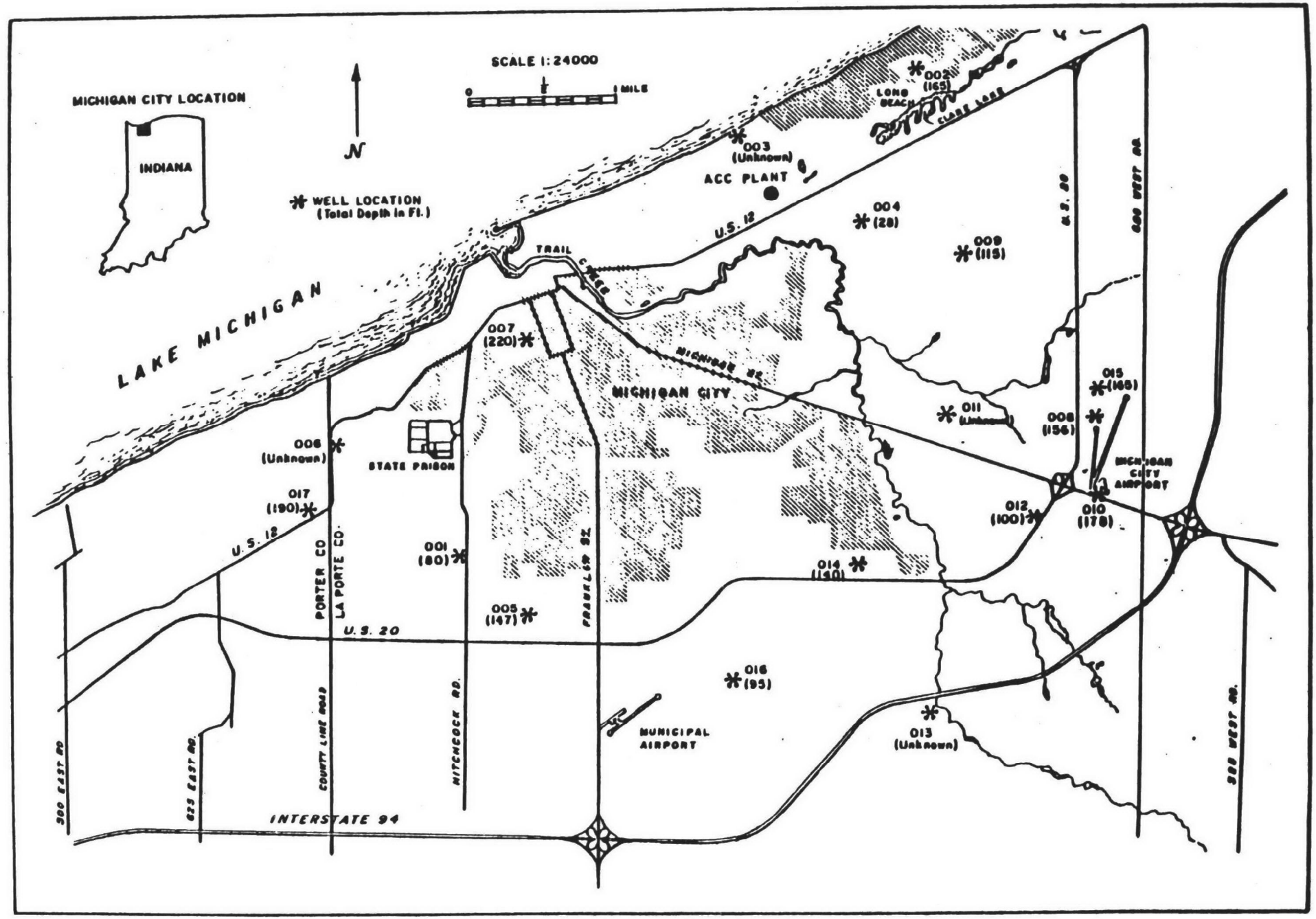

FIGURE 1. STUDY AREA, MICHIGAN CITY

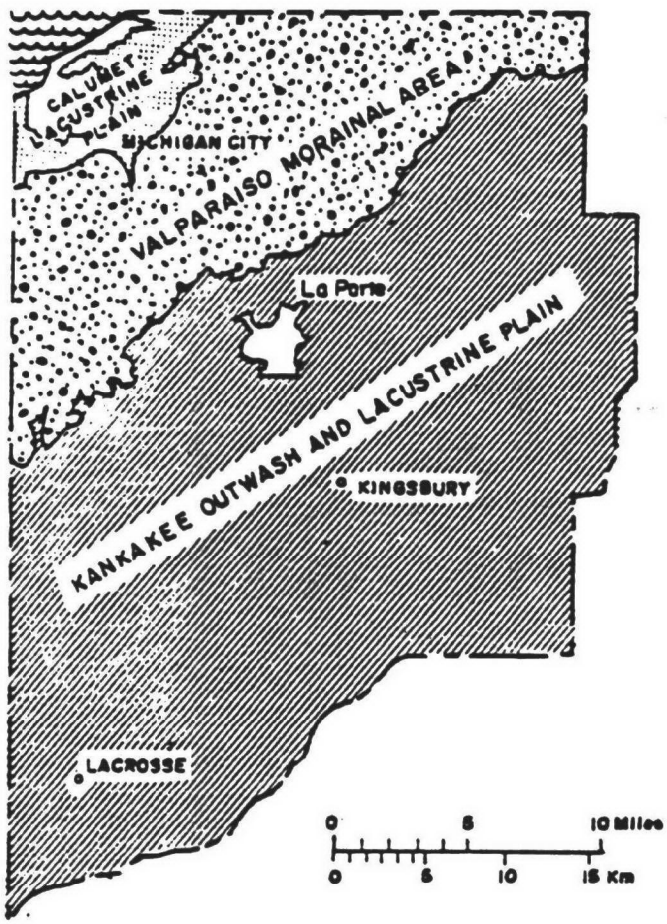

Figure 2. Physiographic map of LaPorte County (Hill, et al., 1979)

miles wide through the southeastern two-thirds of LaPorte County. This resulted in the removal of some sediments, followed by a complete blanketing of older sediments with outwash sand and gravel creating the Kankakee Outwash and Lacustrine Plain.

Stratigraphy

Figure 3 is a stratigraphic column for LaPorte County, Indiana. Although the Ellsorth Shale serves as bedrock for most of LaPorte County, in the Michigan City area the Antrim Shale, which is late Devonian in age and directly underlies the Ellsworth, extends beyond the margins of the Ellsworth and is the bedrock surface. Underlying the Antrim Shale is a sequence of Paleozoic limestone, dolomite, shale, sandstone and gypsum approximately 4000 feet thick. A Precambrian basement complex of dominantly igneous rocks underlies the Paleozoic sediments. No major faults are known to occur in LaPorte or neighboring counties.

Surface deposits in LaPorte County are composed of Quaternary glacial drift. These sediments consist of unconsolidated sand, gravel and clay and attain a thickness of 204 feet at the ACC No. 1 and 195 feet at the ACC No. 2.

The Antrim Shale (Devonian) underlies the glacial drift. It is encountered at a depth of 204 feet at the ACC No. 1 and at a depth of 195 feet at the ACC No. 2 and has a thickness of 51 feet at the ACC No. 1 and 72 feet at the ACC No. 2. The Antrim

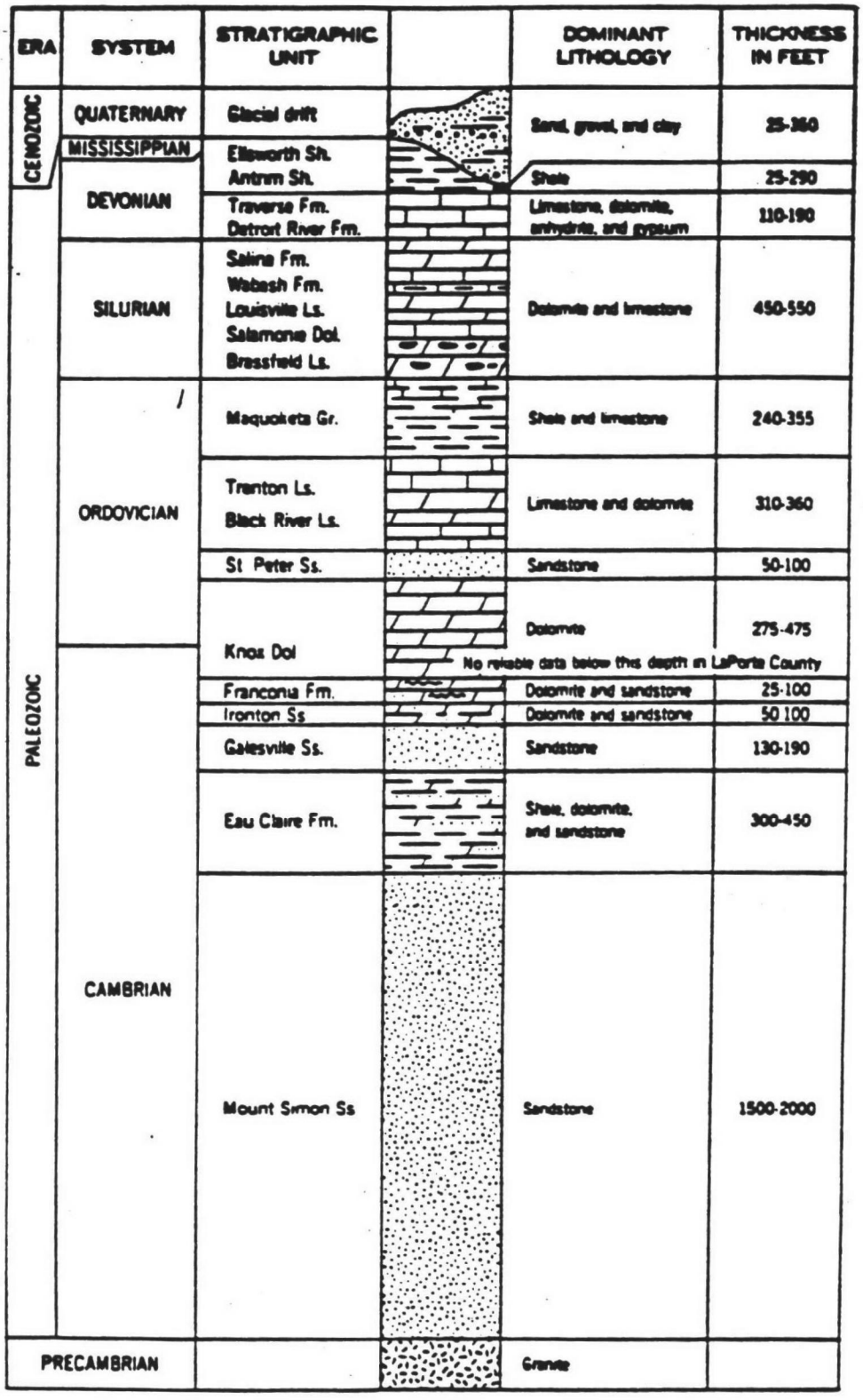

Figure 3. Stratigraphic column for LaPorte County (Hill, et al., 1979)

Shale at the ACC well is described as brown shale, shale and limestone from a driller's log.

The Traverse (Devonian), Detroit River (Devonian), and Wabash (Silurian) Formations underlie the Antrim Shale and are encountered at a depth of 255 feet at the ACC No. 1 and at a depth of 267 feet at the ACC No. 2. These formations are approximately 390 feet thick at the ACC No. 1 while the ACC No. 2 penetrated 28 feet into the Traverse. According to the ACC No. 1 driller's log, these formations consist primarily of gray, soft to hard limestone, with some sandy limestone, dark brown shale, white gypsum, and sandstone. These formations are of particular interest because they are used as waste disposal zones.

Structure

The ACC No. 1 well is located on the southwestern flank of the Michigan Basin. The consolidated sediments are relatively flat with a gentle dip which forms a bowl-like structure known as the Michigan Basin. The Michigan Basin is located to the north and northeast of the Cincinnatti and Kankakee Arch, respectively. The structural dip is toward the northeast at an average rate of approximately 11 feet per mile. The strata in LaPorte County is not disturbed by major faulting.

AMERICAN CYANAMID COMPANY INJECTION WELLS

The two ACC injection wells are located on East Dunes Highway, Route 12, Michigan City, Indiana and are presently classified as Class I injection wells.

Well Data

ACC Well No. 1

The ACC well No. 1 was drilled by Layne-Northern and completed on July 10, 1951 as a barefoot injector opposite the Traverse, Detroit River and Wabash formations. 12" open hole (270'-650') and Total Depth 650'. The 16" O.D. surface casing was set at 210 feet penetrating 6 feet into the Antrim Shale. The original 12 3/4" intermediate casing liner which was set from 170 feet to 257 feet failed in 1954 and a 6" Carlon plastic injection string, with the top 6 feet consisting of 6" Sch. 40 steel pipe, was installed to 270 feet. The cause of failure or what specific damage occurred to the well are unknown.

The annular space between the 6" plastic injection string and the 16" surface casing and between the 6" injection string and the 12 3/4" intermediate casing was cemented with Pozmix cement to 240 feet. Resin cement was circulated from 270 feet to 240 feet in the annular space between the 6" injection string and the 12 3/4" casing and between the 6" string and the outside borehole. There are no records to indicate that there is cement in the annular space between the 16" casing and the formation, the 12 3/4" casing and the 16" casing, and the 12 3/4" casing

and the formation. A Jaswell seal tip was installed at 270 feet. A downhole sketch of ACC Well No. 1 is shown in Figure 4.

The driller's log reports that 205 feet of glacial drift overlay the Antrim Shale which is 50 feet thick at the well site. The Antrim Shale is the confining layer for the injection interval. The Traverse (Devonian), Detroit River (Devonian), and Wabash (Silurian) formations were encountered at 255 feet with a combined thickness of 390 feet. From the driller's log, it was not possible to differentiate these three formations from one another. The injection interval is an artesian aquifer with a preinjection static water level 20 feet above ground level.

ACC Well No. 2

The ACC Well No. 2 was completed in October 1952 to a total depth of 295 feet and is cased to 278 feet. Waste is being injected into the Traverse (Devonian) formation in the interval 278 feet to 295 feet. The SMC-Martin report indicates that the annular space is cemented, though the exact annular spaces are not defined.

The driller's log for ACC Well No. 2 reports that 195 feet of glacial drift (unconsolidated sediments) overlay the Antrim Shale at the well site, with the Antrim Shale being 72 feet thick at this location. The well penetrated 28 feet into the Traverse and the injection zone is under artesian pressure. When drilled, the well flowed at a rate of 1200 gpm. No records are available to indicate the quality of the discharged water.

AMERICAN CYANAMID - DISPOSAL WELL NO. 1
INDIANA

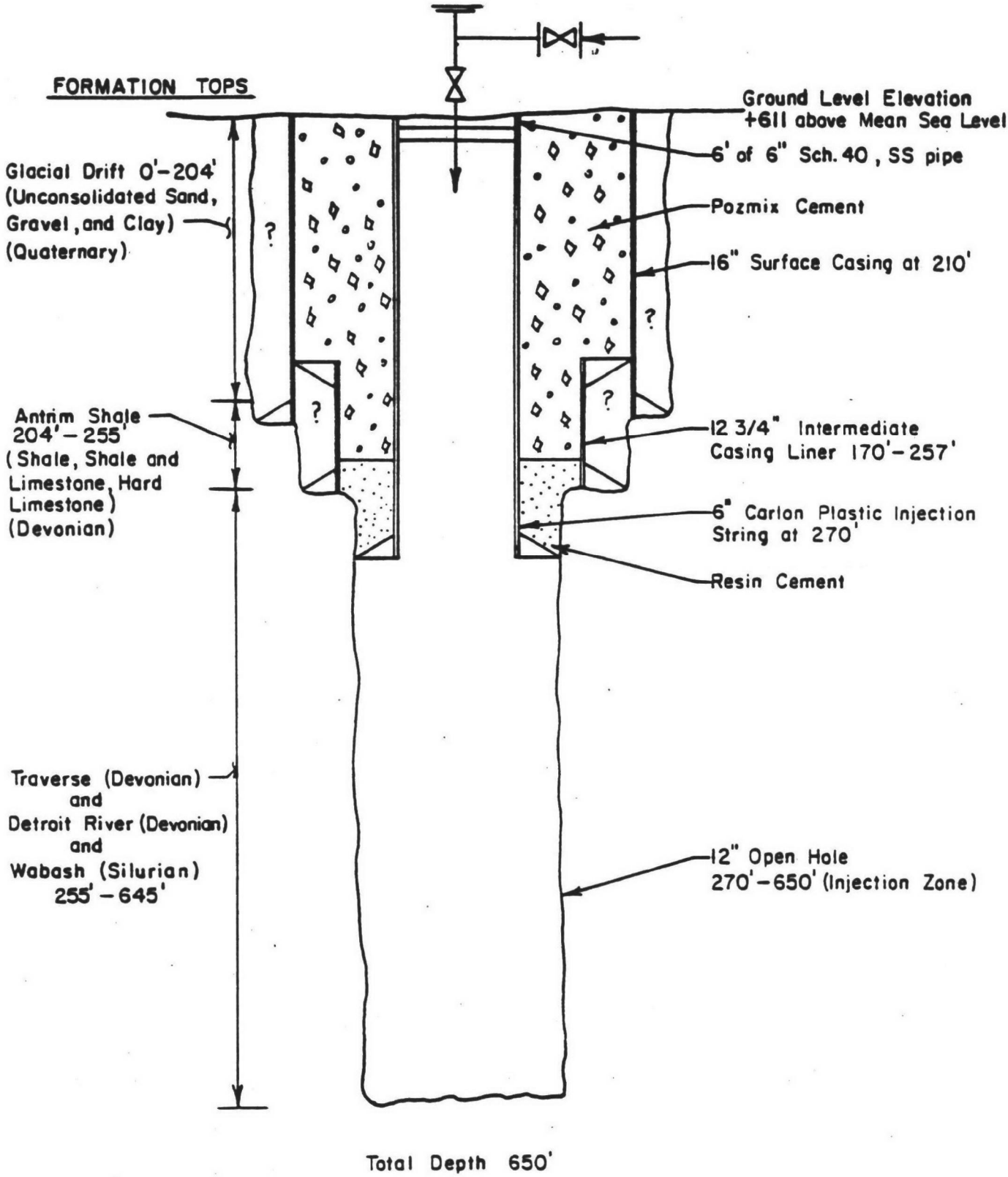

FIGURE 4

Driller's logs for both injection wells are included in Appendix I.

In addition to the injection wells, four test wells at depths of 163, 142, 36, and 32 feet were drilled at the plant site. No information is currently available regarding the original purpose or present status of these wells. A driller's log is available for the 163-foot well and is included in Appendix I.

The ACC Michigan City plant manufactures alumina, alumina-silica cracking powder, silica-alumina fluid cracking catalysts, formed alumina, silica-alumina based hydrodesulfurization catalysts, and purified alumina trihydrate used for petroleum refining. Waste materials are collected in three large settling tanks. Supernatant from the tanks flows into a feed tank prior to injection.

The average injection rate into each well is 400 gpm with maximum and minimum rates of 600 and 200 gpm. From August 1951 to August 1967, 2.07 billion and 1.94 billion gallons of waste have been injected at an average injection pressure of 35 psi for both wells. A typical analysis of the injected waste is given in Table I.

Table 1

Analysis of Wastes Being Injected in ACC Wells No. 1 and No. 2

Constituent	Concentration (in mg/l)
Total Solids	14,000
Filterable Solids	118
Na_2O	6,021
Al_2O_3	187
SO_4	7,681
Specific Gravity	1.0

GROUND-WATER CONSIDERATIONS

The residents of LaPorte County rely on ground water for their water supply, with the exception of Michigan City which receives its water supply from Lake Michigan.

The stratigraphic sequence of the unconsolidated deposits from oldest to youngest can be divided into four units, consisting of two sand and gravel aquifers, and two relatively impermeable glacial tills as shown in Figure 5. The system's total production potential for the county is estimated to be in excess of 400 million gallons per day of which less than five percent is being used. Each stratigraphic unit will now be discussed briefly.

Unit 4, the oldest unit, is a hard till with discontinuous sand and gravel lenses. It overlies most of the bedrock throughout the county; however, it probably, does not occur in the study area. The till is classed as a confining unit although the intra-till sand and gravel lenses may be a potential limited source of ground water. Water quality from this unit is generally good.

Unit 3, the glacial outwash consisting of silty sand and sand and gravel, ranges in depth from 0 to 250 feet with an average thickness of 100 feet. It is the principal aquifer in the county with the potential to yield as much as 3000 gpm from a single well. The aquifer is exposed in the southern part of the county where it forms the surface of the Kankakee Outwash

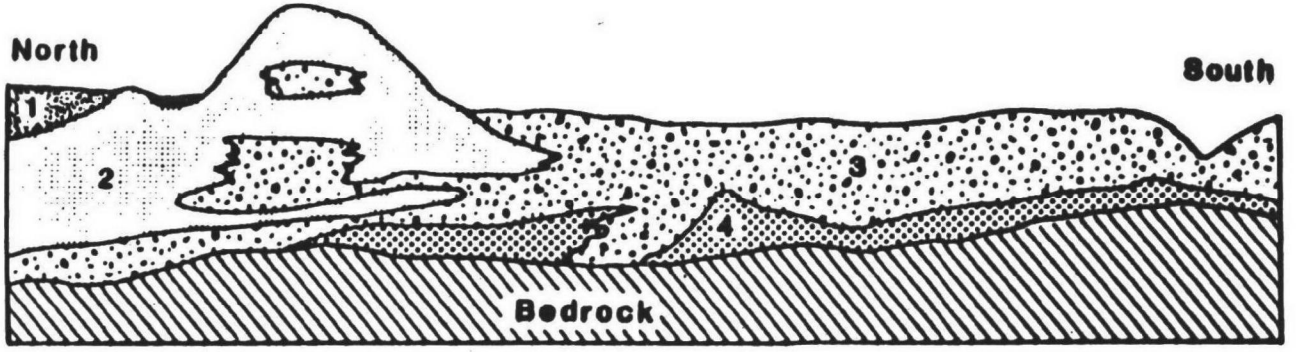

Figure 5. Diagrammatic cross section through LaPorte County showing the relative positions of the major stratigraphic units. The stratigraphic units are: 1) Lacustrine clays and sands, 2) loamy to silty loam till, 3) outwash deposits, and 4) a hard till. (Hill et al., 1979)

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and Lacustrine Plain. In the southern section, Unit 3 acts as an unconfined aquifer with a depth to water generally from 0 to 20 feet. The water quality is generally good. However, locally high concentrations of bicarbonate, chloride, sulfate, and dissolved solids do occur. In the Michigan City area, the unit is confined under Unit 2 (Valparaiso Moraine).

Unit 2 is a calcareous silty till with discontinuous sand and gravel lenses which comprises the Valparaiso Morainal Area. Ground water occurs in the relatively thin sand and gravel lenses which are capable of supplying farm and domestic needs but their production potential is limited by their small size and limited recharge potential. Generally, the water quality is good but the water may be somewhat hard. Unit 2 is best described as a confining layer for Unit 3 resulting in the artesian nature of the latter unit.

Unit 1 is located in the northwestern part of LaPorte County and is the major unit exposed at the surface in the study area. ACC Well No. 1 is located within the Unit 1 boundaries. Unit 1 is an unconfined aquifer and consists primarily of sandy lacustrine material, dune, beach, and shoreline deposits of sand. This unit is an unconfined aquifer capable of yielding in excess of 500 gpm where its saturated thickness is greater than 50 feet. Although it is the second most productive aquifer in the county, the yield from individual wells is limited through much of the unit because its saturated thickness is 20 to 30

feet or less. Water quality is good but the unit is susceptible to contamination from surface sources.

Collection of Ground-Water Samples

Unit 3 which consists of the Kankakee outwash deposits was considered the zone most likely to be contaminated by the injection fluids migrating vertically upward through the overlying confining Antrim Shale and into the unconsolidated sediments. It was also believed that if contamination of an unconsolidated aquifer is occurring, it will be limited to Unit 3 due to its proximity to the injection interval and the confining Unit 2 (Valparaiso Moraine) located above it. Unit 3 was therefore targeted as the sampling zone.

SMC Martin obtained ground-water samples from 17 wells that were believed to be completed in Unit 3. Of these 17 wells, only 5 wells had driller's logs that indicated that they were completed in Unit 3, making it impossible to determine the completion interval of the remaining 12 wells. The location and depths of the wells that were sampled are shown in Figure 1.

Ground-Water Sampling Results

The ground-water samples were analyzed for Al, Ca, Mg, Na, Si, SO_4, TDS, and alkalinity and the test results are listed in Table 2. Five of the 17 wells showed evidence of possible ground-water degradation. The Long Beach Country Club Well No. 002, located about 1 1/4 miles northeast of the ACC plant and completed at a depth of 165 feet in Unit 3 contained the highest concentrations of determined constituents. The analysis of the

Table 2

Chemical Analysis of Ground-water Samples
(concentrations in mg/l) (from SMC Report)

Sample No.	Depth (ft.)	TDS	Ca	Na	Mg	Al	Si	SO_4	Alka-linity	T°C	pH
001	80	305	43.0	42.3	32.6	<0.5	4.65	<1.0	310	13	7.8
002	165	5,580	244	545	124	<0.5	3.68	1,400	360	8	8.2
003		435	82.4	30.1	15.1	<0.5	3.99	200	210	10	7.2
004	28	262	33.5	23.9	10.5	<0.5	5.28	36	62	11	6.8
005	147	311	35.3	71.0	16.6	<0.5	5.61	I.S.	280	10	7.9
006		554	36.0	51.2	27.4	<0.5	5.94	1.0	300	11	8.0
007	220	1,380	125	252	47.9	<0.5	6.90	<1.0	290	12	7.5
008	156	295	66.6	22.9	38.8	<0.5	6.90	<1.0	350	12	7.5
009	115	312	21.8	95.1	6.7	<0.5	4.32	<1.0	240	9	7.7
010	178	289	67.7	12.9	24.3	<0.5	5.94	<1.0	290	11	8.2
011		318	45.5	39.9	27.6	<0.5	4.65	<1.0	310	16	7.2
012	100	268	71.4	6.4	25.0	<0.5	5.61	<1.0	290	11	7.2
013		336	86.6	4.5	29.9	<0.5	6.90	24	310	12	6.8
014	140	353	44.5	45.9	32.9	<0.5	4.65	<1.0	330	17	7.0
015	165	318	37.1	58.0	20.0	<0.5	3.68	<1.0	290	11	7.3
016	95	284	57.0	17.4	28.7	<0.5	4.32	<1.0	290	14	7.4
017	190	279	40.7	27.2	29.5	<0.5	3.68	<1.0	280	11	7.5

I.S. - insufficient sample.

sample taken from Well No. 002 showed high concentrations of TDS (5,580 ppm), Na (545 ppm) and SO_4 (1,400 ppm).

The sample taken from Well No. 007 located two miles southwest of the ACC plant and completed at a depth of 220 feet in Unit 3 contained 1,380 ppm TDS and 252 ppm Na. The absence of measurable SO_4, and Al concentrations would make it appear that the Na and TDS concentrations in this well may not be related to the ACC injection wells.

Samples taken from Well Nos. 003, 004, and 013 contained SO_4 concentrations of 200, 36, and 24 ppm respectively. Though Well Nos. 003 and 004 are within a mile of the ACC plant, the lack of driller's logs makes it difficult to determine the completion zone and to trace the contaminant source to the ACC waste disposal wells.

Well Nos. 006, 008, 012 and 015 all completed in Unit 3 and located on the perimeter of the study area did not show any anamalously high concentrations.

CONCEPT OF AQUIFER EXEMPTION

The concept of "aquifer exemption" will be examined briefly to determine whether the underground sources of drinking water (USDW's) in the study area can be granted aquifer exemption status or not.

A USDW is defined as any aquifer that currently supplies water for human consumption or that contains water with less than 10,000 mg/l of Total Dissolved Solids (TDS). This definition covers all aquifers capable of supplying drinking water, irrespective of whether they are presently being used for that purpose or not.

The UIC regulations stipulate that a USDW may be exempted from coverage if it meets the following criteria:

a. The aquifer does not currently serve as a source of drinking water; and

b. The aquifer cannot now and will not in the future serve as a source of drinking water because:

   1. It is mineral, hydrocarbon, or geothermal energy producing;

   2. It is situated at a depth or location which makes recovery of water for drinking purposes economically or technically impractical;

3. It is so contaminated that it would be economically or technologically impractical to render the water fit for human consumption; or

4. It is located over solution-mining (Class III) well areas subject to subsidence or catastrophic collapse; and

c. The TDS content of the ground water is more than 3,000 and less than 10,000 mg/l and it is not reasonably expected to supply a public water system.

It is important that the various engineering, hydrogeologic, economical, legal and social factors all be considered before granting an exemption status to an aquifer.

In the study area in Michigan City, Indiana, where the two ACC injection wells are located, the injection zone lies between two USDW's. The upper USDW is currently a source of drinking water while the lower USDW is a potential source of drinking water.

The confining layer (Antrim Shale) above the injection zone varies in thickness and is approximately 50 feet in ACC Well No. 1 and 72 feet in ACC Well No. 2. However the possibility of the Antrim Shale thinning out going away from the study area has to be considered in any evaluation. And since the injection zone consists primarily of limestone and dolomite, fractures, vugs and solution channels can be expected to be present. The large volumes of waste being injected at low pressures (35 psi)

indicates presence of fractures. Where the confining layer is not sufficiently thick (at least 200 feet thick for injection rates less than 1000 B/D), fractures may break out of the injection zone and propagate vertically through the confining layer. This may lead to vertical migration of injected wastes into a shallow fresh water aquifer.

Considering all the above factors, it is recommended that the USDW's in the study area should not be granted an "aquifer exemption" status.

REFERENCES

1. SMC Martin Inc. April 1983. "An Aquifer Study for Northwest Indiana." Report prepared for U.S. EPA Region V, Chicago, Illinois.

2. Subsurface Disposal Corporation, July 1981. "Technical Evaluation for American Cyanamid Company No. 1 Well." Report prepared for U.S. EPA Region V, Chicago, Illinois.

3. Geraghty and Miller, Inc. and Booz, Allen and Hamilton, Inc. "Exemption to Designation: Background Support." Report prepared for U.S. EPA, Office of Drinking Water.

Drillers logs for selected wells in the Michigan City area. (All depths and thicknesses in feet.)

Well No. 002[1] Long Beach Country Club

Description	Thickness	Depth	Remarks
Clean beach sand	29	29	
Solid blue clay	111	140	
Clean coarse gravel and boulders	25	165	
Blue shale	--	165	

Well No. 006[1] USGS Well

Description	Thickness	Depth	Remarks
Fine brown sand	5	5	
Sandy dark brown organic clay	3	8	
Fine brown sand	24	32	
Soft gray clay	2	34	
Alt. layers of soft gray clay and fine silty gray sand	12	48	
Sticky gray clay	67	115	
Sticky gray clay with pebbles	27	142	
Silty fine gray sand	3	145	
Gray clay	7	152	
Fine silty sand	2	154	
Gray clay	2	156	
Fine silty gray sand	34	190	
Sandy brown clay with shale	13	203	
Dark brown shale	2	205	

Well No. 007[2] Pullman Standard Car Manufacturing Company

Description	Thickness	Depth	Remarks
Sand	30	30	
Clay	70	100	
Sand	120	220	

Well No. 012[1] Swan Lake Memorial Gardens

Description	Thickness	Depth	Remarks
Brown sand	15	15	
Fine sand	11	26	
Clay-gravel mixed	69	95	

Well No. 015[1] Warnke Road and 212 Road

Description	Thickness	Depth	Remarks
Brown sand	12	12	
Blue clay	103	115	
White sand	5	120	
Clay and silt	25	145	
Gravel - blue	2	147	
Silt	19	166	
White sand	11	177	

ACC Well No. 2[2]

Description	Thickness	Depth	Remarks
Sand	30	30	
Clay, sandy	20	50	
Clay, blue	20	70	
Clay	15	85	
Sand	20	105	
Clay, blue	30	135	
Gravel	23	158	
Clay, blue	37	195	
Shale, brown	40	235	Upper Devonian Series (bedrock surface)
Shale, blue	13	248	
Shale, brown	19	267	
Limestone	28	295	Middle Devonian Series Water at 264 feet; crevice at 283 feet.

ACC Well No. 1[2]

Description	Thickness	Depth	Remarks
Drift	205	205	
Shale, dark grayish-brown, very sporiferous, slightly pyritic	30	235	Upper Devonian Series (bedrock surface)
Shale, dark grayish-brown, slightly sporiferous, slightly pyritic	15	250	
Shale, dark grayish-brown slightly sporiferous, pyritic, with some pyritic dark brownish-gray very cherty sandy dolomite	3	253	
Limestone	2	255	Middle Devonian and Middle Silurian Series
Dolomite, coarse-crystalline, dark brown	5	260	
Dolomite, coarse-crystalline, porous, whitish-brown	6	266	
Dolomite, coarse-crystalline, porous, light tan to dark brown	9	275	
Dolomite, coarse-crystalline, light tan, dark brown and white	5	280	
Limestone, medium to coarse-crystalline, sandy, dolomite, whitish-gray	5	285	
Limestone, fine to coarse-crystalline, sandy, dolomitic, whitish-gray and brown	2	287	
Dolomite, fine to coarse-crystalline, sandy, light tan to dark grayish-brown	13	300	
Limestone, fine to medium-crystalline, sandy, argillaceous, light tan to grayish-brown	5	305	
Limestone, dense to medium-crystalline, slightly argillaceous, grayish-tan to gray	5	310	
Limestone, fine-crystalline, light grayish-tan	10	320	

ACC Well No. 1 - Continued

Description	Thickness	Depth	Remarks
Limestone, fine to medium crystalline, slightly dolomitic, light tan to tan; with some very dark brown argillaceous dolomite	5	325	
Limestone, dense, dolomitic, light tan	5	330	
Limestone, dense, argillaceous, dolomitic, white to light gray	5	335	
Dolomite, fine crystalline, light gray and light tan with gypsum	10	345	
Limestone, hard, dense, gypsiferous, light gray	10	355	
Limestone, fine to medium crystalline, dolomitic, gray to light tan	10	365	
Dolomite, fine to medium crystalline, light to dark brown	15	380	
Dolomite, fine crystalline, slightly vuggy, light to dark brown	10	390	
Dolomite, fine crystalline slightly argillaceous, slightly gypsiferous, light grayish-tan to light brown	15	405	
Limestone, dense, argillaceous, white to light gray, with trace of gray shale	5	410	
Limestone, dense, slightly argillaceous, light gray to light tan	5	415	
Limestone, dense, sandy, slightly dolomitic, white to light gray	5	420	
Limestone, dense, sandy, dolomitic, white to light gray, with some brownish-green and grayish-brown dense dolomite	5	425	

ACC Well No. 1 - Continued

Description	Thickness	Depth	Remarks
Dolomite, dense, slightly vuggy, gray, blue-gray and light tan	5	430	
Dolomite, dense, slightly sand, light tan, white and light gray	5	435	
Dolomite, dense, light tan and light gray	15	450	
Dolomite, medium crystalline, light tan and dark grayish brown	4	455	
Dolomite, medium crystalline, medium porous, dark brown	5	460	
Dolomite, fine crystalline slightly vuggy, white to whitish-tan	47	507	
Dolomite, medium crystalline, medium porous, white to whitish-gray	33	540	
Dolomite, medium to coarse crystalline, white to whitish-gray	5	545	
Dolomite, fine crystalline, white, gray, and pink	5	550	
Dolomite, fine crystalline, white and pink	10	560	
Dolomite, fine to medium crystalline, white and pink	10	570	
Dolomite, fine to medium crystalline, white, whitish-gray, and yellow	15	585	
Dolomite, fine to medium crystalline, white, yellow, and pink	5	590	
Dolomite, fine to medium crystalline, white and whitish-gray	40	630	
Dolomite, very fine crystalline, soft, white to whitish-gray, with some crystalline quartz	5	635	

ACC Well No. 1 - Continued

Description	Thickness	Depth	Remarks
Dolomite, very fine crystalline, gypsiferous, white to whitish-gray, with some crystalline quarts and trace of green shale	5	640	
Dolomite, very fine crystalline, soft to hard, white and whitish-gray	5	645	

ACC Test Boring[2]

Description	Thickness	Depth	Remarks
Sand	8	8	
Sand, muddy	7	15	
Sand and some small gravel	9	24	
Sand, muddy	3	27	
Clay	118	145	
Clay, gravelly	18	163	

1 Water well records, from the Division of Water, Department of Natural Resources, State of Indiana, Indianapolis, Indiana.

2 from Rosenshein and Hunn, 1962.

ACC Well No. 1 - Continued

Description	Thickness	Depth	Remarks
Dolomite, very fine crystalline, gypsiferous, white to whitish-gray, with some crystalline quarts and trace of green shale	5	640	
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ACC Test Boring[2]

Description	Thickness	Depth	Remarks
Sand	8	8	
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1 Water well records, from the Division of Water, Department of Natural Resources, State of Indiana, Indianapolis, Indiana.

2 from Rosenshein and Hunn, 1962.

Section 6.2.21

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Industrial Disposal Well Case Study: Unidynamics, Phoenix, Inc.
AUTHOR: (or INVESTIGATOR)	Engineering Enterprises, Inc. (Prepared for USEPA Region IX)
DATE:	November, 1986
FACILITY NAME AND LOCATION:	Unidynamics, Inc. Goodyear, Arizona USEPA Region IX
NATURE OF BUSINESS:	Defense and Aerospace Equipment
BRIEF SUMMARY/NOTES:	Wells and ponds were used to dispose of solvents. Groundwater contamination on site has been documented downgradient of the wells. TCE has migrated into a drinking water aquifer. The wells were closed in 1982.

UNIDYNAMICS PHOENIX, INC.
INDUSTRIAL DISPOSAL WELL CASE STUDY

I. Site Background

UniDynamics is located at 1000 N. Litchfield Road in Goodyear, Arizona, approximately fifteen miles west of downtown Phoenix. The surrounding area is a combination of medium-light density commercial, industrial, agricultural and residential zoned developments. The plant facilities are located on a 24 acre plot in the center of a 72 acre tract owned by UniDynamics. The nearest residential area is approximately 100 yards to the southeast, across N. Litchfield Road.

UniDynamics Phoenix is a division of UML Industries, Inc. The Phoenix facility was established in 1963 as a research, development and manufacturing plant for defense and aerospace equipment. Typical products include: separation and recovery systems, safing, arming and fusing devices, destruct systems, and pyrotechnic devices and munitions. The manufacturing operations are primarily limited to the machining and assembly of mechanical and electrical components. Plant operations vary somewhat from year to year depending on the nature of the current contract(s) (Ecology and Environment Inc., 1986).

Eleven industrial disposal wells (5W20) and two unlined oxidation ponds were formerly used by UniDynamics Inc. to dispose of a variety of solvents. All disposal wells at the Litchfield site have since been abandoned. Nine groundwater monitoring

wells have been installed by Unidynamics to evaluate the vertical and areal extent of groundwater contamination below the facility. The Phoenix-Litchfield Airport Area (of which Unidynamics is a part) has been designated a Superfund (CERCLA) site by the Environmental Protection Agency (EPA). Hydrogeologic investigations have been conducted at three facilities in the Phoenix-Litchfield Airport Area: the Litchfield Naval Air Facility, the Goodyear Aerospace Corporation facility and the Unidynamics facility (Ecology and Environment, Inc., 1986). Refer to Figure 2 for the locations of these facilities. EPA Region IX is the lead regulatory agency overseeing the hydrogeologic investigation.

II. Chemicals Handled On-Site

UniDynamics Inc. provided information to the Maricopa County Health Department stating that in 1977 the company used five solvents at the facility. In 1981, UniDynamics reported additional solvents which were being either treated, stored or disposed of at the site. These solvents were listed in Unidynamic's Hazardous Waste Part A Permit Application, and Notification of a Hazardous Waste site. The names and reported disposal quantities of chemicals formerly used at the site are listed in Table 1. (EPA Region IX, Docket No. 84-03, 1984)

The disposal of trichloroethylene (TCE) at a rate of approximately 1,000 gallons per year since 1963 is of major concern. TCE has been demonstrated to cause cancer in animals and has also

TABLE 1[1]

CHEMICALS TREATED, STORED OR DISPOSED OF ON-SITE

Compound	Quantity Disposed (gal/yr)
Trichloroethylene (TCE)	1180
Isoprophyl Alcohol	660
Methyl Ethyl Ketone	220
Acetone	165
Toluene	60
Trichloroethane (TCA)	NR[2]
Methanol	NR
Arsenic Trioxide	NR
Copper Cyanide	NR
Cyanides	NR
Cyanogen	NR
Sodium Azide	NR
Sodium Cyanide	NR
Anilin	NR
Benzene	NR
Benzidine	NR
Calcium Chromate	NR
Chloroform	NR
Di-n-Butyl Phthalate	NR
Ethyl Acetate	NR
Formaldehyde	NR
Nitrobenzene	NR
Toluene Disocyanate	NR
Dichloromethane	NR

(1) EPA Region IX, Docket Number 84-03, 1984.

(2) Not Reported

been shown to be a mutagenic material in certain laboratory tests. Short term exposure to TCE has been reported to produce liver and kidney damage and central nervous system disturbances in mammals, including humans. The EPA has determined in its ambient water quality criteria that 2.7 ppb of TCE would be expected to produce one additional case of cancer in a population of one million (F.R./Vol.45, No. 231/ November 28, 1980/p. 79341).

III. Site Geology/Hydrology

The following hydrogeologic section has been excerpted and condensed from:

- Kenneth D. Schmidt's, "Results of the First Phase of the Hydrogeologic Studies at the Unidynamics, Phoenix, Inc. Goodyear Facility", (1985) and

- Ecology and Environment Inc.'s "Phase I Data Summary/Report Phoenix-Litchfield Airport Area" (1986).

Alluvial deposits which lie below the UniDynamics facility to a depth of 250 feet are part of the Upper Alluvial Unit (UAU). Within the UAU, lithologic logs and electric logs indicate the presence of four distinct geologic units in the upper 150 feet. From a depth of approximately 50 to 90 feet, stream channel deposits (a majority of the materials are coarser than sand) are present. These deposits are the most permeable of those encountered to a depth of 250 feet. The deposits overlying the stream channel sands and gravels often contain significant amounts of

clay. A significant clay stratum underlies these upper coarse-grained deposits at a depth of 90 feet, and averages 15 feet in thickness. (Schmidt, 1985)

Deposits below the 90 foot clay stratum are more cemented than the overlying materials, and sand is usually predominant. These deposits are not as permeable as the upper coarse-grained deposits above the clay stratum, and particles larger than gravel are uncommon. A major clay-silt stratum of low permeability is present from about 175-195 feet in depth. Fine grained deposits also predominate from 210 to 230 feet in depth. The strata between 175 and 230 feet probably act as a confining bed between the overlying and underlying deposits. Highly permeable sand is encountered from a depth of 237 to 250 feet. This appears to be the most permeable stratum in the interval between 100 and 250 feet in depth at the facility (Schmidt, 1985).

Two major water-producing units are present above a depth of 250 feet. These occur in the 80 to 170 foot and 230 to 250 foot depth intervals. Depth to water below the facility ranged from 79 to 88 feet below land surface from June 1984 to January 1985. Static water level measurements on-site indicated a hydraulic gradient in the shallow aquifer directed toward the north-northwest at a slope of 6.4 feet per mile. Static water level measurements were also taken in off-site water supply wells. These measurements confirmed a northerly direction of flow in the shallow aquifer beneath the facility. Measurement from off-site

wells completed in the deeper strata indicate a northwest hydraulic gradient within the deeper water producing unit. (Schmidt, 1985)

Aquifer tests (pump tests) were conducted on-site to determine the transmissivity and hydraulic conductivity of tapped portions of the UAU. An aquifer test was conducted at each monitoring well. Water levels at each well were continuously monitored during the drawdown and recovery of the aquifer(s). Aquifer tests indicated that aquifers tapped by intermediate and deep monitoring wells (195'-342' below land surface) appeared to have a good hydraulic connection. The tests also indicated that the shallow water bearing subunits (77'-159' below land surface) could at least be partially isolated from the deeper saturated strata. (Ecology and Environment, Inc., 1986)

Groundwater aquifers below the UniDynamics facility are Underground Sources of Drinking Water (USDW). Based on National Primary and Secondary Drinking Water Regulations, untreated groundwater in the upper zone (80-170 feet below land surface) is unsuitable for drinking water. Total dissolved solids (TDS), nitrate, chloride, and sulfate concentrations in samples from the aquifer exceeded National Primary and Secondary Drinking Water Regulations. Total dissolved solids concentrations, however, were below 10,000 mg/l. The upper aquifer, therefore, can be considered an USDW. Untreated groundwater from the lower aquifer of the UAU (230 to 250 feet below land surface) is also unsuit-

able for drinking water. TDS, nitrate, chloride and sulfate concentrations also exceeded Primary and Secondary Drinking Water Regulations in the aquifer (Ecology and Environment Inc., Table 4.4, 1986). Groundwater occurring at depths greater than 250 feet below land surface is the primary source of drinking water for approximately 5,250 people in the Goodyear-Avondale area (EPA Region IX, Docket No. 84-03, 1984). The City of Goodyear Well #4, located on UniDynamics property, formerly pumped groundwater from depths of 400-515 feet. This water was used by the City of Goodyear before the State of Arizona requested the well's closure.

IV. Identification of Possible On-Site Contaminating Point Sources

The following information has been derived from the EPA's, "Appendix Narrative to the Site Inspection Report - UniDynamics", (1980). UniDynamic employees interviewed by EPA Region IX during their site inspection included three chemists, a safety director, and a manufacturing services manager. Their statements regarding waste discharges at the facility are collectively summarized below.

Most waste chemicals used at the UniDynamics facility between 1963 and 1978 were disposed of on-site. Prior to 1978, a small percentage of TCE was reclaimed by Southwest Solvents of Chandler, Arizona. TCE was disposed of by spraying the solvent on UniDynamic's land to eradicate weeds, or poured into the dis-

posal wells. Based on EPA interviews, exact quantities of TCE and the particular wells into which TCE was disposed could not be identified. Other solvents were disposed of in the 11 disposal wells and 2 unlined oxidation ponds.

Eight of the disposal wells received effluent from settling basins, while the other three wells, located outside the manufacturing building, had wastes disposed directly into them. The location of the disposal wells are indicated in Figure 1. Disposal Wells #1 and #2, and one oxidation pond received principally wash and cooling water with traces of process chemicals from the Ordance Assembly and Test Areas (buildings 3, 17). One oxidation pond was reported to have been teeming with fish life at the time of the EPA site inspection in July of 1980. The manufacturing services manager of UniDynamics stated that less than 50 gpd of cooling process water went to each well or pond.

Disposal Wells #3, #4, #5, and #6, and the other oxidation pond received waste from the Powder Processing Area (Building 11). The waste stream consisted almost entirely of water and detergent used to wash lab glassware. Small amounts of heat powder and process chemicals were also contained in this water.

Disposal Well #7 received a variety of waste streams from the Explosive Production Lab. Cobalt nitrate, ammonium carbonate and perchloric acid were collected in a tank, neutralized, and pumped into Well #7. Lab wash water was collected in a separate

LOCATION OF MONITORING
AND DISPOSAL WELLS

609.012.03

ENGINEERING ENTERPRISES, INC.

Figure 1

[6-234]

tank and pumped to bushes on the south border of the plant site. This practice was discontinued in 1978.

The remaining four disposal wells, #8, #9, #10 and #11 had waste solvents placed directly into them from the Manufacturing and Machine Shop Area. UniDynamic's assembly plant manager stated that a total of 5-10 gallons per week of methyl ethyl ketone, acetone, isopropyl alcohol, and diacetone alcohol was discarded.

V. Disposal Well Descriptions

All but two or three of the disposal wells at UniDynamics have been in existence since 1963 (EPA Site Inspection Report, 1980). The last two wells were drilled in 1976 and 1979. According to the 1980 EPA Site Inspection Report (1980), the wells are 30 to 35 feet deep, approximately 30 inches in diameter and backfilled with baseball-sized rocks. The newer wells are topped by concrete collars, and the well drilled in 1979 contains a perforated tube (EPA Site Inspection Report, 1980). The disposal wells at UniDynamics have not been in use since 1980. These wells have not been plugged but are reported to be silted up (Rosenbloom, 1986).

VI. Facility Investigation - On-Site

UniDynamics Inc. retained Dr. Kenneth Schmidt, a private groundwater quality consultant, and Dames and Moore to conduct a hydrogeologic investigation at the UniDynamics Litchfield Facility. The investigation was conducted during the months of

October 1984 through July 1985 (Ecology and Environment, Inc., 1986).

Nine groundwater monitoring wells were installed at the site (Refer to Figure 1). These wells were installed in order to provide information on the vertical and horizontal variations in lithology, water quality, and hydraulic properties of the UAU. The wells also enabled UniDynamic's consultants to evaluate the vertical and areal extent of groundwater contamination in the UAU below the facility. (Ecology and Environment, Inc., 1986)

The first four monitoring wells, MW-1 through 4, were installed by Ken Schmidt in October 1984 to provide information on the shallow portion of the UAU (less than 190 feet). The second set of monitoring wells, MW-5 through 9, was installed by Dames and Moore in April 1985 to supplement Ken Schmidt's findings. Wells MW-5 and MW-6 were screened at depths of 195.5 ft. - 235.5 ft. and 302 ft. - 342 ft. respectively. These wells provided more extensive information on the lithology, water quality and hydraulic properties of deeper subunits within the UAU. Wells MW-7, MW-8, and MW-9 provided additional information on the lateral extent of contamination and stratigraphy in the upper 135 feet of the UAU. Construction details of the nine monitoring wells on-site are presented in Table 2. (Ecology and Environment, Inc., 1986)

Prior to installing the second set of wells, UniDynamics contracted Tracer Research Corporation (TRC) to conduct a soil

TABLE 2

MONITORING WELL DRILLING AND CONSTRUCTION DATA

(Ecology and Environment, 1986)

Well Number	Location in State Plane Coordinates	Elevation in Feet Above MSL	Depth Drilled/ Date Completed	Nominal Borehole Diameter/Depth	Well Casing Blank Depth *1	Screened Interval *2	Protective or Surface Casing	Gravel Pack	Well Seals	Pump Depth *3	Remarks
9UMW-5	8775.28N 9246.47E	984.0	460 ft. 04/25/86	12 1/4" from 0-210 ft. 6 3/4" from 210-450 ft. 8 3/4" from 210-239.75 ft.	+0.5-235.5 ft., blank from +0.5-195.5 ft.	195.5-235.5 ft	9 5/8 O.D. steel from +0.5 to 195 ft., grouted	Natural pack	Bentonite 189-195 ft. Grout 0-5 ft.	128 ft.	Intermediate Well. Hole plugged from 240-450 ft. (pilot hole)
9UMW-6	8735.78N 9202.55E	989.6	350 ft. 04/24/86	12 1/4" from 0-305 ft. 8 3/4" from 305-350 ft.	+0.5-342 ft., blank from +0.5-302 ft.	302-342 ft.	9 5/8 O.D. steel from +0.5 to 300 ft., grouted	Natural pack	Bentonite 301-295 ft. Grout 0-5 ft.	128 ft.	Deep well
9UMW-7	9490.33N 9534.46E	988.4	135 ft. 04/05/86	12 1/4" from 0-135 ft.	+0.5-127.5 ft., blank from +0.5-77.5 ft.	77.5-127.5 ft.	8' O.D. steel from +0.5-19.5 ft., grouted	Tacoma #2 75-132 ft.	Grout 0-69 ft.	117 ft.	Shallow well
9UMW-8	8753.99N 8818.56E	985.6	135 ft. 04/19/86	12 1/4" from 0-135 ft.	+0.5-128 ft., blank from +0.5-78 ft.	78.0-128.0 ft.	8' O.D. steel from +0.5-20.0 ft., grouted	Tacoma #2 74-131 ft.	Grout 0-70 ft.	117 ft.	Shallow well
9UMW-9	9166.86N 9028.23E	983.2	132 ft. 04/08/86	12 1/4" from 0-135 ft.	+0.5-127.5 ft., blank from +0.5-77.5 ft.	77.5-127.5 ft.	8' O.D. steel from +0.5-20.0 ft., grouted	Tacoma #2 75-134 ft.	Grout 0-72 ft.	117 ft.	Shallow well

*1 6 5/8" O.D. Flush threaded, Schedule 80 PVC, end cap on bottom, Centralizers every 50 feet
*2 6 5/8" O.D. Flush threaded, Schedule 80 PVC, slot size - 0.04", slot spacing - 0.125", 72 slots/row, 8 rows/foot
*3 Grundfos Model SP4-8, 3/4 HP, 230V, range: 11-28 gpm, average 20 gpm, stainless steel

TABLE 2 (continued)

MONITORING WELL DRILLING AND CONSTRUCTION DATA

(Ecology and Environment, 1986)

Well Number	Location in State Plane Coordinates	Elevation in Feet Above MSL	Depth Drilled/ Date Completed	Nominal Borehole Diameter/Depth	Well Casing *1 Blank Depth	Screened *2 Interval	Protective or Surface Casing	Gravel Pack	Well Seals	Pump Depth	Remarks
SLMW-1			250	12"/250'	99	99-159	30'		0-90		
SLMW-2			150	12"/150'	89	89-129	30'		0-80		
SLMW-3			145	12"/145'	89	89-129	30'		0-80		
SLMW-4			145	12"/145'	89	89-129	30'		0-80		

*1 6 5/8" O.D. flush threaded, Schedule 80 PVC, end cap on bottom, Centralizers every 50 feet

*2 6 5/8" O.D. flush threaded, Schedule 80 PVC, slot size - 0.04", slot spacing - 0.125", 72 slots/row, 8 rows/foot

gas survey in January 1985. The results of the soil gas survey were used as an indirect method of measuring the extent and concentrations of groundwater contamination, and aided in placement of wells MW-5 through MW-9 (Ecology and Environment, Inc., 1986).

Groundwater samples from each monitoring well were collected. Samples were withdrawn from MW-1, 2, 3 and 4 during October 30 through November 1, 1984. These samples were collected during pump tests and were analyzed for volatile organic aromatics (VOA) only. Additional samples were collected from MW-1 through MW-4 on November 7, 1984 and January 8, 1985. Samples collected in the second sampling round (November, 1984) were analyzed for inorganic and trace organic compounds. Analyses of the January 1985 samples were limited to VOA and selected inorganic constituents (Ecology and Environment Inc., 1986).

Monitoring wells MW-5 through MW-9 were sampled by Dames and Moore during the aquifer tests conducted from April 30 through May 8, 1985. Groundwater samples were collected after five borehole volumes of water were evacuated, halfway through the pumping period, and just before recovery was allowed to begin. The first two samples were collected for VOA analyses. The third sample (collected at the end of each pump test) was analyzed for major cations, major anions, and constituents included on the EPA Hazardous Substances List. (Ecology and Environment Inc., 1986)

Trichloroethylene (TCE) concentrations detected in Monitoring Wells 1-4 are presented in Table 3. Concentrations of organic compounds detected in Monitoring Wells 5-9 are listed in Table 4. The inorganic quality of groundwater sampled from the nine monitoring wells is summarized in Table 5. A discussion of the analytical results presented in these tables is included in Section VIII of this case study.

VII. Facility Investigation - Off-Site

In September 1982, the Environmental Protection Agency initiated a groundwater sampling program of wells located in the Phoenix Litchfield Airport Area. This included the sampling of the Park Shadows Irrigation Well located 3/4 of a mile southeast of the UniDynamics facility (Refer to Figure 2). Dr. Ken Schmidt, in November 1984, sampled five off-site water supply wells within one mile of the UniDynamics facility. All samples were analyzed for volatile organic compounds using EPA Method 601. Wells sampled by Schmidt with their locational coordinates and perforation intervals are presented in Table 6. The location of these wells relative to the UniDynamics property is shown in Figure 2. Groundwater levels were also measured by Schmidt in each of the off-site wells sampled.

VIII. Discussion of Disposal Well Contamination Data

The contamination of groundwater below the UniDynamics Facility has been documented. Concentrations of trichloroethene (TCE) in the shallow groundwater aquifer have been detected up to

TABLE 3

TCE CONCENTRATIONS IN MONITORING WELLS 1-4

Date	TCE Content (ppb) MW-1	MW-2	MW-3	MW-4
10/30 - 11/1/84*1	<0.5	15,000	14,000 (15,000)	46,000
11/7/84*1	2.5	61,000 (86,000)*2	13,000	42,000
1/8/85*1	2.1	77,000 (83,000)	26,000	55,000
5/13/85*3	<0.5	64,000	28,000	35,000 (97,000)

*1 After Schmidt, January 1985

*2 Values in parentheses are for duplicate samples

*3 Results from Dames & Moore, May 1985

TABLE 4

ORGANIC CONSTITUENTS DETECTED IN MONITORING WELLS 5-9

USING EPA METHODS 624, 625 and 608 #1

Constituent	MW-5 05/02/85 0822	MW-5 05/02/85 1005	MW-5 05/12/85 1145	MW-6 04/30/85 0806	MW-6 04/30/85 1000	MW-6 04/30/85 1153	MW-6 04/30/85 blank	MW-7 05/08/85 0845	MW-7 05/08/85 1100	MW-7 05/08/85 1350	MW-8 05/01/85 1130	MW-8 05/01/85 1245	MW-8 05/01/85 1345	MW-9 05/06/85 1300	MW-9 05/06/85 1400	MW-9 05/06/85 1550
Carbon Tetrachloride	•	•	•	•	•	•	•	11	•	•	3.4	5.5	7.2	•	•	•
Chloroform	•	•	•	•	•	•	1.5	30	6.0	7.0	•	•	•	•	1.2	•
Tetrachloroethene	•	•	•	•	•	•	•	52	12	13	1.5	1.7	2.0	•	•	•
Trichloroethene	•	•	•	3.2	3.6	2.7	•	19000	11000	11000	950	1300	1600	58	29	33
Benzene	•	•	•	•	•	•	•	9.8	•	•	•	•	•	•	•	•
1,1,1-Trichloroethane	•	•	•	•	•	•	•	6.8	•	•	•	•	•	•	•	•
1,1-Dichloroethene	•	•	•	•	•	•	•	39	1.5	8.0	•	•	•	•	•	•
Methylene Chloride	•	•	•	•	•	•	•	200	•	•	•	•	•	•	•	•

• Not detected

#1 After Dames and Moore, July 1985

UNIT: ug/l (ppb)

TABLE 5

INORGANIC WATER QUALITY

(all concentrations in mg/l (ppm))

(Ecology and Environment, 1986)

Constituent	MW-1 11/07/84	MW-1 05/13/85	MW-2 11/07/84	MW-2 05/13/85	MW-3 11/07/84	MW-3 05/13/85	MW-4 11/07/84	MW-4 05/13/85
Calcium	527	527	410	420	310	247	365	271
Magnesium	214	214	150	155	113	93	130	104
Sodium	810	1120	580	920	670	990	630	960
Potassium	8	7.6	10	7.1	8	5.8	8	6.4
Chloride	920	991	870	1073	720	800	720	881
Bicarbonate	315	390	242	300	267	354	268	344
Sulfate	2440	2800	1340	1840	1340	1650	1390	1600
Nitrate	51	43.4	62	58.5	57	48.7	57	48.7
Fluoride	0.24	1.6	0.54	0.19	0.29	0.24	0.24	0.22
Iron	<0.05	<0.05	0.09	<0.05	0.19	0.06	0.15	0.07
Manganese	<0.01	<0.01	0.01	<0.01	0.04	<0.01	0.01	<0.01
Zinc	NT	NT	NT	NT	NT	NT	NT	NT
Boron	4.3	4.0	3.7	3.8	2.9	3.2	2.9	3.2
Tin	NT	NT	NT	NT	NT	NT	NT	NT
Aluminum	NT	NT	NT	NT	NT	NT	NT	NT
Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Barium	0.9	<0.5	0.6	<0.05	<0.5	0.5	<0.5	<0.5
Silica	38	38	36	36	34	30	35	30
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury	0.0002	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002
Selenium	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	<0.01	NT	<0.01	NT	<0.01	NT	<0.01	NT
Copper	NT	NT	NT	NT	NT	NT	NT	NT
Cyanide	NT	NT	NT	NT	NT	NT	NT	NT
Vanadium	NT	NT	NT	NT	NT	NT	NT	NT
Antimony	NT	NT	NT	NT	NT	NT	NT	NT
Total Dissolved Solids @ 180°C	5257	6200	3697	4780	3327	4045	3497	4090
pH	7.0	6.86	7.2	7.1	7.4	7.41	7.3	7.4
EC (micromhos/CM @ 25°C)	7600	7000	5100	6100	4800	5350	5000	5500
Temperature (°C)	22.2	24.6	22.7	25.1	22.2	24.5	22.2	24.4

ND - Not Detected
NT - Not Tested

TABLE 5 Cont.

INORGANIC WATER QUALITY

(all concentrations in mg/l (ppm))

Constituent	MW-5 05/02/85	MW-6 04/30/85	MW-7 05/08/85	MW-8 05/01/85	MW-9 05/06/85
Calcium	492	NT	357	NT	294
Magnesium	220	NT	139	NT	111
Sodium	124	NT	550	NT	580
Potassium	6.3	NT	6.2	NT	5.7
Chloride	899	NT	712	NT	796
Bicarbonate	150	NT	288	NT	311
Sulfate	925	NT	1370	NT	985
Nitrate	71.8	NT	43.4	63.8	54.9
Fluoride	2.4	NT	0.2	NT	0.19
Iron	0.17	0.11	0.21	0.70	0.48
Manganese	<0.01	0.01	0.04	0.20	0.02
Zinc	0.06	0.04	0.09	0.18	0.10
Boron	0.19	NT	2.5	NT	1.9
Tin	ND	<0.01	ND	0.01	<0.01
Aluminum	ND	<0.5	ND	0.5	<0.5
Arsenic	NT	<0.01	<0.01	<0.01	<0.01
Barium	<0.5	<0.5	<0.5	<0.5	<0.5
Silica	20	NT	22	NT	30
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Selenium	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	<0.01	<0.01	<0.01	<0.01	<0.01
Cyanide	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	<0.5	<0.5	<0.5	NT	<0.5
Antimony	<1.0	<1.0	<1.0	<1.0	<1.0
Total Dissolved Solids @ 180°C	3275	NS	3480	NT	3090
pH	7.09	7.29	7.04	7.04	6.89
EC (micromhos/CM @ 25°C)	4250	2250	4500	3350	4350
Temperature (°C)	27.4	28.2	24.5	25.5	25.5

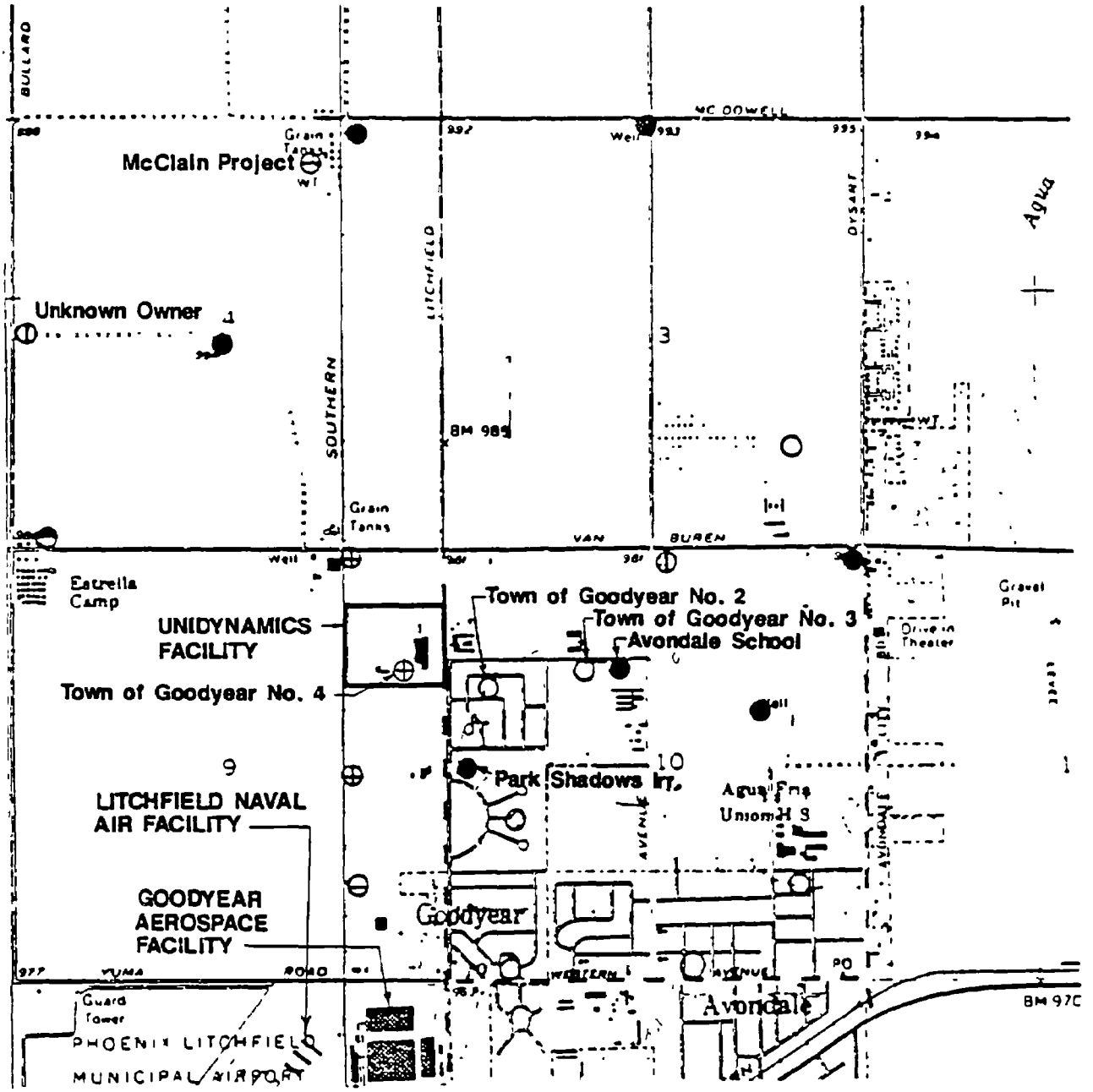
ND - Not Detected
NT - Not Tested

EXPLANATION

- ○ Public Supply
- ● Irrigation
- ◒ Domestic
- ⊖ Industrial
- ◐ Unused
- ⊕ Backfilled or Plugged

N

Scale (approx) 1"=2000'



LOCATION OF WELLS INVENTORIED IN NOVEMBER 1984

20

ENGINEERING ENTERPRISES, INC.

709.012.06 Figure 2

[6-245]

TABLE 6[1]

GENERAL INFORMATION:
SAMPLED OFF-SITE WELLS

Location and Construction Details of Off-Site Wells Sampled

Well Name	Type	Direction from UniDynamics	Perforated Interval (FT)	Depth to Groundwater (FT)
McClain Project	Industrial	north	---	93.8
---	Domestic	west northwest	75-250	107.2
Town of Goodyear 2	Irrigation	southeast	368-514	76.4
Avondale School	Irrigation	east	150-300	69.5
Town of Goodyear 3	Public Supply	east	246-260	*

(1) Schmidt, 1985.

(2) —: Unknown

(3) *: not measured

86,000 ppb. As noted earlier, the EPA has determined in its ambient water quality criteria that 2.7 ppb of TCE would be expected to produce one additional case of cancer in a population of one million. The State of Arizona has also established a Drinking Water Action Level of 5 ppb for TCE.

Concentrations of TCE in groundwater below the facility are highest in shallow monitoring wells downgradient of Disposal wells 8, 9, 10 and 11 (Refer to Figure 1). The highest TCE concentrations were found in MW-4, located approximately 325 feet northwest of disposal wells 8 through 11. TCE concentrations in water sampled from MW-2 were as high as 86,000 ppb. The next highest TCE concentration (55,000 ppb) detected in groundwater below the site was found in water sampled from MW-4. TCE was detected in MW-3, located west of MW-2, in concentrations up to 26,000 ppb. Chloroform and Freon-113 were also detected in MW-3 in concentrations of 91 ppb and 54 ppb, respectively.

Two monitoring wells downgradient of Disposal Wells 8 through 11 were completed in the middle and lower sections of the UAU (MW-5 and MW-6). TCE concentrations found in waters tapped by MW-5 (195-236 feet below land surface) and MW-6 (302-342 feet) were below the Arizona Drinking Water Action Limit (5 ppb) for TCE.

Tricholoroethylene concentrations found in the remaining shallow monitoring wells ranged from 0.5-11,000 ppb. TCE concentrations in MW-1 (upgradient from disposal wells 8, 9, 10

and 11) ranged from less than 0.5 ppb to 2.5 ppb. Concentrations of TCE found in groundwater downgradient of Disposal Wells 3 through 6 (MW-8) ranged from 11,000-19,000 ppb.

Groundwater from the Town of Goodyear Well #4 was also contaminated with TCE. Prior to the well's closure in 1984, samples were withdrawn from the well by the Arizona Department of Health Services and the EPA. These samples contained 20.1 and 32 ppb TCE respectively (EPA Region IX, Docket No. 84-03, 1984). These results are especially significant; contaminated groundwater was obtained from the well at a depth of 400-515 feet below land surface. Groundwater contamination from UniDynamic's operations therefore, may not be limited to the upper water bearing strata.

Volatile organic compounds (other than TCE) were detected in at least one round of samples from Monitoring Wells 3, 7, 8 and 9. The widest variety of volatile organic compounds were detected in MW-7. Chloroform, tetrachloroethylene (PCE), benzene, 1,1 dichloroethene and methyl chloride were detected in MW-7 at concentrations exceeding the Arizona Department of Health Services' Interim Water Quality Criteria. Of these constituents, PCE was the most concentrated in MW-7 at 52 ppb. Carbon tetrachloride and PCE concentrations exceeded the State's Interim Water Quality Criteria in MW-8. Both constituents were detected in concentrations below 10 ppb. Chloroform was detected in MW-8 at 1.2 ppb, exceeding the State's Interim Water Quality Criterion

of 0.5 ppb. As noted earlier, chloroform was also detected with freon-113 and PCE. Concentrations of these constituents in MW-3 were between 50 and 100 ppb. It is currently unknown if these chemicals are products of in-situ reactions or whether they were directly introduced into the subsurface. Off-site groundwater contamination resulting from UniDynamics disposal practices has not been documented. Off-site wells sampled by Schmidt (which are listed in Table 6) contained volatile organic compounds in concentrations below 0.5 ppb. An irrigation well sampled (see Park Shadows Irrigation Well, Figure 2) by EPA Region IX was found to contain 5.6 ppb TCE in 1982. The source of this contamination has not been determined.

IX. Assessment

Groundwater contamination on-site has been documented downgradient of UniDynamics disposal wells. The analytical results of samples withdrawn from shallow Monitoring Wells MW-1, 2, 3, 4, 7 and 8 implicate the disposal wells as former sources of groundwater contamination.

Groundwater present in the 80-170 foot depth interval of the Upper Alluvial Unit is contaminated below the site. All samples collected from monitoring wells perforated in this zone contained trichloroethylene (TCE). Concentrations of TCE detected in this zone were thousands of times greater than Arizona's TCE Drinking Water Action Limit of 5 ppb. Groundwater samples withdrawn from a second water producing unit (230-250 feet below land surface)

contained TCE in concentrations below 5 ppb. It is currently unknown whether this aquifer is in hydraulic communication with the upper water bearing unit. Groundwater sampled from aquifer(s) deeper than 250 feet below land surface was also shown to be contaminated. Samples withdrawn from the Town of Goodyear #4 Well in 1982 contained TCE in concentrations below 5 ppb. It is currently unknown whether this aquifer is in hydraulic communication with the upper water bearing unit. Groundwater sampled from aquifer(s) deeper than 250 feet below land surface was also shown to be contaminated. Samples withdrawn from the Town of Goodyear #4 Well in 1982 contained TCE concentrations ranging from 20-32 ppb. (This well was perforated from 400-515 feet below land surface.) Point sources which may have caused the contamination of this deeper stratum are the disposal wells at the UniDynamics facility or the disposal trench and pond system located on the Goodyear Aerospace-Naval Airfield properties. (TCE was disposed of in the Goodyear Aerospace ponds and groundwater contamination below the site has been documented [Ecology and Environment Inc., 1986].)

Untreated groundwater contained in the water bearing units occurring at 80-170 feet and 230-250 feet below land surface is unsuitable for drinking water. Nitrate, sulfate, and chloride concentrations in these aquifers are above National Primary and Secondary Drinking Water Regulations. Groundwater occurring below 250 feet, however, is used by the Town of Goodyear for

drinking water. As discovered in Goodyear Well #4 (located on UniDynamics property), TCE has migrated into this drinking water aquifer in limited areas of the Phoenix-Litchfield area.

The off-site sampling programs have provided no evidence to date that TCE has migrated off the UniDynamics site. Of the five off-site wells sampled by Schmidt, however, only two are downgradient from the UniDynamics facility. Additional monitoring wells along the property's north and west boundaries would enable investigators to better delineate the TCE contamination plume(s). Because UniDynamics' disposal wells formerly injected:

- wastes above a USDW currently used as a drinking water source,
- wastes containing chemicals defined as "hazardous" under 40 CFR Part 261 Subpart D,
- wastes judged to be of significant volume and concentration to potentially migrate beyond UniDynamic's property boundaries,

these disposal wells are assessed to have posed a high potential to contaminate an USDW.

UNDERGROUND INJECTION CONTROL PROGRAM
FILE INVESTIGATION REPORT

SECTION I - General Information

Name of Facility: Unidynamics Phoenix, Inc.

Address: 1000 N. Litchfield Road
Goodyear, AZ 85062

Telephone: (602) 932-8100

Owner Address and Telephone (if different from above):

Unidynamics Phoenix, Inc.. P. O. Box 2990, Phoenix, AZ 85062-2990

Nature of Business: Research, development and manufacturing of defense and aerospace equipment.

Use of Injection Well (s) (drainage, direct disposal, etc.):
3 wells - direct disposal of TCE and other solvents
Others received effluent from settling basins

Identification, Permit or EPA Number (s): AZD - 008398620

Injection Well (s) Location (township, range and section, latitude and longitude, verbal description, land marks, etc.):

(on site)

Type of Injection Well (s) -
Industrial Drainage: x 5W20
Storm-runoff:
Other (specify):

Injection Well (s) Currently Operating: Yes _____ No X silted-up
temp. abandoned

If No, Last Date of Operation: 1978

Date of Construction of Injection Well (s): all but 2 or 3 have been in existence since 1963

Years Injection Well in Operation:
15 years

SECTION II - Hydrogeologic Information

Injection Formation - Name: Upper alluvial unit

- **Description:**
- **Extent of Injection Zone (s) Below Land Surface (or elevation above Mean Sea Level):**
- **Minimum Distance from Injection Well to Underground Source of Drinking Water (U.S.D.W.):**

Location (depth below land surface, areal extent, etc.) and description (thickness, lithology, etc.) of Any Relatively Impermeable Strata (aquitard (s)) Present:

Depth approximately 90'
Thickness approximately 15'

Underground Sources of Drinking Water -

Confined:

Unconfined:

Depth to Perched Water Table (if present): 80 ft.

Depth to Water: *80 ft. to perched zone, 230 ft. deeper unit*

Saturated Thickness: 90 ft. for perched zone, 20 ft.deeper unit

Description and Characteristics:

Extent of Use of U.S.D.W. (extensive, moderate, municipal, domestic, potential, etc.):

USDW is the primary source of water for approximately 5,250 people in the Goodyear/Avondale area.

Comments:

Attach the Following Information (note if unavailable) -

- X Map of Facility Grounds:
- Well Log (s) for Injection Well (s):
- As-built Diagram of Injection Well (s):
- X Consultant Reports for Injection Well (s) and/or Site Hydrogeology:
- X Monitoring Data for Injection Well:
- Monitoring Well Data -
  - X Number of Monitoring Wells:
  - X Location: Vertical and Horizontal Distance and Direction of Monitoring Well (s) From Injection Well:
  - X Depth of Completion and Sampling Interval:
  - X Chemical and Physical Analyses:
- Downgradient Water Supply Wells (within a one-quarter mile radius of the injection well) -
  - X Number of wells:
  - Location: Vertical and Horizontal Distance and Direction of Supply Well (s) from Injection Well:
  - Chemical and Physical Analyses:
  - X Status of Wells (operating, abandoned, etc.) Temp. abandoned
  - Status of Any Nearby Surface Waters (possibly affected by injection well operation):

SECTION III - Operating Data

Injection Rate, Frequency, and Volume (drainage area, precipitation, etc.)

TCE - 1000 gal/yr.
Isop. Alcohol - 660 gal/yr.
Toluene - 60 gal/yr.
Methly ethyl ketone - 220 gal/yr.
Acetone - 165 gal/yr.
Wash & coolant waters

Description of Injection Operation (including brief history):

Spent solvents were either sprayed to kill weeds or dumped down dry wells

Fluid Source: Industrial facility

Fluid Composition/Characteristics (including any treatment process): Solvents, acids

Most of the wells received effluent from selling basins. Three wells received untreated waste solvents

Contaminant (s) and Potential Source (s) of Contamination:

Method of Disposal (transport to well):

Piped

Previous Problems with Well (clogging, overflowing, etc.) -

No _____

Yes _____ **Description of Problem:**

Operating Records Attached: Yes _____ **No** X

Injection Fluid Analyses Attached: Yes _____ **No** X

SECTION V

Primary Contact Information Sheet

Name: Simon Navarro

Phone: (602) 257-2335

Address: 2005 North Central Avenue
Phoenix, Arizona 85004

Affiliation (local, state, federal, etc.):

ADHS

Notes:

Section 6.2.22

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Industrial Disposal Well Case Study: Honeywell, Peoria Avenue Facility
AUTHOR: (or INVESTIGATOR)	Engineering Enterprises, Inc. (Prepared for USEPA Region IX)
DATE:	November, 1987
FACILITY NAME AND LOCATION:	Honeywell, Peoria Avenue Facility Phoenix, Arizona USEPA Region IX
NATURE OF BUSINESS:	(Not Available)
BRIEF SUMMARY/NOTES:	Paint sludges, thinners, varnish, and solvents were disposed in two wells. Wastes generated by circuit board manufacturing processes were disposed in three wells. Given the hydrogeologic information collected to date, the threat to groundwater formerly posed by the disposal wells cannot be assessed. The wells were closed in 1982.

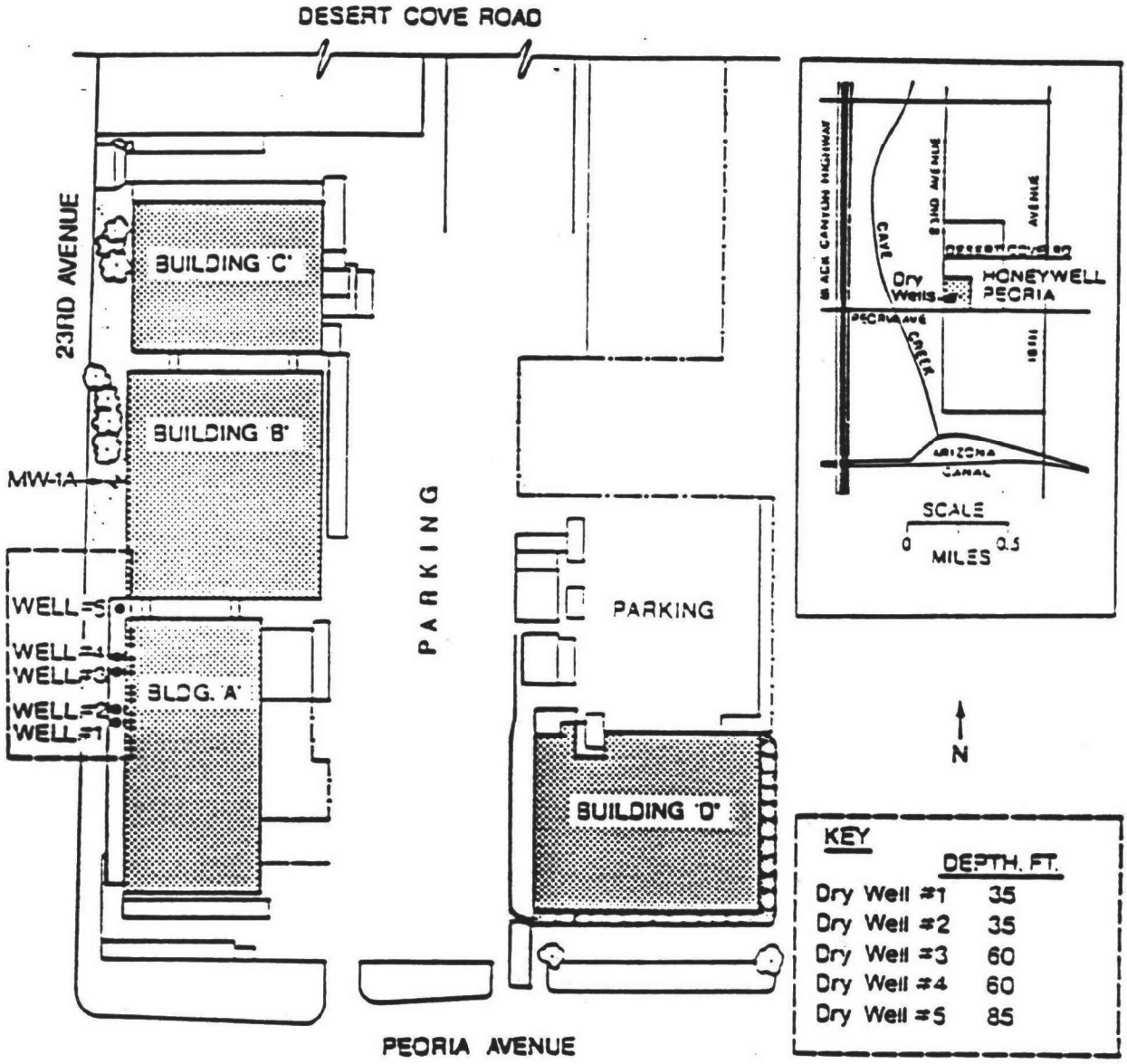
Honeywell's Peoria Avenue Facility
Industrial Disposal Well Case Study

I. Site Background

Between 1964 and 1979, a group of five industrial disposal wells (5W20) were used for waste disposal at Honeywell's Peoria Avenue Facility in Phoenix, Arizona. Paint sludges, thinners, varnish and solvents were disposed in two of the wells. Wastes generated by the plant's circuit board manufacturing process were disposed in the remaining three wells. Honeywell, after detecting groundwater contamination at its Deer Valley facility, voluntarily contacted the Arizona Department of Health Services about its disposal practices at its Peoria Avenue facility. Honeywell initiated the capping of all industrial disposal wells at the Peoria Avenue facility in February, 1982. The layout of the facility is indicated in Figure 1.

II. Chemicals Handled On-Site

The chemicals used in the circuit board manufacturing process consisted of copper plating solutions, sulfuric acid, fluoroboric acid and boric acid. These waste solutions contained heavy metals including copper, chromium, nickel, lead and tin. The other chemicals of concern are those associated with painting, such as thinner, varnish and solvents. An estimate of the contents and volumes of chemicals injected into the disposal wells is contained in Table 1.



(From Tetra Tech Inc.'s " Final Report Phase I Hydrogeologic Investigation...", 1985)

Figure 1. Honeywell - Peoria Avenue Facility: Disposal Well Location

ENGINEERING ENTERPRISES, INC.

Table 1

DISPOSAL WELL CHEMICAL CONTENT ESTIMATES*

CHEMICAL	7 YEAR CHEMICAL TOTAL	7 YEAR SOLUTION TOTAL
1. CUPOSIT #1175	64 GAL.	2,657.2 GAL.
2. SHIPLEY #746	919 GAL.	4,051 GAL.
H_2O_2	364 GAL.	
3. HCL	455 GAL.	2,548 GAL.
4. HCL	910 GAL.	2,548 GAL.
5. SHIPLEY CATALYST #9F	294 GAL.	1,176 GAL.
HCL	454 GAL.	
6. SHIPLEY ACCELERATOR #19	1,018 GAL.	2,548 GAL.
7. SHIPLEY COPPER 328A	74 GAL.	1,274 GAL.
328S	74 GAL.	
328C	15 GAL.	
8. SHIPLEY CUPOSIT #1175	114 GAL.	4,550 GAL.
9. AMMONIUM PERSULPHATE	13,104 LBS.	8,190 GAL.
	171 GALS.	7,280 GAL.
10.	1,456 GALS.	7,280 GAL.
11. COPPER PYROSULFATE		248 GAL.
M & T C-10-XB	83 GAL.	
M & T C-11-XB	8.75 GAL.	
	1.5 GAL.	
12. FLUOBORIC ACID (49% GRADE)	910 GAL.	9,100 GAL.
13. FLUOBORIC ACID (49% GRADE)	910 GAL.	9,100 GAL.
14. STANNOUS FLUOBORATE (40.6%)	11.5 GAL.	68 GAL.
LEAD FLUOBORATE (51%)	3.5 GAL.	
FLUOBORIC ACID (49%)	10 GAL.	
BORIC ACID	20 LBS.	
KENVERT RTL #324A	2.75 GAL.	
15. HCL	637 GAL.	1,310 GAL.
16. BORIC ACID	4.6 LBS.	14.7 GAL.
NICKEL CHLORITE	2.5 QT.	
NICKEL SULFAMATE	7.35 GAL.	
ANTIPIT ARIZ (M&T)	9.5 OZ.	

*Requested from Honeywell by ADHS

III. Site Geology/Hydrology

The following section has been excerpted from Tetra Tech Inc.'s report entitled, "Final Report: Phase I Hydrogeologic Investigation at Honeywell".

The Honeywell facility is situated in a large alluvial basin within a half mile of the North Phoenix Mountains. The alluvial basin is filled with unconsolidated sands and gravels to a depth of over 1000 feet. Within this large basin are volcanic plugs, such as the North Phoenix Mountains, which rise above the floor of the valley. These mountains are composed of relatively impermeable bedrock and, thus, act as a barrier to groundwater flow. Along the edge of such mountains, where erosion has begun to remove weathered debris, the aquifer materials may be coarser and, therefore, more permeable than in the central portion of the valley.

The alluvial basin sediments consist of upper, middle and lower units. The upper alluvial sand and gravel unit is recent alluvium, composed of unconsolidated and weakly consolidated gravel, volcanic and caliche fragments, sand, silt and clay. The thickness of this unit ranges from 0-1200 feet. In the vicinity of the Honeywell plant, well logs indicated a thickness of approximately 150-200 feet.

The underlying unit is a silty clay layer called the middle fine-grained unit (MFGU). This layer consists of fine grained material containing more than 50 percent silt and clay.

Constituents include gypsum, playa and alluvial deposits, stringers of fine grained granitic sand, and volcanics. The MFCU is present throughout most of Phoenix, but is probably not continuous due to either structural deformities such as faulting, or to facies changes. The thickness of the MFGU layer ranges from 0-1400 feet. In the vicinity of the Honeywell Plant, the thickness is between 500 and 800 feet. The MFGU may act as an aquitard or confining layer, resulting in perched or artesian conditions in some areas. The hydraulic conductivity of this unit is about three orders of magnitude (1000 times) less than that of the aquifer units above or below it.

The lower conglomeratic sand and gravel unit is a conglomerate consisting of sand, metamorphic and volcanic fragments and 20-30 percent clay. This conglomerate unit, which can be up to 1000 feet or more thick, is underlain by granite. In the vicinity of the Honeywell site, this unit is encountered between 650 and 1000 feet below the land surface.

Natural recharge to the groundwater in the Phoenix area is low. Average annual precipitation over the period 1931 to 1970 was about 8 inches. Average annual Class A pan evaporation over the same period was 105 inches. Most of the natural recharge takes place during fall and winter storms. Soils in the area are moist for only three months of the year at most. Some soils have a layer of either calcium carbonate or calcium sulfate salts which have accumulated below the surface.

Water levels and groundwater flow directions in the Phoenix area have changed over the past 50 years as a result of large groundwater withdrawals. The 1982 water levels in the vicinity of the Honeywell site indicate a general groundwater flow direction to the north or northeast with a gradient of 0.02. The direction and magnitude of the groundwater gradient, however, is strongly influenced by pumping. Saturated sediments below the Honeywell site were first encountered during the construction of a monitoring well at a depth of 457 feet. Following well development, however, the static water level rose to a depth of 341 feet, indicating that the upper aquifer is confined or semi-confined. (Tetra Tech, 1985).

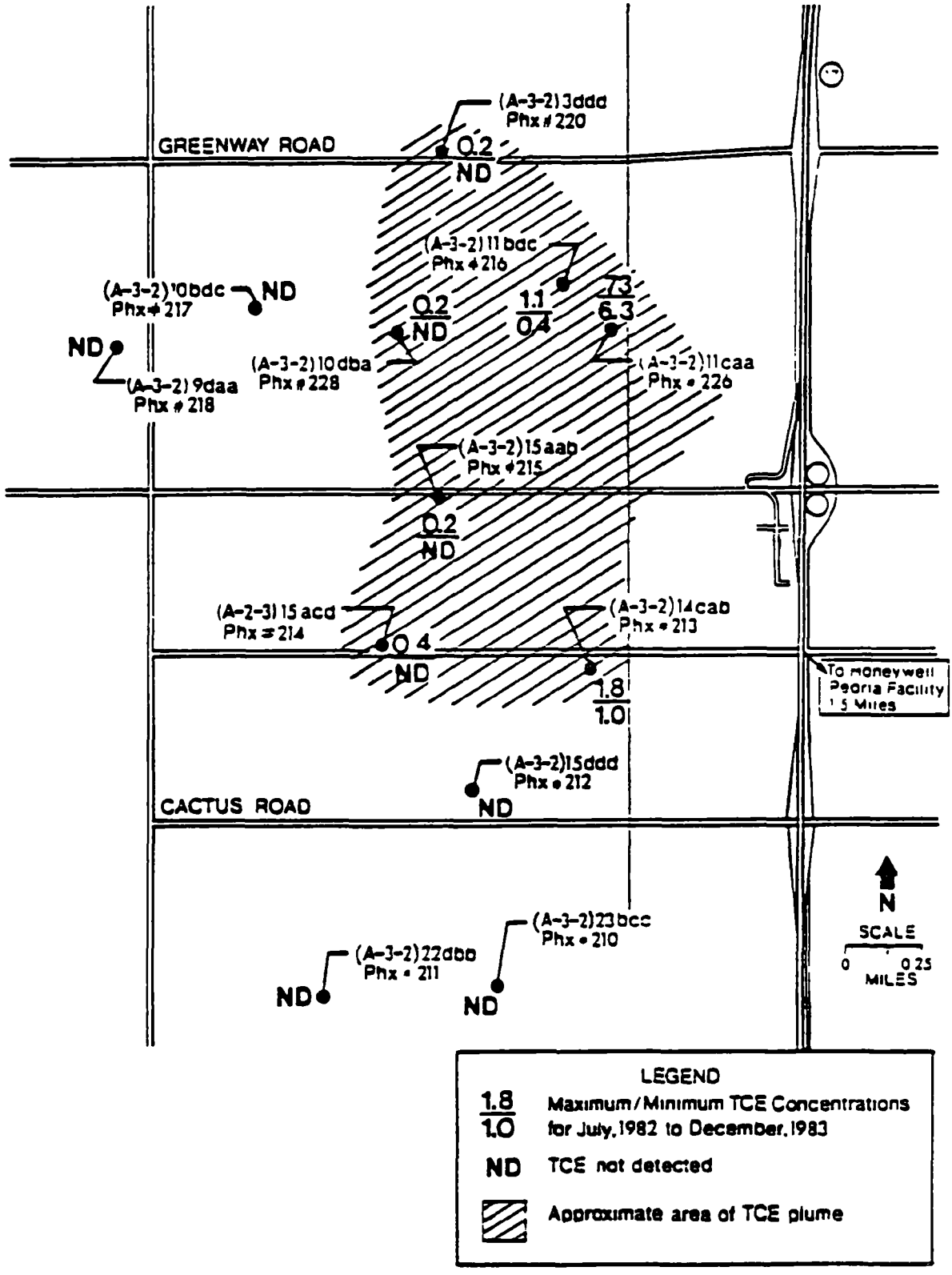
Water quality data are only available for wells located a distance of a mile or more from the Honeywell site. Available data for the major ions indicate moderate total dissolved solids concentrations (greater than 500 mg/l), moderate hardness (150 mg as $CaCO_3$/l), and nitrate concentrations up to 10 mg-N/l. Long term data for the closest well (about one mile away) for the period 1940 to 1970 show decreases in concentrations from about 115 mg/l to 20 mg/l for sulfate, and from about 310 to 170 mg/l for chloride. Electrical conductivity, an indicator of total dissolved solids, decreased from about 1800 umhos/cm to 1000 umhos/cm over the same time period. A changing source of groundwater could be responsible for these decreases (Tetra Tech, 1985).

Metals were detected in a pumping well located approximately one mile to the north of the Honeywell facility. Detectable levels of cadmium, copper, chromium and lead were found in this well.

Sampling of volatile organics in the City of Phoenix wells over the period from July, 1982 to December, 1983 showed elevated concentrations of Trichloroethylene (TCE) on at least one occasion in 7 out of 12 wells (Figure 2). The highest concentration (73 ug/l) of TCE was identified in well #226, which is located 2-1/2 miles northwest of the Honeywell site. Well #213, located about 2 miles away, had concentrations ranging from 1.0 to 1.8 ug/l.

IV. Identification of On Site Contaminating Point Sources

Disposal Wells #1 and #2 were used for the disposal of paint sludge, thinner, varnish and solvents. Buckets of waste were periodically disposed of into these wells. Disposal Wells #3 and #4 were piped to receive wastes from the printed circuit board plating baths. These wastes included copper plating solutions, sulfuric acid, fluoroboric acid and boric acid. Wells #3 and #4 also received spent wastewater used in regenerating the deionization resin bed at the plant. The waste volumes discharged to Wells #3 and #4 together totaled about 55 to 60 thousand gallons. This was a larger volume of fluid than the disposal capacity of the two wells, so Disposal Well #5 was installed to handle the overflow. Wells #1 through #4, and #5 to



(From Tetra Tech Inc.'s "Final Report Phase I Hydrogeologic Investigation...", 1985)

Figure 2. TCE Concentrations (ug/l) In Groundwater Northwest of Peoria Site

ENGINEERING ENTERPRISES, INC.

a lesser degree, were located in a topographic low and subjected to periodic flooding by storm runoff.

V. Disposal Well Description

All of the disposal wells at the Honeywell facility were uncased holes filled with crushed rock. All wells were 5 feet in diameter. Wells #1 and #2 were 35 feet deep, Wells #3 and #4 were 60 feet deep, and Well #5 extended to a depth of 85 feet. The distance between the bottom of Well #5 and the static groundwater level was approximately 400 feet.

Wells #1 and #2 were constructed in 1964 and were in operation until 1979. Wells #3, #4 and #5 were in use from 1971 until 1979. All five wells were capped in 1982.

VII. Facility Investigation - On Site

Tetra Tech, Inc. installed Monitoring Well MW-1a to obtain soil and water samples downgradient from the disposal wells. Well MW-1a was drilled with a 6-inch bit to a depth of 500 feet. The well was completed with 6-foot section of Johnson screen with 0.06-inch slot openings and a stainless steel plate on the bottom. MW-1a is located at the closest possible downgradient site relative to the disposal wells, a distance of 62 feet from Well #5 (Figure 1). The original monitoring well site was located 12 feet north of Well #5. Unrecorded electrical lines were encountered, however, and the well location was subsequently moved.

Soil samples were taken by Tetra Tech, Inc. with a standard penetration test (SPT) split barrel sampler at depths of 97, 152, 207, 249 and 300 feet. The SPT sampler was unable to penetrate soils below a depth of 300 feet. Soils were collected from drill bit cuttings at 457 and 500 feet below land surface. A final sample was taken at the bottom of the hole (501 feet below land surface) with a core barrel sampler. All eight soil samples were shipped to a laboratory for chemical analysis. Parameters measured included total organic carbon (TOC), pH, volatile organics, and metals. The last sample taken, at a depth of 501-502 feet, was tested for permeability and grain size. (Tetra Tech, Inc., 1985)

The results of the soil sample chemical analysis are presented in Tables 2 and 3. Volatile organics were found to be below the detection limit (0.3 mg/kg) in all soil samples (Table 2). Metal concentrations were within typical background concentration ranges, as shown in Table 3, and did not exceed EP toxicity limits or RCRA. The soil solution pH values were alkaline, ranging between 7.6 and 10. The TOC values were higher in the deeper clay material (207 - 500 feet deep), with values from 44 to 526 mg/kg. The value of 1030 mg/kg from the sample taken at 501 feet, appears to be erroneous since TOC was below detection in the sample from 500 feet. (Tetra Tech, Inc., 1985)

Table 2

VOLATILE ORGANICS IN SOIL SAMPLES FROM MW-1A
(Tetra Tech, 1985)

	Soil Sample Numbers							
	2	3	4	5	6	7	8	9
Depth (ft)	97	152	207	249	300	459	500	501
Sampling Date	9/06/85	9/09/85	9/10/85	9/11/85	9/12/85	9/17/85	9/19/85	9/23/85
Date Extracted EPA Method 8010	9/16/85	9/16/85	9/16/85	9/16/85	9/16/85	9/26/85	9/23/85	9/23/85
Parameters								
1,1,2,2,-Tetrachloroethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,1,2-Trichloroethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,1-Dichloroethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,1-Dichloroethene, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,2-Dichloroethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
trans, 1,2-Dichloroethene, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,2-Dichloropropane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2-Chloroethylvinylether, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bromodichloromethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bromomethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bromoform, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chlorobenzene, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Carbon Tetrachloride, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloroethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloroform, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloromethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dibromochloromethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dichlorodifluoromethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Methylene chloride, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Tetrachloroethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,1,1-Trichloroethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Trichloroethylene, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Trichlorofluoromethane, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Vinyl chloride, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
cis-1,3-Dichloropropene, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
trans-1,3-Dichloropropene, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table 3

METALS, pH AND TOC RESULTS FOR SOIL SAMPLES FROM MW-1A
(Tetra Tech,1985)

Parameters	Soil Sample Number 2	3	4	5	6	7	8	9	Range For Typical Soil[a]
Depth (ft)	97	152	207	249	300	459	500	501	
pH	9.2	8.3	7.6	8.1	10	8.8	9.4	9.1	
TOC, mg/kg	98	79	44	86	200	526	<50	1030	
Tin, mg/kg	<100	<100	<100	<100	<100	<100	<100	<110	2-200
Nickel, mg/kg	20	25	31	27	19	17	13	17	10-1000
Copper, mg/kg	16	16	20	18	17	16	15	<22	2-100
Chromium, mg/kg	12	19	16	11	11	23	9.1	16	5-3000
Lead, mg/kg	7.5	6.4	7.7	6.2	7.4	8.1	8.3	7.4	2-200
Boron, mg/kg	1.3	1.1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	10
EP Leachate[b]									Criteria[c]
Arsenic, mg/l	<0.029		<0.029		<0.022			<0.023	5
Barium, mg/l	<0.67		<0.67		<0.67			<0.44	100
Cadmium, mg/l	<0.011		<0.011		<0.011			0.046	1
Chromium, mg/l	<0.035		<0.035		<0.042			<0.033	5
Lead, mg/l	<0.21		<0.21		<0.21			<0.21	5
Mercury, mg/l	<0.01		<0.01		0.01			0.089	0.2
Selenium, mg/l	<0.037		<0.037		<0.043			<0.026	1
Silver, mg/l	<0.021		<0.021		<0.021			<0.020	5

[a]Greenland and Hayes, 1981 except boron value is from M.J. Dudas (personal communication)

[b]Acetic acid leach at pH = 4 following U.S. EPA's EP Procedure

[c]Criteria is 100 times drinking water standard (see Table 1)

Two samples of ground water were taken from the monitor well and analyzed for volatile organics. One sample was taken and analyzed for metals. The results of these analyses are presented in Tables 4 and 5. Volatile organics were below the detection limit of 0.5 ug/l, and only low levels of boron, copper, and lead were detected.

VIII. Discussion of Disposal Well Contamination Data

The eight soil samples collected from MW-1a between the depths of 97 feet and 501 feet indicated neither contamination by volatile organics, nor contamination by metals.

Two ground water samples collected from MW-1a contained volatile organics in concentration below the detection limit of 0.5 ug/l. Inorganic constituents were also detected in samples extracted from MW-1a. Of these, boron, copper, and lead were the only constituents present above detection limits. Boron, copper, and lead were detected at 0.4, 0.2, and 0.6 ppm respectively.

IX. Assessment

Detrimental effects on the quality of groundwater and soils were not discovered at Monitoring Well MW-1a below a depth of 97 feet. Clean permeable sands were discovered overlying the semi confining MFGU at a depth of 177 feet below land surface. Uncontaminated semi-confined groundwater was also discovered below MW-1a at a depth of 457 feet. The subsurface investigation, however, was deficient in several respects:

Table 4

VOLATILE ORGANICS AND pH DATA FOR WATER SAMPLES FROM MW-1A
(Tetra Tech,1985)

Parameters	Sample Number	
	13	14
Sampling Date	10/1/85	10/1/85
Sampling Time	1317	1325
Date Shipped	10/1/85	10/1/85
Date Extracted	10/3/85	10/15/85
pH	8.2	7.2
EPA Method 601		
1,1,2,2-Tetrachloroethane, ug/L	<0.5	<0.5
1,1,2-Tetrachoroethane, ug/L	<0.5	<0.5
1,1-Dichloroethane, ug/L	<0.5	<0.5
1,1-Dichloroethene, ug/L	<0.5	<0.5
1,2-Dichloroethane, ug/L	<0.5	<0.5
trans-1,2-Dichloroethene, ug/L	<0.5	<0.5
1,2-Dichloropropane, ug/L	<0.5	<0.5
2-Chloroethylvinylether, ug/L	<0.5	<0.5
Bromodichloromethane, ug/L	<0.5	<0.5
Bromomethane, ug/L	<0.5	<0.5
Bromoform, ug/L	<0.5	<0.5
Chlorobenzene, ug/L	<0.5	<0.5
Carbon Tetrachloride, ug/L	<0.5	<0.5
Chloroethane, ug/L	<0.5	<0.5
Chloroform, ug/L	<0.5	<0.5
Chloromethane, ug/L	<0.5	<0.5
Dibromochloromethane, ug/L	<0.5	<0.5
Dichlorodifluoromethane, ug/L	<0.5	<0.5
Methylene chloride, ug/L	<0.5	<0.5
Tetrachloroethene, ug/L	<0.5	<0.5
1,1,1-Trichloroethane, ug/L	<0.5	<0.5
Trichloroethylene, ug/L	<0.5	<0.5
Trichlorofluoromethane, ug/L	<0.5	<0.5
Vinyl chloride, ug/L	<0.5	<0.5
cis-1,3-Dichloropropene, ug/L	<0.5	<0.5
trans-1,3-Dichloropropene, ug/L	<0.5	<0.5

Table 5

METALS DATA FOR WATER SAMPLE FROM MW-1A
(Tetra Tech,1985)

Parameter	Sample #13B	
Sampling Date	10/1/85	
Sampling Time	1353	
Date Shipped	10/1/85	
Method Used	ICAP	AA
Nickel (mg/l)	<0.1	--
Lead (mg/l)	<0.2	0.055
Tin (mg/l)	<0.2	--
Copper (mg/l)	0.2	--
Chromium (mg/l)	<0.1	<0.04
Boron (mg/l)	0.4	--

- Only one monitoring well (MW-1a) was completed on-site.

- Soils above 97' feet in MW-1a were not sampled for laboratory analyses.

- Soils directly below the five industrial disposal wells were not sampled.

A stratigraphic profile of Monitoring Well MW-1a indicates that permeable gravel cobble, and sand strata with intermittent clayey-sand lenses laterally extend from land surface to depths exceeding 100 feet. The disposal wells on-site, whose depths ranged from 35 to 85 feet below land surface, were completed in these strata. The low permeable clayey-sand lenses may have possibly retarded the vertical drainage of injected wastes and provided routes for these fluids to laterally migrate away from the disposal wells. Solution wastes which may have migrated laterally in shallow permeable strata (35-97 feet) would have possibly been detected in MW-1a soils if the shallower soils had been sampled and analyzed.

Contamination data from soils directly beneath the disposal wells is absent. (Note that MW-1a is located 62 feet from the nearest disposal well.) Depth discrete contamination data in the area is vital in identifying possible migratory pathways which contaminants have taken. These pathways remain unidentified.

Given the hydrogeologic information collected to date, the threat to ground water formerly posed by Honeywell's disposal

wells cannot be assessed. Numerous soil borings in the disposal well area, rather than yards away, would be required for such an assessment. Depth discrete soils sampled to the semi-confining clay layer would need to be collected and analyzed for organic and inorganic constituents. These borings would also be required to delineate the areal extent of the semi-confining clay stratum encountered in MW-1a.

UNDERGROUND INJECTION CONTROL PROGRAM
FILE INVESTIGATION REPORT

SECTION I - General Information

Name of Facility: Honeywell and Peoria Avenue Facility

Address: Peoria & 23rd Avenue
Phoenix, Arizona

Telephone:

Owner Address and Telephone (if different from above):
Process Management Systems Division (602) 863-5000
Honeywell Inc.
16404 North Black Canyon Highway, Phoenix, AZ 85023

Nature of Business:
Circuit Board Manufacturing

Use of Injection Well (s) (drainage, direct disposal, etc.):
Direct Disposal and Drainage

Identification, Permit or EPA Number (s):

Injection Well (s) Location (township, range and section, latitude and longitude, verbal description, land marks, etc.):

Type of Injection Well (s) -
Industrial Drainage:
Storm-runoff:
Other (specify): Industrial Disposal Well (5W20)

Injection Well (s) Currently Operating: Yes _____ No X

If No, Last Date of Operation: All 5 dry wells capped in 1982

Date of Construction of Injection Well (s): 1 & 2 1964
3 - 5 1971

Years Injection Well in Operation:
1964 - 1979 wells 1 & 2
1971 - 1979 3, 4 & 5

SECTION II - Hydrogeologic Information

Injection Formation - Name: Upper Unit

- Description: Recent Alluvium

- Extent of Injection Zone (s) Below Land Surface (or elevation above Mean Sea Level): 35 to 85 feet below land surface

- Minimum Distance from Injection Well to Underground Source of Drinking Water (U.S.D.W.): USDW static level is 361 ft. below the surface at Phoenix well #239. Phoenix well #239 is 1/4 mile away from injection well.

Location (depth below land surface, areal extent, etc.) and description (thickness, lithology, etc.) of Any Relatively Impermeable Strata (aquitard (s)) Present: MFGU middle
Depth - 177 ft.
Thickness 300 ft.

Underground Sources of Drinking Water -

Confined: Semi confined (?) to confined varies across the area

Unconfined:

Depth to Perched Water Table (if present):

Depth to Water: 457 ft.

Saturated Thickness:

Description and Characteristics:

Extent of Use of U.S.D.W. (extensive, moderate, municipal, domestic, potential, etc.):

U.S.D.W is used extensively by Phoenix and Salt River Project.

Comments:

Attach the Following Information (note if unavailable) -

- X Map of Facility Grounds: page 4
- Well Log (s) for Injection Well (s): No logs for injection wells however there is a drillers log for a monitor well (appendix #1)
- As-built Diagram of Injection Well (s): Not available. Uncased holes filled with crusehd rock. Diameter of wells was 5 ft.
- X Consultant Reports for Injection Well (s) and/or Site Hydrogeology:
- Monitoring Data for Injection Well:
- Monitoring Well Data -
  - X Number of Monitoring Wells:
  - X Location: Vertical and Horizontal Distance and Direction of Monitoring Well (s) From Injection Well: 62' north of injection wells
  - X Depth of Completion and Sampling Interval:
  - X Chemical and Physical Analyses:
- Downgradient Water Supply Wells (within a one-quarter mile radius of the injection well) -
  - Number of wells:
  - Location: Vertical and Horizontal Distance and Direction of Supply Well (s) from Injection Well:
  - Chemical and Physical Analyses:
  - Status of Wells (operating, abandoned, etc.)
  - Status of Any Nearby Surface Waters (possibly affected by injection well operation):

SECTION III - Operating Data

Injection Rate, Frequency, and Volume (drainage area, precipitation, etc.)

Volumes #3 & #4 totaled 55-60 thousand gallons

Volumes to #1, 2, & 5 are not available

Description of Injection Operation (including brief history):

Wells #1 and #2 were used for the disposal of paint sludge, thinner, varnish and solvents.
Wells #3, #4, and #5 received water from water treatment system.

Fluid Source: Industrial waste, circuit board manufacturing

Fluid Composition/Characteristics (including any treatment process): Paint sludge, thinner, varnish and solvents. Also back flushed water from water treatment.

Contaminant (s) and Potential Source (s) of Contamination:

Method of Disposal (transport to well):

Wells 1 & 2, dumped by buckets and storm run off (as per phone call to Sandra Eberhardt) Also, wells 3, 4 & 5 piped from circuit board plating baths and back flush water from regenerating the deionization unit.

Previous Problems with Well (clogging, overflowing, etc.) -

No _____

Yes ___X___ Description of Problem: One well #5 was drilled as an overflow for wells #3 and #4.

Operating Records Attached: Yes _____ No ___X_____

Injection Fluid Analyses Attached: Yes ___X___ No _____

SECTION IV - Prior Site Inspection Specifics

Name and Affiliation of Inspectors:

Name and Affiliation of Facility Contact:

Date: Time:

Reason for Inspection:

Number of Injection Wells:

Number of Injection Wells Inspected:

Site Conditions:

Inspection Comments:

SECTION V

Primary Contact Information Sheet

Name: Sandra Eberhardt

Phone: (602) 257-2336

Address: 2005 North Central Avenue
Phoenix, AZ 85004

Affiliation (local, state, federal, etc.):

ADHS: Office of Emergency Response and Environmental Analysis

Notes: Primary reference: Phase I Hydrogeologic Investigation at Honeywell Process Management Systems Division's Peoria Avenue Facility in Phoenix, AZ. Prepared by Tetra Tech, Inc., 3746 Mt. Diablo Blvd., Lafayette, CA 94549
(415) 283-3771

Section 6.2.23

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Industrial Disposal Well Case Study: Puregro-Bakersfield, California
AUTHOR: (or INVESTIGATOR)	Engineering Enterprises, Inc. (Prepared for USEPA Region IX)
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Puregro Co. Bakersfield, California USEPA Region IX
NATURE OF BUSINESS:	Fertilizer and Pesticide Distribution
BRIEF SUMMARY/NOTES:	Well used to collect rinse water runoff and spillage that occurred during material transfers. Chemicals handled on site included 1,2-dibromo-3-chloropropane (DBCP) until the State of California banned its use because of possible carcinogenic and toxic effects. Order was issued requiring subsurface investigations and soil contamination assessments. Use of this well was discontinued in 1980.

INDUSTRIAL DISPOSAL WELL CASE STUDY: PUREGRO - BAKERSFIELD, CALIFORNIA

I. SITE BACKGROUND

PureGro Company is located approximately 15 miles north of Bakersfield, California near the intersection of Highway 99 and Kimberlina Road. This facility is located within a small light industrial district surrounded by agriculturally utilized lands. Several metal corrugated buildings, numerous above ground storage tanks, and a groundwater supply well are located on the property. PureGro presently stores and distributes a variety of agricultural chemicals from their Bakersfield facility.

An industrial disposal well (5W20) was used at PureGro to collect rinse water runoff and spillage that occurred during material transfers. The Central Valley Regional Water Quality Control Board (CVRWQCB) ordered that the disposal well be abandoned in 1981. The CVRWQCB subsequently issued an order requiring a subsurface investigation be conducted to assess the soil and groundwater contamination at the site.

II. CHEMICALS HANDLED ON SITE

1,2 - dibromo-3-chloropropane (DBCP) was handled on, and distributed from, the PureGro facility prior to August of 1977. DBCP was extensively used as a pesticide throughout the San Joaquin Valley until 1977 when the State of California banned its use because of its possible carcinogenic and toxic effects. A listing of all other pesticides and/or herbicides handled at the facility has not been released.

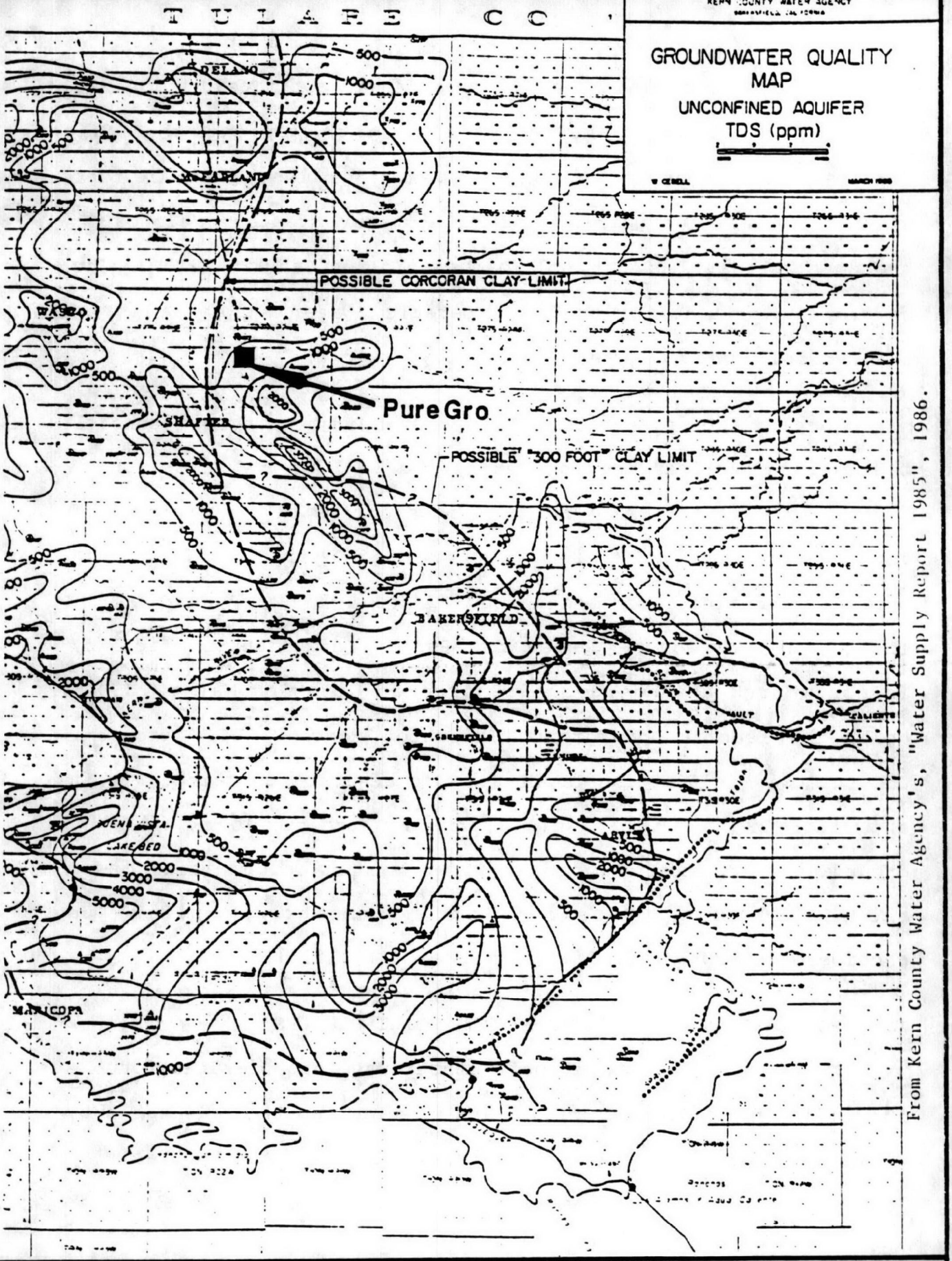
III. SITE GEOLOGY/HYDROLOGY

Geology

The PureGro facility is underlain by primarily unconsolidated and semi-consolidated materials with fine to coarse grained alluvial sands and occasional gravel interbeds and silty clay lenses. A subsurface investigation (drilling program) revealed sands occurring between 15 and 68 feet beneath the site. Deposits graded to finer sandy and clayey silts from 70 to 93 feet below ground level. A 10 foot clayey silt stratum was encountered in several borings between 90 and 110 feet below ground level. Further drilling to 210 feet revealed alternating layers of poorly sorted sands, silty sands, and silty-clayey lenses. Although not confirmed on site, the base of the unconsolidated deposits is reported to extend to a depth of approximately 1500 feet (Dames and Moore, January 1985). The Corcoran clay, a confining layer prevalent in Kern County, is shown to be absent beneath the site (Figure 1, Kern County Water Agency, 1986). Figure 1 shows the estimated coverage of the Corcoran clay near the PureGro Site.

Hydrology

Water bearing deposits reportedly underlying the site help comprise the most extensive groundwater basin in the state: the San Joaquin Basin. Groundwater beneath the site is believed to be unconfined because of the probable absence of the Corcoran Clay layer. Perched water tables in the immediate vicinity of PureGro's facility have not been encountered. A depth to water map published by the Kern County Water Agency (KCWA) is presented



From Kern County Water Agency's, "Water Supply Report 1985", 1986.

GROUNDWATER QUALITY MAP
PURE GRO - BAKERSFIELD, CALIFORNIA

EEI ENGINEERING ENTERPRISES, INC.

709-012-06 Figure 1

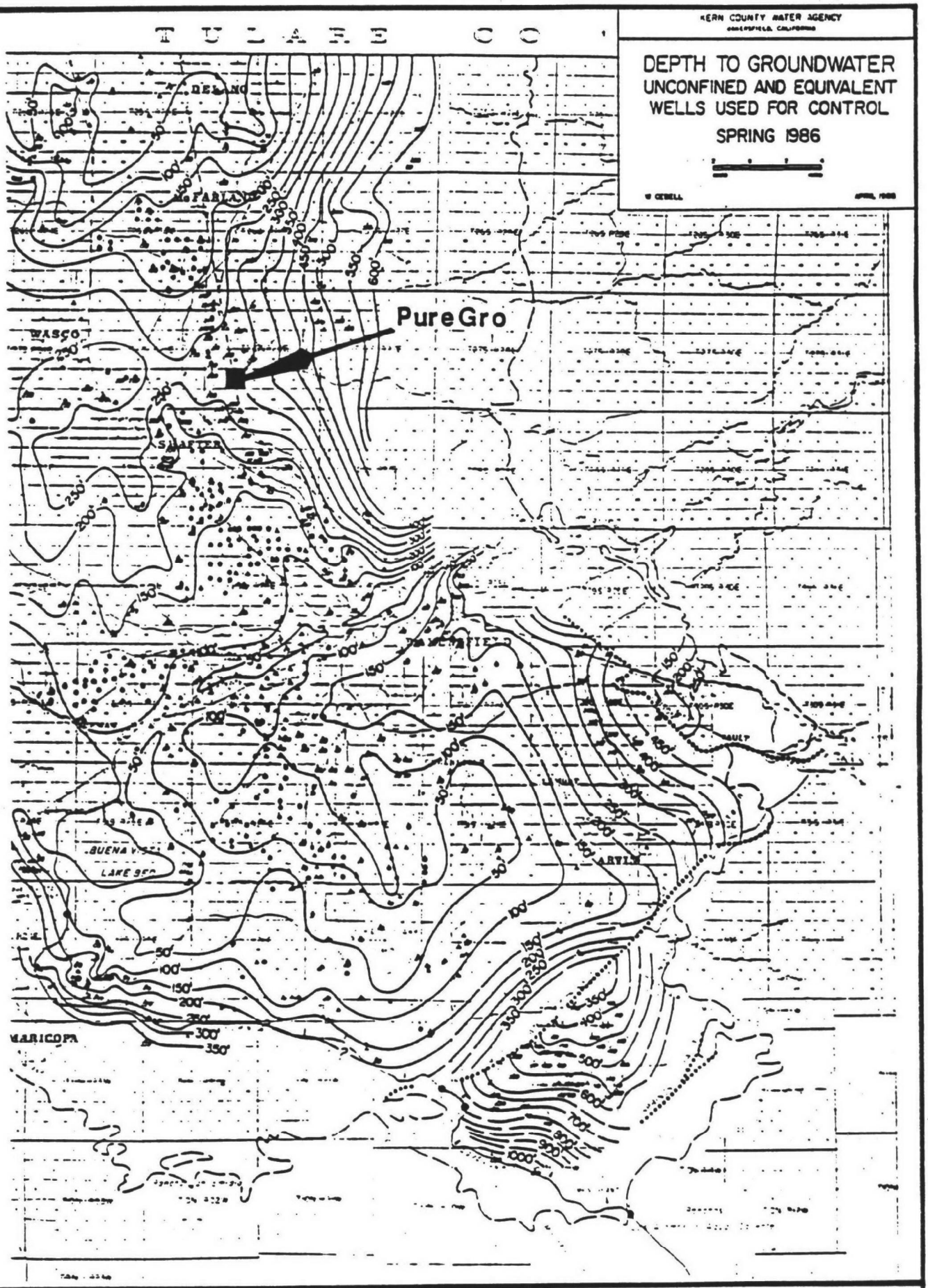
[6-284]

in Figure 2. Groundwater below the site was estimated to lie 280 to 290 feet below ground elevation in the spring of 1986. Seasonal variations are reported to average less than 10 feet within the past two years. The groundwater gradient "slopes to the northwest at 0.004 ft/ft" (Dames & Moore, January 1985). The degree of influence exerted by operating water supply wells on the regional water gradient is largely unknown.

Total dissolved solids (TDS) present in groundwater beneath the PureGro facility is reported by the KCWA to average slightly over 500 mg/l (see Figure 1). Groundwater use in the vicinity of the site is currently used for "crop irrigation and not for private or municipal domestic use" (Dames & Moore, August 1986). The groundwater aquifer below the PureGro distribution facility is considered an Underground Source of Drinking Water (USDW) under the federal Underground Injection Control (UIC) program. The following definition applies: Groundwater "contained within a portion of an aquifer which contains significant quantity of groundwater to supply a public water system and contains fewer than 10,000 mg/l TDS and is not an exempted aquifer" is considered a USDW (Safe Drinking Water Act, 1974).

IV. POSSIBLE ON SITE CONTAMINATING POINT SOURCES

An industrial disposal well constructed and operated for the injection of rinse water runoff and chemical spillage is the only known point source discharger present on the PureGro facility (conversations with T. Souther, Central Valley Regional Water Quality Control Board, CVRWQCB).



From Kern County Water Agency's, "Water Supply Report 1985", 1986.

DEPTH TO GROUNDWATER
PURE GRO - BAKERSFIELD, CALIFORNIA

EEI ENGINEERING ENTERPRISES, INC.

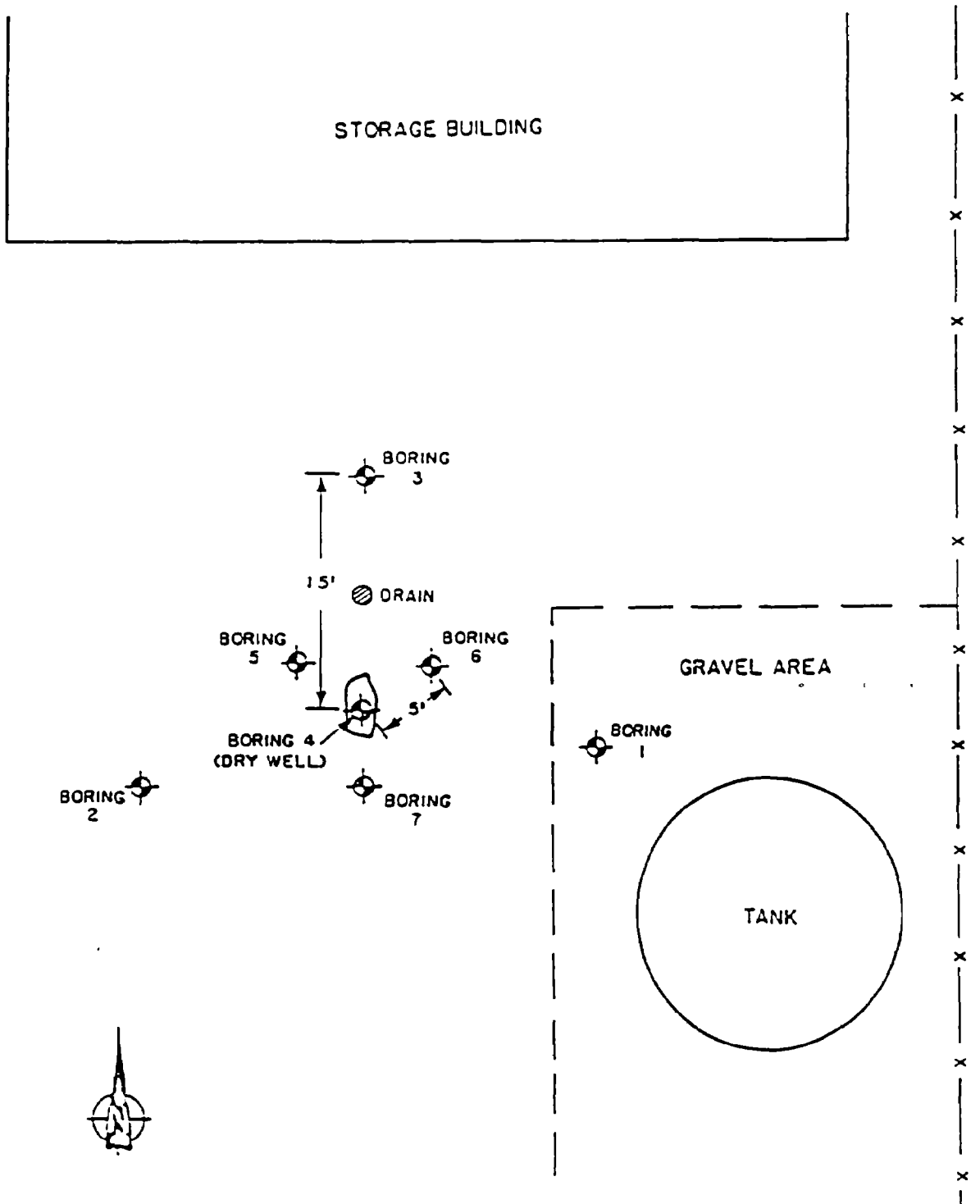
709-012-06 Figure 2

V. DISPOSAL WELL DESCRIPTION

"The industrial disposal well is located in a concrete paved work pad surrounded by asphalt paving and consists of a buried concrete chamber. The chamber is connected via an overflow pipe and overflow weir to a second, smaller concrete chamber. This chamber, in turn, is equipped with an overflow pipe designed to connect to an underground drain field" (Dames and Moore, August 1986). Upon excavation, however, the overflow pipe was discovered to be cut several feet from the disposal well and no leach lines were found. Construction plans for the disposal system were not discovered. The disposal well was constructed in 1969 and was abandoned in 1981 after a site inspection by the Central Valley Regional Water Quality Control Board revealed its presence. Plans for permanent abandonment are in progress (conversations with T. Souther, CVRWQCB).

VI. FACILITY INVESTIGATION - ON SITE

Seven soil borings were drilled with a 6-inch hollow stem auger around the industrial disposal well in August of 1984. Soil Borings 1, 2, and 3 circumscribe the well at 15 feet and Borings 5, 6, and 7 are each 5 feet from the center of the disposal well (Refer to Figure 3). Boring 4, drilled in the center of the disposal well, was completed to 141 feet below ground level. All other soil borings were completed to depths ranging from 55 to 61 feet. Undisturbed samples were initially collected at 2.5-foot intervals and subsequently collected at 10-foot intervals once a depth of 10 feet was reached.



From Dames and Moore's, "Final Report Subsurface Investigation ...", 1985.

BORING LOCATION SKETCH MAP
PURE GRO - BAKERSFIELD, CALIFORNIA

ENGINEERING ENTERPRISES, INC.

709-012-06 Figure 3

"Organochlorine pesticides, Trifluralin and Dacthal, were identified in the shallow samples from Boring 4 and Boring 5. DBCP was found in every sample. The concentration of DBCP in the samples from the three borings 15 feet from the center boring (Borings 1, 2, 3, Figure 3), ranged from 0.008 ppm to 4.0 ppm. The concentration of DBCP in the borings 5 feet from the center boring (Borings 5,6,7) ranged from 0.10 ppm to 19 ppm. The concentration of DBCP in samples from the center boring, which was located in the dry well, ranged from 0.39 ppm to 1500 ppm" (Dames & Moore, January 1985). Sampling data gathered during the subsurface investigation is presented in Table 1.

One groundwater monitoring well, GW-1, was drilled approximately 75 feet downgradient (as inferred from local piezometric surface maps) from the industrial disposal well. Soil samples were collected at 10-foot intervals. Drilling was suspended at 215 feet below land surface so the collected soil samples could be analyzed for the presence of DBCP (Dames and Moore, January 1985). These results are presented in Table 1. Dames and Moore further reported that after reviewing the soil sample analyses, PureGro and the Central Valley Regional Water Quality Control Board decided not to extend the boring to a greater depth, and to abandon plans for the installation of a monitoring well at the location (Final Report, January 1985). As of this writing, no monitoring wells extending to groundwater have been constructed on site.

TABLE 1

SUMMARY OF CHEMICAL ANALYSIS DATA

Boring No.	Depth (ft)	Pesticide Concentration (ppm) DBCP	Organochlorine	Organophosphorus
1	0.5	0.83	<0.01	<0.1
1	10.5	0.06		
1	60.5	1.0		
2	1.5	0.17		
2	20.5	4.0		
2	55	0.10		
3	10.5	0.008		
3	58.5	0.057		
4	8.5	1500.	Trifluralin 100. Dacthal 10. Unknown (I) 20.	<0.1 DEF 40 ppm
4	8.5	93.		
4	16	1100.		
4	30.5	4.6		
4	55.5	0.39		
4	76	1.5		
4	91	4.0	<0.01	<0.1
4	106	15.		
4	123	6.2		
4	141	0.39		
5	2	11.	Dacthal 0.02 Unknown (II) (0.02) Unknown (III) (0.1)	<0.1
5	16	0.10	Dacthal 0.02	<0.1
5	59.5	0.17		
6	21	6.2		
6	61	0.94		
7	21	19.		
7	58	0.42		
GW-1	0.5	<0.0001		
	40	0.0008		
	60	0.0008		
	80	0.041		
	90	0.015		
	110	0.021		
	115	0.0015		
	150	<0.0001		
	190	0.0003		
	210	0.0001		

From Dames & Moore's, "Final Report Subsurface Investigation ...", 1985.

A ground water supply well located approximately 400 feet north of PureGro's disposal well has been sampled between May and October of 1985. DBCP was not detected in the May sample and August and October's samples were found to contain 0.04 ppb DBCP. This is well below California's Drinking Water Action Level for DBCP of 1 ppb.

VII. FACILITY INVESTIGATION - OFF SITE

An off-site investigation has not been conducted to date. Two off-site wells have been located approximately 600 and 800 feet north of PureGro's supply well. These wells have not been sampled.

VIII. DISCUSSION OF DISPOSAL WELL CONTAMINATION DATA

The highest concentration of DBCP found on-site was located 8.5 feet below the disposal well intake. DBCP concentrations in soils below the well decreased with depth until a low permeability layer at 106 feet below ground level was encountered. DBCP concentrations detected below this stratum were less than 1 ppm. "Samples from Borings 1,2, and 3 (15 feet from the center boring) yielded relatively low (maximum 4.0 ppm) DBCP concentrations. Boring 2 had a small increase (from 0.17 to 4.0 ppm) in DBCP concentration at 20 feet below land surface. The three borings 5 feet from the center boring had DBCP concentrations that also appear to peak at 20 feet below land surface, with concentrations as high as 19 ppm in Boring 7 " (Dames & Moore, August 1986).

Most soil samples collected from GW-1 (located 75 feet from the disposal well) consistently showed levels of DBCP below California's soil cleanup level of 1 ppm. One elevated DBCP concentration, however, was found in soils located directly above the low permeability layer located at a depth of approximately 80 to 90 feet.

An analysis of the soil sampling data collected at PureGro supports the following conclusions:

- The concentration of DBCP beneath the industrial disposal well generally decreases with depth and lateral distance from the point of injection.

- Contamination is largely attributable to the vertical infiltrative effects of DBCP in the given subsurface environment.

- Low permeability soils located 90 to 125 feet below ground level have abated the infiltration of DBCP to depths below 125 feet.

- The areal extent of contamination above 1 ppm of DBCP extends between 15 and 75 feet away from the disposal well discharge point.

IX. ASSESSMENT

Groundwater information for the Bakersfield site is severely limited; it is currently not known if or when DBCP will reach an Underground Source of Drinking Water (USDW). Based on the site information available, this injection well is assessed by EEI to

have a low contamination potential. This assessment, however, should not be interpreted to convey the belief that additional investigative work is not warranted. This assessment is subject to change once more site information becomes available.

The injection well formerly used at the PureGro Bakersfield facility injected waste water above the San Joaquin Basin. The reported TDS content of groundwater (Kern County Water Agency) in the general area of the site was approximately 500 mg/l. This is well below the maximum TDS content required for aquifers to be classified USDW's. The overall quality of the underlying groundwater is currently unknown. Dames and Moore (PureGro's hydrogeologic consultant) reported that municipalities and private parties do not use groundwater in the vicinity. It is unknown whether water below the PureGro site comprises an aquifer of Class II or better quality. (Refer to Section 5 for the Class II groundwater definition.) Groundwater below the site is therefore judged by EEI to be an aquifer which " may or may not be" a potential source of drinking water. This classification is subject to change once groundwater data specific to the site is obtained.

Based on the chemical analyses of soils from the site, EEI judges that injection did not occur in sufficient volumes to potentially cause degradation of groundwater beyond the PureGro Facility. Soils sampled 100 feet above the reported water table in Monitoring Well GW-1 did not contain DBCP concentrations above California's Drinking Water Action Level for DBCP. Analytical data from the seven soil borings on site also show that DBCP

concentrations in soils near the disposal well decrease significantly with depth.

The construction of additional monitoring wells is essential to determine the effect of the disposal well on underlying groundwater. These wells will enable site investigators to:

- firmly establish a hydraulic gradient below the site.
- characterize the water quality and DBCP concentration in the groundwater beneath the facility.

The Central Valley Regional Water Quality Control Board has reviewed a draft remedial action plan submitted by PureGro. The draft included proposals for remedial measures and the additional construction of monitoring wells. A revised site assessment addressing groundwater contamination beneath PureGro's Bakersfield facility may be performed after further groundwater sampling and monitoring is conducted at the site.

UNDERGROUND INJECTION CONTROL PROGRAM
FILE INVESTIGATION REPORT

SECTION I - General Information

Name of Facility: Pure Gro Company

Address: Rt. 11, Box 548
Bakersfield, CA 93312-9811

LOCATION: HWY 99 & Kimberlina Road

Telephone: 805/393-2322

Owner Address and Telephone (if different from above):
PureGro/Unical
1276 Halyard Drive
West Sacramento, CA 95691

Nature of Business:
Fertilizer & Pesticide Distribution Facility

Use of Injection Well (s) (drainage, direct disposal, etc.):
Near surface disposal of rinsewater and chemical spill runoff.

Identification, Permit or EPA Number (s):

Injection Well (s) Location (township, range and section, latitude and longitude, verbal description, land marks, etc.):
T27S, R26E, SE CT 29
Site is 15 miles N of Bakersfield, California

Type of Injection Well (s) -
Industrial Drainage:
Storm-runoff:
Other (specify): 1 industrial disposal

Injection Well (s) Currently Operating: Yes _____ No X

If No, Last Date of Operation: 1981

Date of Construction of Injection Well (s): 1969

Years Injection Well in Operation: 12

SECTION II - Hydrogeologic Information

Injection Formation - Name: Quaternary Alluvium

- **Description:** Unconsolidated sands and gravels
- **Extent of Injection Zone (s) Below Land Surface (or elevation above Mean Sea Level):** 0-5' Below Land Surface
- **Minimum Distance from Injection Well to Underground Source of Drinking Water (U.S.D.W.):** 250'-300'

Location (depth below land surface, areal extent, etc.) and description (thickness, lithology, etc.) of Any Relatively Impermeable Strata (aquitard (s)) Present:

10' thick clayey silt layer between 93'-103' beneath dry well

Underground Sources of Drinking Water -

Confined:

Unconfined: X

Depth to Perched Water Table (if present): None

Depth to Water: 270'-290' (from 1985 Kern County Piezo Map)

Saturated Thickness: Unknown. Possibly to 1500' with semi-confined layers in between.

Description and Characteristics:

Unconsolidated and semi-consolidated fine-coarse grained clean to silty sand with some gravel and clay occurring as thin discontinuous interbeds

Extent of Use of U.S.D.W. (extensive, moderate, municipal, domestic, potential, etc.):

Part of the San Joaquin Basin. Basin as a whole is used for irrigation, domestic, industrial, municipal and stock use. Limited potential in south for further development. Use is locally limited for agricultural purposes according to PureGro's consultant.

Comments:

Attach the Following Information (note if unavailable) -

X Map of Facility Grounds:

X Well Log (s) for Injection Well (s):

NA As-built Diagram of Injection Well (s):

X Consultant Reports for Injection Well (s) and/or Site Hydrogeology:

NA Monitoring Data for Injection Well:

- Monitoring Well Data -

0 Number of Monitoring Wells:

- Location: Vertical and Horizontal Distance and Direction of Monitoring Well (s) From Injection Well:

- Depth of Completion and Sampling Interval:

- Chemical and Physical Analyses:

- Downgradient Water Supply Wells (within a one-quarter mile radius of the injection well) -

1 Number of wells:

Horizontal X Location: Vertical and Horizontal Distance and Direction of Supply Well (s) from Injection Well:

Chemical X Chemical and Physical Analyses:

X Status of Wells (operating, abandoned, etc.)

- Status of Any Nearby Surface Waters (possibly affected by injection well operation):

SECTION III - Operating Data

Injection Rate, Frequency, and Volume (drainage area, precipitation, etc.)

A dry well was used for collection of rinsate runoff and chemical spillage that occurred during material transfers. Estimate of injection rate and volume unavailable.

Description of Injection Operation (including brief history):

1969-1981 Injection of rinsate runoff and chemical spillage.

Fluid Source: Rinsate runoff and chemical spills

Fluid Composition/Characteristics (including any treatment process):

No treatment process. Injected chemicals included DBCP, Trifluralin, Dacthal.

Contaminant (s) and Potential Source (s) of Contamination:

DBCP Organochloride pesticides: Trifluralin & Dacthal

Method of Disposal (transport to well):

Liquid Transport (water)

Previous Problems with Well (clogging, overflowing, etc.) -

No _____ Unknown

Yes _____ **Description of Problem:**

Operating Records Attached: Yes _____ **No** X

Injection Fluid Analyses Attached: Yes _____ **No** X

Section 6.2.24

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Industrial Disposal Well Case Study: Mefford Field-Tulare, California
AUTHOR: (or INVESTIGATOR)	Engineering Enterprises, Inc. (Prepared for USEPA Region IX)
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Mefford Field Tulare, California USEPA Region IX
NATURE OF BUSINESS:	Crop Dusting
BRIEF SUMMARY/NOTES:	Wells were used for disposal of agricultural chemicals and hydrocarbons, wash water used to clean cropdusting planes and chemical containers, and waste petroleum products. Groundwater contamination has been documented. Additional monitoring wells should be installed.

INDUSTRIAL DISPOSAL WELL CASE STUDY: MEFFORD FIELD - TULARE, CALIFORNIA

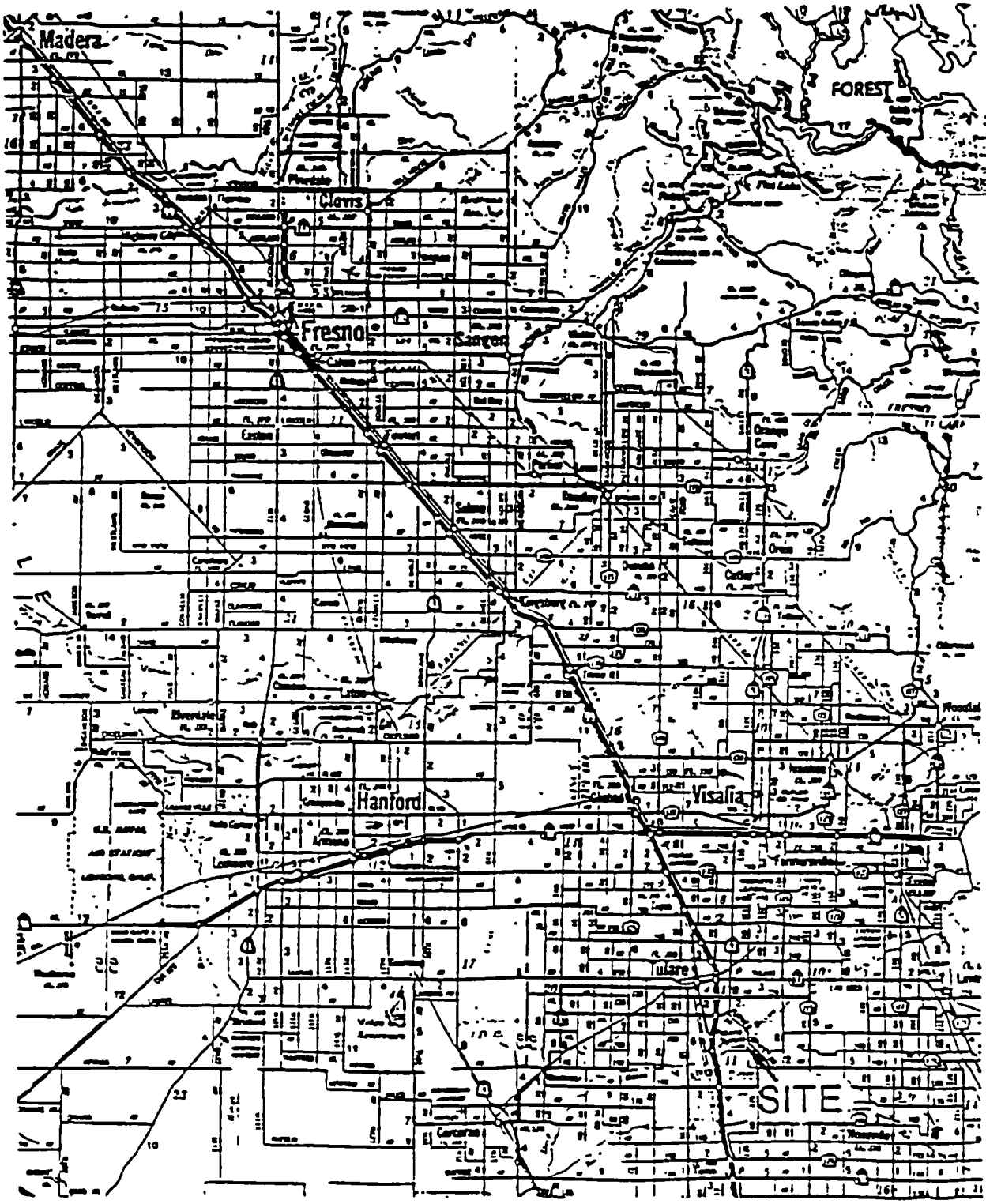
I. SITE BACKGROUND

Mefford Field is located approximately three miles southeast of Tulare, California just off of Highway 99 (see Figure 1). Mefford Field was started by the Mefford brothers in 1938. The airfield is presently owned by the City of Tulare. Crop dusters first began operating out of the airport in 1950. Hangers were built on the airport and private aerial (pesticide) applicators were responsible for installing their own utilities. Tracts of land were leased to commercial parties for a period of twenty five years with extension. Five commercial businesses are presently operating out of Mefford Field: Fry Aviation, Tulare Mosquito Abatement District, Moore Aviation, Inc., Gryphon Aviation, and Johnston Aircraft Service, Inc. Sumps connected to disposal wells are located on tracts leased to Moore Aviation, Inc. and Johnston Aircraft Services.

II. CHEMICALS HANDLED ON SITE

A. MOORE AVIATION, INC.

According to Moore Aviation's owner, Robert Moore, chemicals used in his crop dusting operation are neither stored nor handled at the hangar. All mixing and loading is usually done in the field or along the runway. Previous owners of the hangar (before Moore's purchase in 1978) are suspected of handling various pesticides and herbicides on the property.



From Kleinfelder and Associates', "Report of Phase I Site Assessment ... Mefford Field", 1986.

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SCALE

SITE LOCATION PLAN
MEFFORD AIRFIELD-TULARE, CALIFORNIA

ENGINEERING ENTERPRISES, INC.

609-012-03 Figure 1

[6-301]

B. JOHNSTON AIRCRAFT SERVICE, INC.

Johnston Aircraft Service, Inc. has operated from their hangar at Mefford Field since 1956. The hangar is used as an airplane repair shop. Oils, solvents, and greases are currently handled on site. These waste products are reportedly disposed of in drums which are hauled off the location.

C. TULARE MOSQUITO ABATEMENT DISTRICT (TMAD)

The District has one crop dusting plane and several vehicles which are used to apply insecticides. The following chemicals are reported to be commonly used by TMAD: Golden Bear Oil 1356, Baygon WP, Dursban M, and Altasid SR 10.

D. FRY AVIATION

Fry Aviation owns two aerial application planes which operate from their hangar at Mefford Field. Chemicals commonly used on the premises are: Dibrom, Orthene, Diazinon 50W, Buctirl, Comite, Alfa tox, Lorsban, Disyston, Dimethoate 267, paraquat, sodium chlorate and sulfur dust.

E. GRYPHON AVIATION

This hangar was used as a crop dusters school until 1980. Since then, one aircraft has been used for commercial crop dusting. As a result, a variety of chemicals have been handled on the property. The aircraft is reportedly filled with agricultural chemicals in the field or occasionally on the runway strip. A list of agricultural chemicals handled on the property has not been compiled.

III. SITE GEOLOGY/HYDROLOGY

The following geologic and hydrogeologic information pertaining to Tulare's Mefford Field largely consists of excerpts taken from Kleinfelder and Associates; "Report of Phase I - Site Assessment...", June 1986.

A. GEOLOGY

Mefford Field is located on the coalescing alluvial fan deposits of the Kings, Tule and Kaweah Rivers. The regional geologic formations may be classified into three general units: the basement complex, the Quaternary continental and alluvium deposits of the Coast Ranges, and the Quarternary alluvium of the Sierra Nevada Mountains.

1. Basement Complex

The basement complex is an impermeable layer of Pre-Tertiary consolidated metamorphic and igneous rocks and unconsolidated deposits of Pliocene, Pleistocene, and recent age. The depth of this complex below the site is unknown.

2. Quaternary Continental and Alluvial Deposits of the Coast Ranges

These unconsolidated continental and alluvial deposits are present beneath the site at an approximate depth of 20,000 ft. The continental deposits can be subdivided into deposits formed in oxidizing or reducing subsurface environments. Oxidized deposits encountered are those of reddish-brown silts and clays. Reduced

deposits are typically micaceous sands, silts and clays. Older alluvial deposits consist of fine to medium sands and silty sands with occasional clay or gravel lenses.

3. Quarternary Alluvial Deposits of the Sierra Nevadas

Above the continental and alluvial deposits of the Coast Ranges lie the alluvial deposits of the Sierra Nevadas. These alluvial deposits extend upward to, or near, land surface at Mefford Field. These younger alluvial deposits are comprised of arkosic deposits, fluviatile sands, and silty sands. The relatively impermeable E-clay is reportedly contained within the younger alluvium at an approximate depth of 440 to 500 ft. below the airport. The A-clay and C-clay are apparently absent in the Tulare area.

A subsurface boring program indicated silty sands extending to 18 feet below land surface at the airport. These sands were moderately dense with good to poor sorting characteristics. Beneath the silty sand layer is a fine to medium grained sand with coarse sand and fine gravel lenses. This stratum was encountered to a depth of 39 feet. Site specific information regarding the Sierra Nevada alluvium below 40 ft. is unavailable.

B. HYDROLOGY

Aquifers below the Tulare vicinity are reported to be semi-confined and confined, above the E-clay layer. Aquifers below the E-clay are considered to be confined. Groundwater below the airport has ranged in depth from 17 ft. to 20 ft. below land surface. The groundwater table has fluctuated roughly 2.5 ft. over a period extending from April to August of 1986. This is largely in response to changes in pumping requirements posed by local irrigation wells. The local hydraulic gradient beneath the site has not been determined. Regional water maps indicate a general gradient directed toward the southwest within the area. Local pumping influences coupled with hydraulic influences from Elk Bayou may effect a directional change in the gradient toward the north-northwest (conversation with J. Waters, Water Superintendent, Tulare County Environmental Health Department).

Groundwater below the site is part of the expansive San Joaquin Water Basin. Much of the groundwater in the Tulare vicinity meets the federal Underground Injection Control (UIC) program's definition of an Underground Source of Drinking Water (USDW). Groundwater is used for domestic, agricultural, and industrial purposes.

IV. POSSIBLE ON SITE CONTAMINATING POINT SOURCES

Possible contaminating point sources located on the airport grounds have been identified previously by the authors. These possible sources were described in site reports by Kleinfielder and Associates, Inc.. These sources consist of the following: a

reservoir (dump), a pesticide loading area, underground storage tanks, a pit, and two sumps with connected disposal wells. Figure 2 shows the location of these possible sources of contamination.

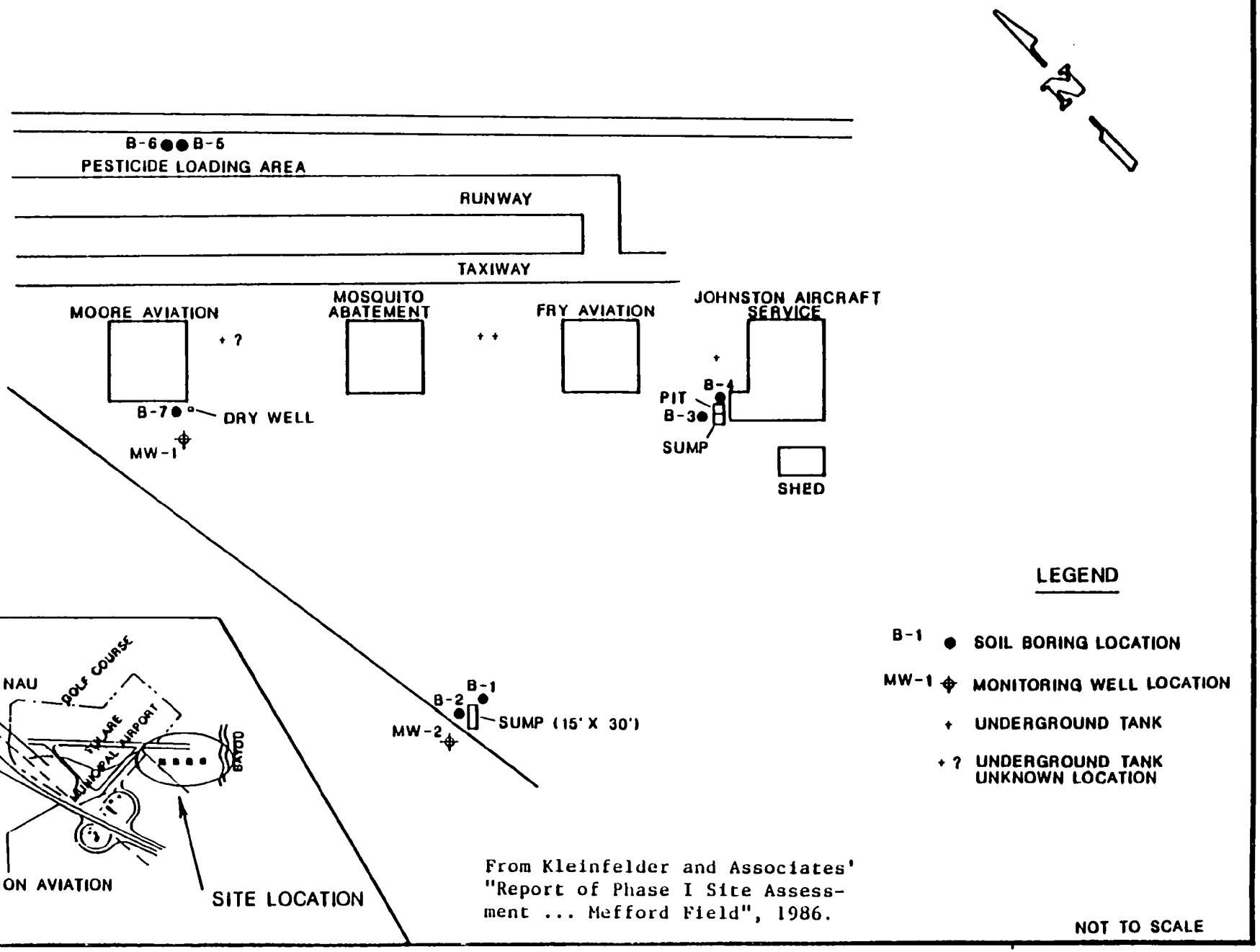
A dump was formerly used by aerial chemical application firms operating from the airfield. Cans, pesticide containers, and trash were disposed of in the dump. The dump, which is located in the south section across from the airstrip, has since been abandoned.

Several aviation company owners have reported to the Central Valley Regional Water Quality Control Board that crop dusting planes are being filled along the airport's runway. A specific pesticide loading area was selected for investigation after consultations were held with City officials and crop dusting operators.

Underground storage tanks containing aviation fuel and chemicals are possible contaminating point sources at Mefford Field. Tanks are located on lands leased by Gryphon Aviation, Johnston Aircraft and Moore Aviation. Two additional underground storage tanks are located between the TMAD and Fry Aviation hangars.

A pit measuring 10 ft. deep, 14 ft. wide, and 30 ft. long was formerly used by TMAD. This pit received drainage water from the wash down area and wash rack sump when TMAD cleaned their

BORING LOCATION PLAN
MEFFORD AIRFIELD-TULARE, CALIFORNIA



From Kleinfelder and Associates' "Report of Phase I Site Assessment ... Mefford Field", 1986.

NOT TO SCALE

ENGINEERING ENTERPRISES, INC.

609-012-03

Figure 2

[6-307]

plane and ground vehicles. This practice has been suspended and the drainage pipe leading to the pit is currently plugged.

Two sumps connected to disposal wells are located on tracts leased by Johnston Aircraft Service and Moore Aviation, Inc. Outside the Moore Aviation hangar is a wash area where their plane was formerly washed. Wash water has been collected in a sump and drained into a disposal well. A sump which was formerly connected to a disposal well was once used at Johnson, Aircraft. This sump and disposal well were used to dispose of waste fluids including oils, solvents and greases.

V. DESCRIPTION OF DISPOSAL WELLS

As discussed in the previous section, two sump and disposal well systems were once used at the sites currently leased by Moore Aviation, Inc. and Johnston Aircraft Services. Limited construction details are available regarding these systems.

At Moore Aviation, a two-baffled sump was located directly beneath a wash rack. This sump contained approximately 100 gallons of liquid at the time of inspection (T. Souther of the Central Valley Regional Water Quality Control Board). The sump has since been capped off. The sump was formerly connected to a disposal well which was located approximately 15 ft. from the sump. Construction details of this disposal well are not available.

A 2 ft. square by 4 ft. deep sump was also inspected at Johnston Aircraft Services. The sump was found to contain fluids which were believed to be spent oils, and greases (C. Johnson, Kleinfelder and Associates). According to the owner, the sump previously drained into a disposal well. This gravel filled disposal well was estimated to be "ten ft. deep by ten ft. round (diameter)." (Kleinfelder and Associates, "Report of Phase I - Site Assessment...", 1986). The owner has stated that he believes the sump no longer drains into the disposal well.

VI. FACILITY INVESTIGATION - ON SITE

A. Soils

Nine (9) 2-inch soil borings were drilled at Mefford Airport in April of 1986. Two of these borings were completed as ground water monitoring wells. B-1 and B-2 were drilled adjacent to a sump located within the TMAD yard. B-3 was placed adjacent to the sump and B-4 was placed in the (reported) gravel-filled pit area, on the west side of the Johnston Aircraft Service building. Soil borings B-5 and B-6 were drilled in the pesticide loading area northeast of the runway. B-7 was drilled near the dry well (disposal well) at the Moore facility. The locations of the soil borings are shown in Figure 2. (Kleinfelder and Associates, "Report of Phase I - Site Assessment..." 1986). Table 1 lists the depths at which samples were withdrawn from each boring.

Of those field samples collected, 11 samples were sent to a laboratory for chemical analysis. These soils were tested for organochlorine and organophosphorus pesticides, chlorinated

TABLE 1

SOIL BORING AND SAMPLING

	Number of Borings	Soil Sampling Depth, ft.	Depth of Boring or Completed as Monitoring Well, ft.
Dry Well	1 (B7)	2, 5, 10, 15, 20	20
	1 (MW1)	10, 20, 30, 40	40
TMAD Sump	2 (B1 & B2)	2, 5, 10, 15, 20	20
	1 (MW2)	10, 20, 30, 40	40
Johnston Sump	1 (B3)	2, 5, 10, 15, 20, 25, 30	30
	1 (B4)	10, 15	16
Loading Area Near Runway	2 (B5 & B6)	0, 2, 5	6

From Kleinfelder and Associates', "Report of Phase I Site Assessment ... Mefford Field", 1986.

herbicides and substituted urea. Analytical results from Borings B-4 and B-7 are included in Tables 2-3.

B. Groundwater

Two 2-inch PVC monitoring wells, MW-1 and MW-2, were drilled and completed to depths of 40 ft. and 30 ft. respectively. These wells were placed downgradient of the Moore Aviation disposal well and the TMAD sump (as inferred from regional groundwater elevation maps). Groundwater samples were collected from MW-1 and MW-2 in June and September of 1986. These samples were analyzed for the following constituents: halogenated and aromatic volatiles, organochlorine and organophosphorous pesticides, carbamate and urea compounds, and chlorinated herbicides. Table 4 presents the analytical results for all water samples collected from MW-1 and MW-2.

Two of three water supply wells currently operating on the airfield grounds have been sampled. The first water well sampled was the Gryphon Well. This well supplies the Gryphon hangar which also currently serves as the administration building. The Gryphon Well was sampled in June and September of 1986. The Fry and Johnston Well was also sampled in September, 1986. This well services the Fry, Johnston, TMAD and Moore hangars. This sample was collected at the Fry Aviation tap. The June, 1986 sample withdrawn from the Gryphon Well was sampled for organophosphorous and organochlorine pesticides, chlorinated herbicides, carbamates, halogenated volatile hydrocarbons and aromatic hydrocarbons. Those samples collected in September, 1986 were

File: W-3020-1
June 18, 1986

TABLE 2 - SOIL SAMPLE ANALYTICAL RESULTS - BORING 4

Method Name	EPA Method	Depth	Sample#	Concentration	D.L.*	Action Level/Agency**
Constituents						
Halogenated Volatiles	8010	10 ft	3724			
1,1-dichloroethane				0.1	0.05	1 / CVRWQCB
1,1,1,-trichlorethane				1.7	0.05	200 / CVRWQCB
Aromatic Volatiles	8020	10 ft	3724			
Benzene				2.3	0.05	0.70 / CVRWQCB
Toluene				5.6	0.05	100 / CVRWQCB
Xylene				21.0	0.1	620 / CVRWQCB

* D.L. = Detection Limit

** Agency = Agency Publishing Action Level: CVRWQCB = Central Valley Region Water Quality Control Board, Marshak, Jon B., July 1985. Designated total level in a solid to protect ground water.

NOTE: Constituents not listed were below the detection limits.
All concentrations, detection limits and action levels are in mg/kg.

From Kleinfelder and Associates', "Report of Phase I Site Assessment ... Mefford Field", 1986

From Kleinfelder and Associates', "Report of Phase I Site Assessment ... Mefford Field", 1986.

File: W-3020-1
June 18, 1986

TABLE 3 - ANALYTICAL RESULTS - BORING NO. 7

Method Name	EPA Method	Depth	Sample#	Concentration	D.L.*	Action Level/Agency**
Constituents						
Organochlorine	8080	15 ft	3799			
p,p DDE				0.38	0.05	1 / DHS/TTLC
Organophosphorous	8140	15 ft	3799			
DEF				1.1	0.05	Not Established
Diphenamid				1.0	1.0	40 / CVRWQCB
Methyl Parathion				0.05	0.05	30 / CVRWQCB
Parathion				0.08	0.05	30 / CVRWQCB
Chlorinated Herbicides	8150	15 ft	3799			
DNBP				2.8	1.0	39 / CVRWQCB
Substituted Urea	632 Modified	15 ft	3799			
Diuron				2.3	1.0	Not Established

* D.L. = Detection Limit

** Agency = Agency Publishing Action Level: DHS-TTLC = Department of Health Services. Total Threshold Limit Concentration

CVRWQCB = Central Valley Region Water Quality Control Board, Marshak, Jon B., July 1985. Designated total level in a solid to protect ground water.

NOTE: Constituents not listed were below the detection limits.
All concentrations, detection limits, and action levels are in mg/kg.

File: W-3020-1
June 18, 1986

TABLE 3 - SOIL SAMPLE ANALYTICAL RESULTS - BORING NO. 7

Method Name / Constituents	EPA Method	Depth	Sample#	Concentration	D.L.*	Action Level/Agency**
Organochlorine	8080	20 FT	3801			
p,p DDE				10	0.05	1 / DHS/TTLC
p,p DDT				2	0.05	1 / DHS/TTLC
					2.4×10^{-3}	/ CVRWQCB
Organophosphorous	8140	20 FT	3801			
Diphenamid				3.0	1.0	40 / CVRWQCB
Parathion				2.1	0.05	30 / CVRWQCB
Phorate				0.2	0.05	0.7 / CVRWQCB
Trifluralin				30	0.05	700 / CVRWQCB
Diazinon				0.4	0.05	14 / CVRWQCB
Chlorinated Herbicides	8150	20 ft	3801			
All Constituents				None Detected		
Substituted Urea	632 Modified	20 ft	3801			
Diuron				1.5	1.0	Not Established

* D.L. = Detection Limit

** Agency = Agency Publishing Action Level: DHS-TTLC = Department of Health Services. Total Threshold Limit Concentration

CVRWQCB = Central Valley Region Water Quality Control Board, Marshak, Jon B., July 1985. Designated total level in a solid to protect ground water.

NOTE: Constituents not listed were below the detection limits.
All concentrations, detection limits, and action levels are in mg/kg.

From Kleinfelder and Associates', "Report of Phase I Site Assessment ... Mefford Field", 1986.

File: W-3020-1
October 20, 1986

DRAFT

TABLE 4

COMPARISON OF CHEMICAL CONCENTRATIONS AND OCCURRENCES
BETWEEN SAMPLING ROUNDS
(Chemical Concentrations in ug/l)

	MONITORING WELL #1		MONITORING WELL #2		ACTION
	6-18-86	8-4-86	6-18-86	8-4-86	LEVEL/AGENC
Halogenated Volatiles					
Bromodichloromethane	ND	1	ND	ND	--
Chlorobenzene	6	6	ND	ND	130/DOHS
Chloroform	18	6	ND	ND	100/EPA
1,2-dichloroethane	7	3	ND	ND	1/DOHS
1,1,1-trichloroethane	ND	2	17	6	200/DOHS
1,2-dichloropropane	4	ND	ND	ND	10/DOHS
1,1-dichloroethene	ND	ND	9	3	6/DOHS
Aromatic Volatiles					
Benzene	6	5	ND	ND	0.7/DOHS
Chlorobenzene	ND	5	ND	ND	130/DOHS
Ethyl benzene	1	30	ND	ND	1400/EPA
Toluene	6	20	ND	ND	100/DOHS
Xylenes	27	200	ND	ND	620/DOHS
Organochlorine Pesticides					
BHC	ND	0.2	ND	ND	0.3/DOHS
Lindane	ND	0.3	ND	ND	
p,p DDE	0.6	ND	ND	ND	
p,p DDT	0.1	0.7	ND	ND	50/EPA
Organophosphorus Pesticides					
Diazinon	ND	0.3	ND	ND	14/DOHS
Dimethoate	ND	3.0	ND	ND	140/DOHS
Phorate	ND	0.5	ND	ND	
Carbamate and Urea Compounds					
Carbofuran	ND	35	ND	ND	
Diuron	200	10	4	1	
Chlorinated Herbicides					
Dicamba	43	60	ND	ND	8.75/NAS
2,4 - D	ND	130	ND	ND	
2,4,5 - T	ND	2	ND	ND	
2,4,5 - TP	12	50	ND	ND	5.25/NAS
DNBP	500	20	ND	ND	39/NAS

ND = Not Detected

Adapted from Kleinfelder & Associates, "Draft Report of Phase I ... Mefford Field", 1986.

DOHS=California Dept. of Health Services
NAS =National Academy of Sciences
EPA =Environmental Protection Agency

analyzed for phenols in addition to these constituents mentioned above. The analytical results of the September, 1986 water samples are presented in Table 5.

VII. FACILITY INVESTIGATION - OFF SITE

Two domestic water wells and one public water well located within 1/2 mile of Mefford Field were sampled in September of 1986. These wells served a motel (Sky Ranch Motel), a rental home (Franks Equipmental Rental), and a park (Elk Bayou Park). Refer to Figure 3 for their locations. The wells located at the motel and rental home are thought to be hydraulically downgradient of Mefford Field. Water samples withdrawn from these off site wells were sampled and analyzed for a range of constituents. These included organophosphorous and organochlorine pesticides, chlorinated herbicides, carbamates, and hydrocarbons. Refer to Table 5 for the analytical results of the off site water well samples.

VIII. DISCUSSION OF DISPOSAL WELL CONTAMINATION DATA

A. Soils

Soils below the sump and disposal well areas at Moore Aviation and Johnson Services are the only soils that showed traces of agricultural chemicals and hydrocarbons at Mefford Field. Soil samples collected at the pesticide loading area and the TMAD sump were reported to be free of contaminants. Various agricultural chemicals and hydrocarbons, however, were detected in soils sampled from Borings B-7, near Moore Aviation, and Boring B-4, near Johnston Aircraft Service.

File: W-3020-1
October 20, 1986

DRAFT

TABLE 5

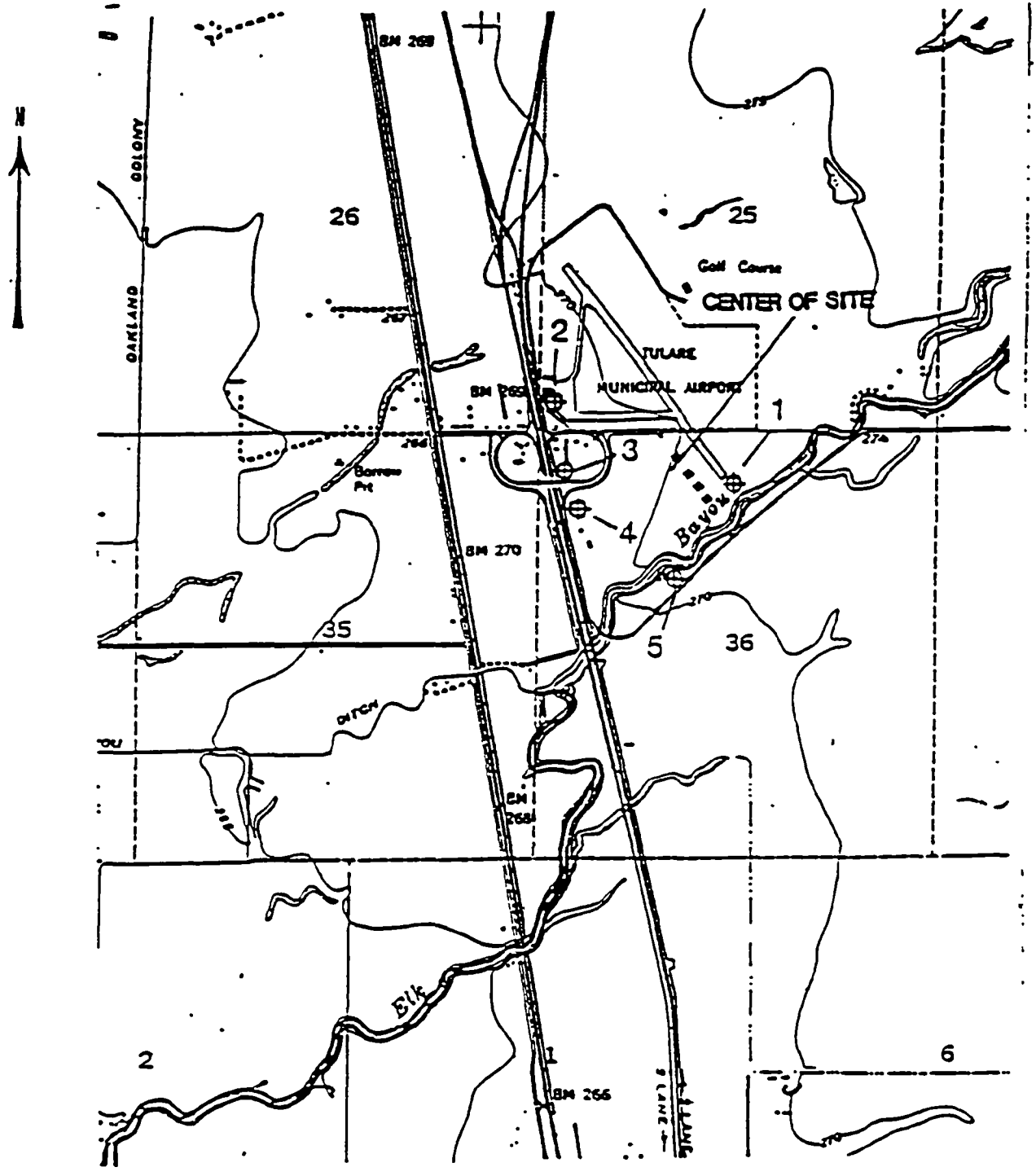
ANALYTICAL RESULTS: DOMESTIC WELL WATER SAMPLES

		Concentration (ug/l)						
Location*	Sample#	EPA 601	EPA 602	EPA 604	EPA 614	EPA 632	EPA 608	EPA 622
DW-3	2003	-	ND	-	-	-	-	
DW-3	2004	ND	-	-	-	-	-	-
DW-3	2005	-	-	ND	ND	ND	ND	-
DW-7	2006	ND	-	-	-	-	-	-
DW-1	2007	-	ND	-	-	-	-	-
DW-1	2008	-	-	ND	ND	ND	ND	ND
DW-5	2009	ND	-	-	-	-	-	-
DW-5	2010	-	ND	-	-	-	-	-
DW-5	2011	-	-	ND	ND	ND	ND	ND
DW-2	3821	-	-	ND	-	-	-	-
DW-4	3824	-	-	ND	ND	ND	ND	ND
DW-4	3825	ND	-	-	-	-	-	-
DW-4	3826	-	ND	-	-	-	-	-

* Location: DW-1, Fry drinking water source
DW-2, Gryphon Aviation
DW-3, Sky Ranch Motel
DW-4, Frank's Equipment - Rental House
DW-5, Elk Bayou - Old Well

ND = Not Detected
- = Not Analyzed

EPA 601 : Purgeable Halocarbons
EPA 602 : Purgeable Aromatics
EPA 604 : Phenols
EPA 614 : Phenoxy Herbicides
EPA 608 : Organochlorine Pesticides
EPA 622 : Organophosphorous Pesticides
EPA 632 : Carbamates



SCALE IN MILES

0 ½

From Kleinfelder and Associates, "Draft Report of Phase I... Mefford Field", 1986.

DOMESTIC WELLS

1

1. FRY&JOHNSTON
2. GRYPHON AVIATION
3. SKY RANCH MOTEL
4. FRANKS RENTAL HOUSE
5. ELK BAYOU, OLD WELL

DOMESTIC WELL LOCATIONS
MEFFORD AIRFIELD-TULARE, CALIFORNIA

ENGINEERING ENTERPRISES, INC.

609-012-03 Figure 3

Aromatic and halogenated hydrocarbons were detected in Boring B-4 at a depth of 10 ft. Benzene was the only constituent found in the sample to exceed a Regional Soil Cleanup Action Limit (see Table 1). Boring B-3, which is also near the Johnston sump and disposal well, was sampled at a depth of 10 ft. Contaminants were not detected. Additional samples withdrawn from Borings B-3 and B-4 (as shown in Table 1) were not analyzed for chemical constituents. As a result, the vertical distribution of contaminants detected in soils northeast of the Johnston Disposal Well is unknown.

Pesticides and herbicides were detected in Boring B-7 at depths of 15 ft. and 20 ft. (refer to Tables 2 and 3). All constituents in the 15 ft. sample were present in concentrations below regional soil cleanup action levels. DDE (dichlorodiphenyldichloroethylene) and DDT (dichlorodiphenyltrichloroethane) were detected in the 20 ft. sample at concentrations exceeding the Total Threshold Limit Concentration established by the California Department of Health Services (DOHS). These contaminants were detected in stained soils near the water table vadose zone interface.

B. Groundwater

Agricultural chemicals and volatile hydrocarbons have been detected in on-site monitoring well samples. Contaminants, however, have not been detected in domestic water wells on, or downgradient of Mefford Field.

Groundwater sampled from monitoring well MW-1 has contained a wide variety of contaminants. Chloroform, chlorobenzene 1,2-dichloroethane, 1,2-dichloropropane, benzene, ethyl benzene, toluene, xylene, DDE, DDT, Diuron, Dicamba, 2,4,5-TP, and DNBP were all detected in the June, 1986 sample withdrawn from MW-1. Additional constituents detected in the September, 1986 sample of MW-1 were: bromodichloromethane, BHC, Lindane, Diazinon, Dimetroate, Phorate, Carbofuran, 2,4-D and 2,4,5-TP. Constituents whose concentrations exceed California's Drinking Water Action Limits in MW-1 are: 1,2-dichloroethane, benzene, 2,4-D, 2,4,5-TP, Dicamba, and Carbofuran.

Changes in contaminant concentrations measured between the June, 1986 and September, 1986 samples may possibly be attributed to one or more of the following: a fluctuating water table, in situ chemical degradation, a leaky underground storage tank (Kleinfelder and Associates, "Draft Report of Phase I...", 1986:16). Contaminant concentrations were essentially constant in groundwater samples extracted from monitoring well MW-2 in June and September of 1986. These samples contained 1,1,1-trichloroethane, 1,1-dichloroethene and Duiron. 1,1-dichloroethene concentrations exceeded the California Department of Health Services' Drinking Water Action Limit in both monthly samples.

Two domestic water wells on the Mefford Field grounds were sampled and found to be free of agricultural chemicals and hydrocarbons. Three domestic wells within 1/2 mile of Mefford

Field also showed no trace of these chemicals. Possible explanations for this anomaly are:

- the domestic wells sampled are perforated in deeper water bearing zones than those penetrated by MW-1 ard MW-2,
- the contaminant concentrations downgradient of the airport have been diluted to levels below detection limits,
- the domestic wells are not hydraulically downgradient of the contaminating point sources at Mefford Field,
- the contaminant plume does not outwardly extend to those domestic wells sampled.

IX. ASSESSMENT

Industrial disposal wells formerly operating at Mefford Field posed a moderate contamination threat to USDW. Soil samples collected near the Moore and Johnston disposal wells implicate these wells in the former disposal of agricultural chemicals and hydrocarbons. At the Moore Aviation site, wash water formerly used to clean crop dusting planes and chemical containers is suspected of containing pesticides. Waste petroleum products were formerly disposed of in the Johnston disposal well.

The capability of existing vadose zone sediments to attenuate the chemicals disposed of in these wells is unknown. Stained, contaminated samples have been encountered in soils lying 20 feet above the groundwater table. Water samples extracted from MW-1 and MW-2 indicate to the authors of this study that injected chemicals have migrated through the vadose zone sands and into the groundwater.

Ground water contamination has been documented on the Mefford Field property. Agricultural chemicals and hydrocarbons have been detected in groundwater below the site. Contaminated water samples were extracted from monitoring wells near the TMAD sump and the Moore Aviation disposal well. Six chemical compounds were detected in water samples at concentrations exceeding California Drinking Water Action Limits.

Hydrologic factors have contributed to the occurrence of ground water contamination at Mefford Field. Injected fluids must only migrate 17 to 20 ft. to reach groundwater below the airport. Chemicals have limited time to degrade or become attenuated in vadose zone soils before they diffuse into the groundwater.

Additional monitoring wells should be drilled and completed at various depths. These wells are required to:

- delineate the areal and vertical extent of the contamination plume on site,
- Determine the hydraulic effects of Elk Bayou on groundwater gradients below the Field.

Well locations should include positions downgradient of the Johnston Disposal Well, the former dump, and all underground storage tanks. Existing monitoring wells should be sampled quarterly. Domestic water wells should be sampled each month until the contaminant plume on site is delineated.

UNDERGROUND INJECTION CONTROL PROGRAM
FILE INVESTIGATION REPORT

SECTION I – General Information

Name of Facility: Mefford Field

~~Address~~ **LOCATION:** Just SE of intersection of Highways #99 and #66

Telephone: (209) 688-2001

Owner Address and Telephone (if different from above): City now owns airfield
Land: City of Tulare Technical Contact: Mr. Joseph E. Donabed
411 E. Kern Ave.
Tulare CA 93274
Nature of Business:
Moore Aviation lessee crop dusting. Johnson Aircraft Services
Robert Moore: Owner of Hangar Air Plane Engule Repair Mr. Johnson, Owner
Use of Injection Well (s) (drainage, direct disposal, etc.):

2 disposal wells: 5W-20's

Identification, Permit or EPA Number (s):

Injection Well (s) Location (township, range and section, latitude and longitude, verbal description, land marks, etc.):

T 20 S R 24 E Sec. 25

Type of Injection Well (s) –
Industrial Drainage:
Storm-runoff:
Other (specify): 2 disposal wells 5W - 20's

Injection Well (s) Currently Operating: Yes _____ No X

If No, Last Date of Operation:
January 1, 1985 or before (?)
Date of Construction of Injection Well (s): Unknown crop dusting started at airport in 1950. First lease was in 1956
Years Injection Well in Operation:

Unknown exactly (20 - 30 yrs. in all probability).

SECTION II - Hydrogeologic Information

Injection Formation - Name: Unknown

- **Description:**
- **Extent of Injection Zone (s) Below Land Surface (or elevation above Mean Sea Level):**
- **Minimum Distance from Injection Well to Underground Source of Drinking Water (U.S.D.W.):**

Location (depth below land surface, areal extent, etc.) and description (thickness, lithology, etc.) of Any Relatively Impermeable Strata (aquitard (s)) Present:

E-clay at 440' - 500'

Underground Sources of Drinking Water -

Confined:

Unconfined: Semi San Joaquin Basin Aquifer

Depth to Perched Water Table (if present): NA

Depth to Water: 19' (25' - 40' estimated by DWR)

Saturated Thickness:

Description and Characteristics:

DWR 1985 gradient is to S-SW 20 ft./ mi
Significant sand lenses, potential for high permeabilities.

Extent of Use of U.S.D.W. (extensive, moderate, municipal, domestic, potential, etc.):

Moderate - Extensive
Domestic, agricultural, industrial, county.
According to Joe Donabed, County of Tulare has wells in the area for water supply. confirmed.

Comments:

3 water supply wells on airport site
1 water supply well NW of airport
2 wells south of airport

Attach the Following Information (note if unavailable) -

X Map of Facility Grounds:

- Well Log (s) for Injection Well (s):

- As-built Diagram of Injection Well (s):

-X Consultant Reports for Injection Well (s) and/or Site Hydrogeology:

X Monitoring Data for Injection Well:

- Monitoring Well Data -

  X Number of Monitoring Wells:

  - Location: Vertical and Horizontal Distance and Direction of Monitoring Well (s) From Injection Well:

  X Depth of Completion and Sampling Interval:

  X Chemical and Physical Analyses:

- Downgradient Water Supply Wells (within a one-quarter mile radius of the injection well) -

  2 Number of wells:

  X Location: Vertical and (Horizontal) Distance and Direction of Supply Well (s) from Injection Well:

  X Chemical and Physical Analyses:

  X Status of Wells (operating, abandoned, etc.)

  X Status of Any Nearby Surface Waters (possibly affected by injection well operation):

SECTION III - Operating Data

Injection Rate, Frequency, and Volume (drainage area, precipitation, etc.)

Description of Injection Operation (including brief history):

Agricultural chemicals used by crop dusters. In past years, planes were washed off and rinse water went down a dry well; some rinsing and or disposal of chemical rinsates from buckets may have been disposed of in the well.

Fluid Source:

Fluid Composition/Characteristics (including any treatment process): Various agricultural chemicals. Pesticides (DDE, DDT above action limits).

Contaminant (s) and Potential Source (s) of Contamination:

DDE, DDT, Phenoxyherbicide 2, 4, S TP Dicamba, dichloroethane. benzene all above DOHS action levels. Drywell on Moore property.

Method of Disposal (transport to well):

Direct Disposal and drainage

Previous Problems with Well (clogging, overflowing, etc.) -

No _____ Unknown

Yes _____ **Description of Problem:**

Operating Records Attached: Yes _____ **No** X

Injection Fluid Analyses Attached: Yes _____ **No** X

SECTION IV - Prior Site Inspection Specifics

Name and Affiliation of Inspectors: Jim Souther, CVRWQCB
Jerry Prine

Name and Affiliation of Facility Contact: Robert Moore, Owner of
Moore Aviation

Date: July 18, 1985 **Time:**

Reason for Inspection:
CVRWQCB ordered site inspection for invest of organizations and other ground contaminants

Number of Injection Wells:

Number of Injection Wells Inspected:

Site Conditions:

Inspection Comments:

Inspectors interviewed owner of drywell Robert Moore also investigated other areas where pollutant sources may exist, (pits, etc.).

Section 6.2.25

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	Industrial Disposal Well Case Study: Kearney-KPF-Stockton, California
AUTHOR: **(or INVESTIGATOR)**	Engineering Enterprises, Inc. (Prepared for USEPA Region IX)
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Kearney-KPF Stockton, California USEPA Region IX
NATURE OF BUSINESS:	Manufacturing, Silver Plating, Galvanizing
BRIEF SUMMARY/NOTES:	Rinse waters from silver plating contained concentrations of copper, cyanide, and silver in excess of 1 mg/l. Waste streams from galvanizing contained high concentrations of lead and zinc. Data is inadequate to delineate extent of subsurface contamination.

XXIII

INDUSTRIAL DISPOSAL WELL CASE STUDY: KEARNEY-KPF - STOCKTON, CALIFORNIA

I. SITE BACKGROUND

"KPF Electric Company, now Kearney - KPF, first began operations in 1951 at their plant site on East Alpine Avenue in Stockton, California (refer to Figure 1 for the location). From 1951 until 1965, the manufacturing plant, which includes a silver plating process, was the only operation on site. The company then expanded operations to include a galvanizing operation in 1972" (Canonie Environmental Hydrogeologic Assessment Report, [HAR], 1986).

All liquid wastes from the silver plating and galvanizing operations were discharged to the surface. These liquid wastes flowed into two topographic depressions on Kearney-KPF's property. One depression, or "pond", was drained by an industrial process water disposal well (5W20) for thirteen years. By January 1986, the Central Valley Regional Water Quality Control Board (CVRWQCB) had requested Kearney-KPF to halt all disposal of liquid wastes and rinse waters from the silver plating and galvanizing operations. The CVRWQCB subsequently required Kearney-KPF to conduct a hydrogeologic investigation in accordance with the California Toxic Pits Cleanup Act (TPCA). Kearney-KPF retained Canonie Environmental of Stockton, California to conduct the investigation.

VICINITY MAP
KEARNEY - KPF

(References: USGS 7.5 Minute Series Quadrangle Map of Stockton West California. Dated 1968. Scale 1"=2000')

EEI ENGINEERING ENTERPRISES, INC.

609-012-03

Figure 1

[6-330]

II. CHEMICALS HANDLED ON SITE

Various chemicals were used in the silver plating and galvanizing operations. Listed below are chemicals identified to have been used in these processes at one time.

Silver Plating Operations

- Trichloroethylene (TCE) until 1971
- Chloroethene
- Hydrochloric acid
- Nitric acid
- Sulfuric acid
- Sodium cyanide
- Mercuric oxide
- Silver cyanide

Galvanizing Operation

- Oakite (solution of sodium hydroxide, sodium carbonate, terpenes, and carboxylate type chelating agents)
- Hydrochloric acid
- Zinc chloride flux

In June 1985 and March 1986 the silver plating rinse water and the galvanizing waste solutions were tested for metal constituents. These constituent concentrations and volumes of discharged waste waters are presented in Tables 1 and 2. Rinse waters from the silver plating operation contained concentrations of copper, cyanide, and silver in excess of 1 mg/l. Waste streams generated from the galvanizing operation contained concentrations of lead and zinc at high concentrations. The CVRWQCB has requested that these waste solutions be analyzed for all priority pollutants (as defined by the State of California).

TABLE 1
CHARACTERIZATION OF DISCHARGE WASTE STREAMS
KEARNEY - KPF

	SILVER PLATING		GALVANIZING		
	Rinse Water (Alkaline Stream) (3/25/86)	Rinse Water (Acid Stream) (3-25-86)	(1) Oakite (6/11/86)	(1) (Spent Acid) (6/11/85)	Rinse Water (3/25/86)
ANALYTES(S) (MG/L)					
pH	9.0	1.9	12.8	0.2	2.4
	(2)				
Antimony	ND 0.02	0.02			0.03
Arsenic	ND 0.01	ND 0.01			ND 0.01
Beryllium	ND 0.005	0.007			ND 0.005
Cadmium	0.006	0.005			0.11
Chromium	ND 0.005	0.041			0.32
Copper	6.0	121			0.5
Cyanide	5.2				NA
Lead	0.006	ND 0.005	1.4	180	6.4
Mercury	0.002	ND 0.001			ND 0.001
Nickel	ND 0.05	ND 0.05			0.28
Selenium	ND 0.005	0.008			0.048
Silver	1.21	0.002			0.01
Thallium	ND 0.01	ND 0.01			0.10
Zinc	0.2	0.08	12	52000	134.0

(1) Samples were collected prior to the onset of the HAR investigations for analyses of selected heavy metals.

(2) ND (denotes none detected to a level of x.

From Canonie Environmental's 'Kearney-KPF: Hydrogeologic Assessment Report...',1986.

TABLE 2

SUMMARY OF ESTIMATED WASTE VOLUMES

Operation/ Constituent	Total Time of Discharge	Total Volume (gal)	Volume Per Year (gal/yr)	Discharge Location
Silver Plate Rinse Water				
Acid and Alkaline Water Rinse	35.0	510,000	15,000	Pond 2
Acid	34.5	4,700	130	Pond 2
Galvanizing Wate Solutions				
Oakite	12.75	190,000	14,000	Pond 1
Water Rinse	13.30	1,700,000	120,000	Pond 1
Spent Acid	12.75	200,000	17,000	Pond 1

From Canonie Environmental's "Kearney-UPF: Hydrogeologic Assessment Report...", 1986.

III. SITE GEOLOGY/HYDROLOGY

A. GEOLOGY

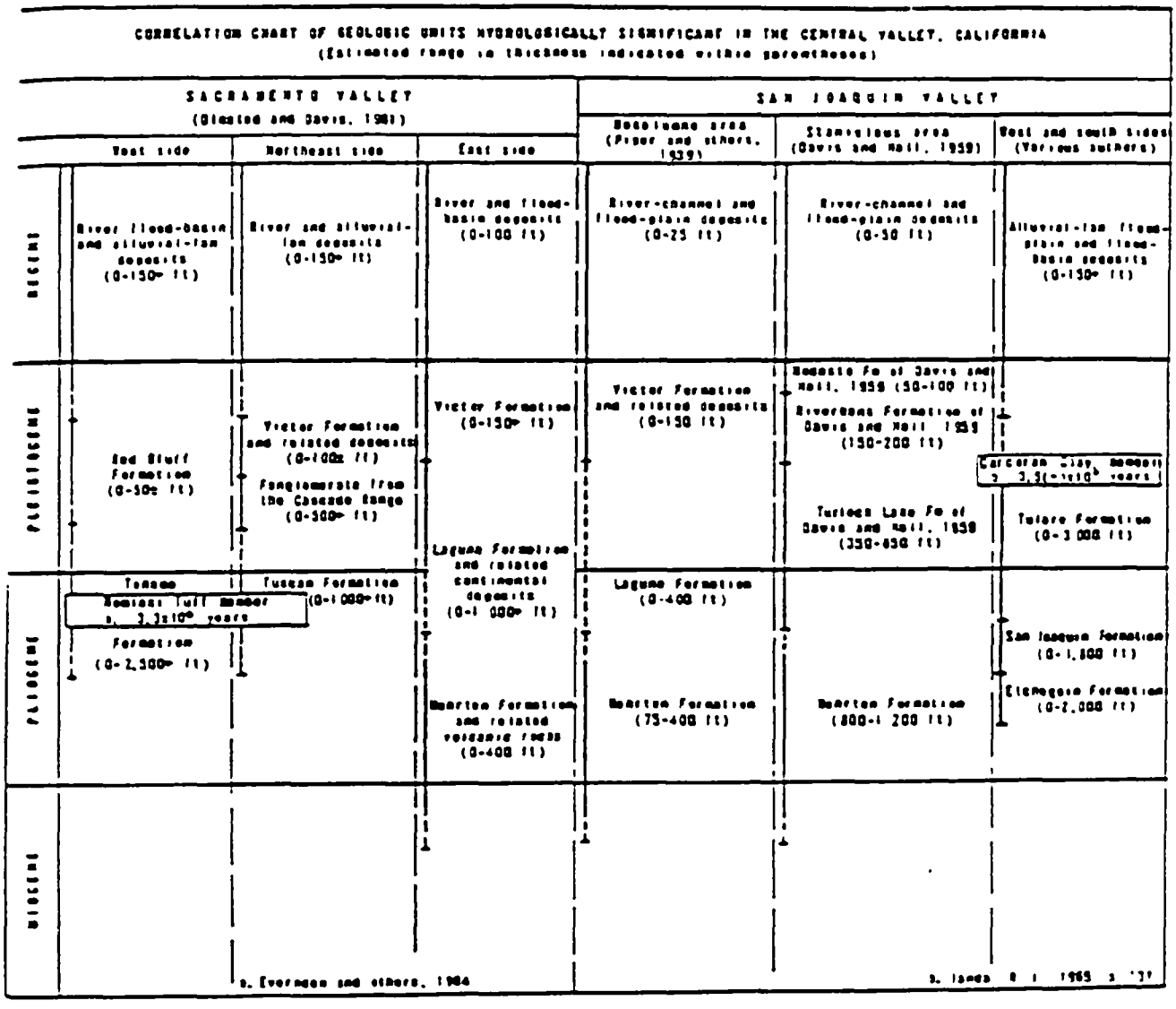
Geologic units of hydrologic significance located below the Kearney site are similar to those studied by Piper (1939, Piper, et. al.) in the Mokelumne area northeast of Stockton, California (Bailey, USGS, 1966). The unconsolidated water-bearing strata consist of the River Channel, Flood Plains, Victor and Laguna formations. See Table 3 for the approximate thicknesses of these formations. These unconsolidated deposits reportedly consist of silt, sandy silt, sand, gravels and clays (Bailey, USGS, 1966). Monitoring and water supply wells located on site most likely penetrate the Victor and Laguna Formations. The exact depths and thicknesses of each formation below Kearney-KPF's property have not been determined.

B. HYDROLOGY

The aquifer(s) located beneath Stockton and its outlying communities help comprise the upper San Joaquin Water Basin. Site specific hydrologic information pertaining to these aquifer(s) is minimal. Groundwater has been detected approximately 35 ft. below land surface. Piezometric elevation measurements taken from two Kearney-KPF monitoring wells indicate an essentially flat water table below the site (NW hydraulic gradient =0.0013, Canonie Environmental, 1986). Regional groundwater data, however, characterizes a hydraulic gradient (which has historically changed direction) directed to the E-NE. This hydrologic contradiction is yet to be resolved. Groundwater has been detected approximately 35' below land surface.

TABLE 3

CORRELATION CHART OF GEOLOGIC UNITS HYDROLOGICALLY SIGNIFICANT IN THE CENTRAL VALLEY, CALIFORNIA
(Estimated range in thickness indicated within parentheses)



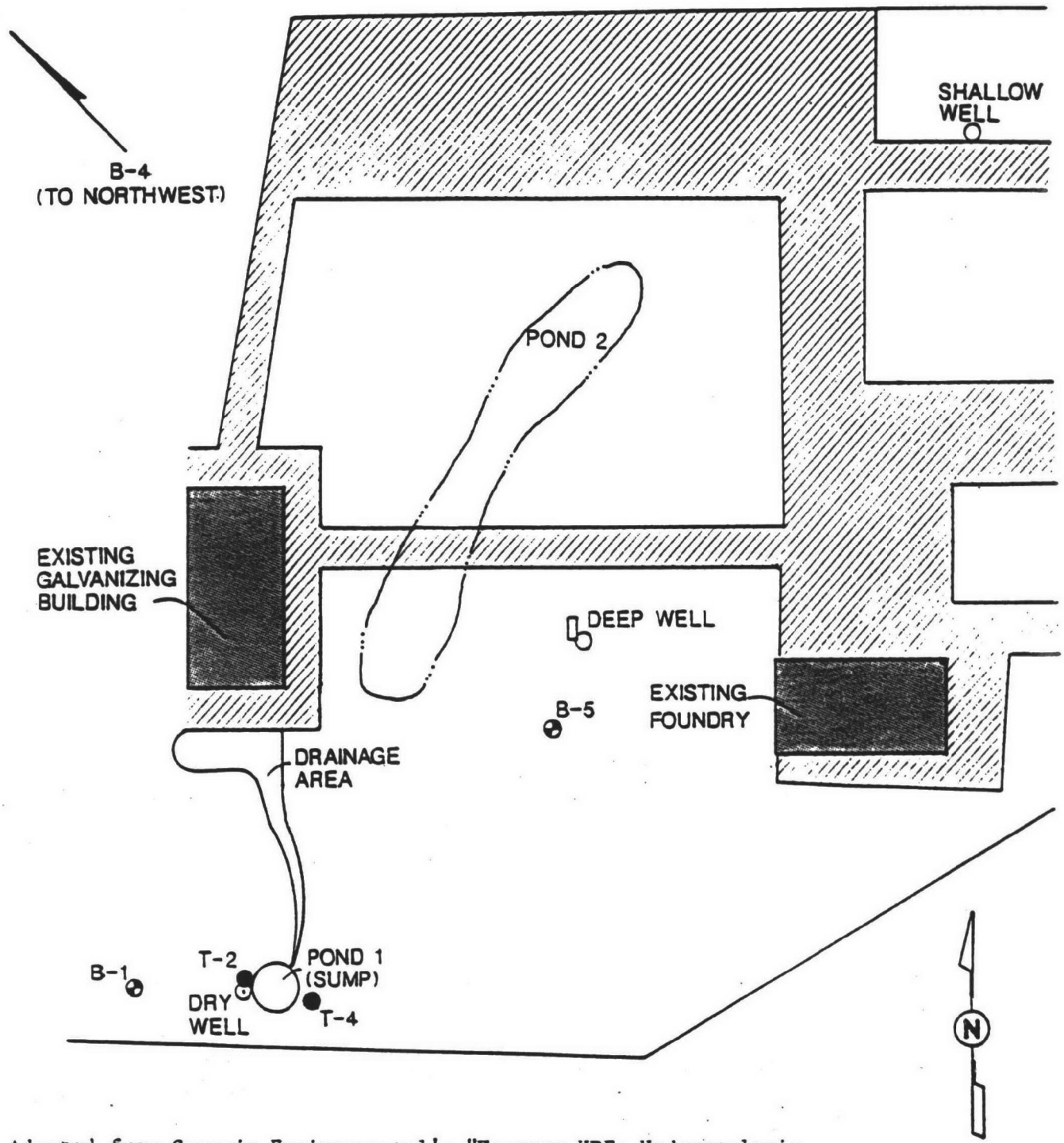
Twenty-eight off-site water supply wells have been located within one mile of the Kearney-KPF site boundary. These wells are used for domestic, industrial, and irrigation purposes. Groundwater use studies concerning northern California report that ground water is used for over half of the area's irrigation needs and nearly all of its domestic needs (Bailey, USGS, 1966). Seven wells near the Kearney-KPF property are used for municipal drinking water supply purposes. The aquifer(s) below, and surrounding the site are collectively classified as an Underground Source of Drinking Water (USDW).

IV. POSSIBLE ON SITE CONTAMINATING POINT SOURCES

Two drainage ponds and one industrial disposal well (5W20) were used to dispose of liquid wastes on site. A two inch PVC discharge pipe was installed to transport waste solutions from the silver plating lab to Pond 2. Pond 1 received galvanizing waste solutions from the galvanizing building. This pond's dimensions were approximately 25 feet in diameter by 4 feet deep. A 4-foot diameter industrial disposal well was constructed near Pond 1 to drain (by gravity) the standing liquid waste solution from the pond. Refer to Figure 2 for the locations of these discharge areas.

V. DISPOSAL WELL DESCRIPTION

An industrial process water disposal well was constructed (hand dug) in 1972. This well was dug approximately 17 feet west of Pond 1 in order to provide drainage for the pond. Industrial waste drainage from Pond 1 drained into the disposal well. The



Adapted from Canonie Environmental's "Kearney-KPF: Hydrogeologic Assessment

ON SITE CONTAMINATING POINT SOURCES
KEARNEY - KPF

ENGINEERING ENTERPRISES, INC.

609-012-03 Figure 2

disposal well was completed to a depth of 22 feet and was reported to penetrate a 7-foot thick sandy stratum. Porcelain from Kearney-KPF's foundary was used to backfill the uncased borehole.

VI. FACILITY INVESTIGATION - ON SITE

A. SOILS

Test pit, shallow boring, and deep boring soil samples were collected on the Kearney-KPF property by Canonie Environmental. The pH of all samples collected was measured so that soils polluted from the discharged acidic waste streams could be identified. Metals analyses were performed on selected soil samples found to have low pH's.

Soil Boring T-2 (see Figure 2) was drilled adjacent to the industrial disposal well borehole, which is approximately 5 feet west of Pond 1. Soil Boring T-4 was drilled 38 feet southeast of Boring T-2. Boring T-2 soils sampled between depths of 7 and 36 feet below land surface (bls) were confirmed to have a low pH. Soils sampled from depths of 20 to 26 feet bls at Boring T-4 were also found to have low pH levels. Metal concentrations (zinc, iron) were correspondingly high (refer to Table 4). Depth-pH information for Borings T-2 and T-4 is presented in Figure 3 and in the boring logs for each borehole.

TABLE 4

CHEMICAL ANALYSES OF SELECTED SOIL SAMPLES FROM THE DEEP BORINGS

WELL SAMPLE DEPTH (FT)	SOIL pH	Heavy Metal Concentrations for Total Threshold Limit Concentrations (1) (mg/kg) Pb	Zn	Fe	Cu	Hg	Ag (4)	Cn (4)	Heavy Metal Concentrations for Soluble Threshold Limit Concentrations (2) (mg/l) Pb	Zn	Fe	Cu	Hg	Ag (4)	Cn (4)
B-5/20-21	7.1	6.2	34	14800	24	ND 0.1(3)	-	-	ND 0.5	ND 25	20	ND 2.5	ND 0.2	-	
B-5/21-22	7.2	9.2	60	18000	40	ND 0.1	-	-	ND 0.5	ND 25	5.1	ND 2.5	ND 0.2	-	
T-1/21-24	6.3	4.8	30	12800	15	ND 0.1	ND 0.5	ND 1.0	ND 0.5	ND 25	17	ND 2.5	ND 0.2	ND 0.5	(5)
T-2/18-21	3.4	45.	880	19000	20	ND 0.1	-	-	1.2	60	108	ND 2.5	ND 0.2	-	
T-2/22-23	4.0	9.8	1400	28800	50	0.4	-	-	ND 0.5	139	129	ND 2.5	ND 0.2	-	
T-4/21-24	3.7	8.8	420	13000	17	ND 0.1	-	-	ND 0.5	37	68	ND 2.5	ND 0.2	-	
T-4/24-25	3.8	23.	1290	26000	37	ND 0.1	-	-	ND 0.5	75	62	ND 2.5	ND 0.2	-	
T-5/22-25	6.4	4.5	210	11000	15	ND 0.1	-	-	1.3	77	151	ND 2.5	ND 0.2	-	
T-5/25-26	6.6	7	48	21000	42	0.3	-	-	0.5	ND 25	28	ND 2.5	ND 0.2	-	

(1) Analyzed using acid digestion procedures outlined in the CAM.

(2) Analyzed using WET as described in the CAM.

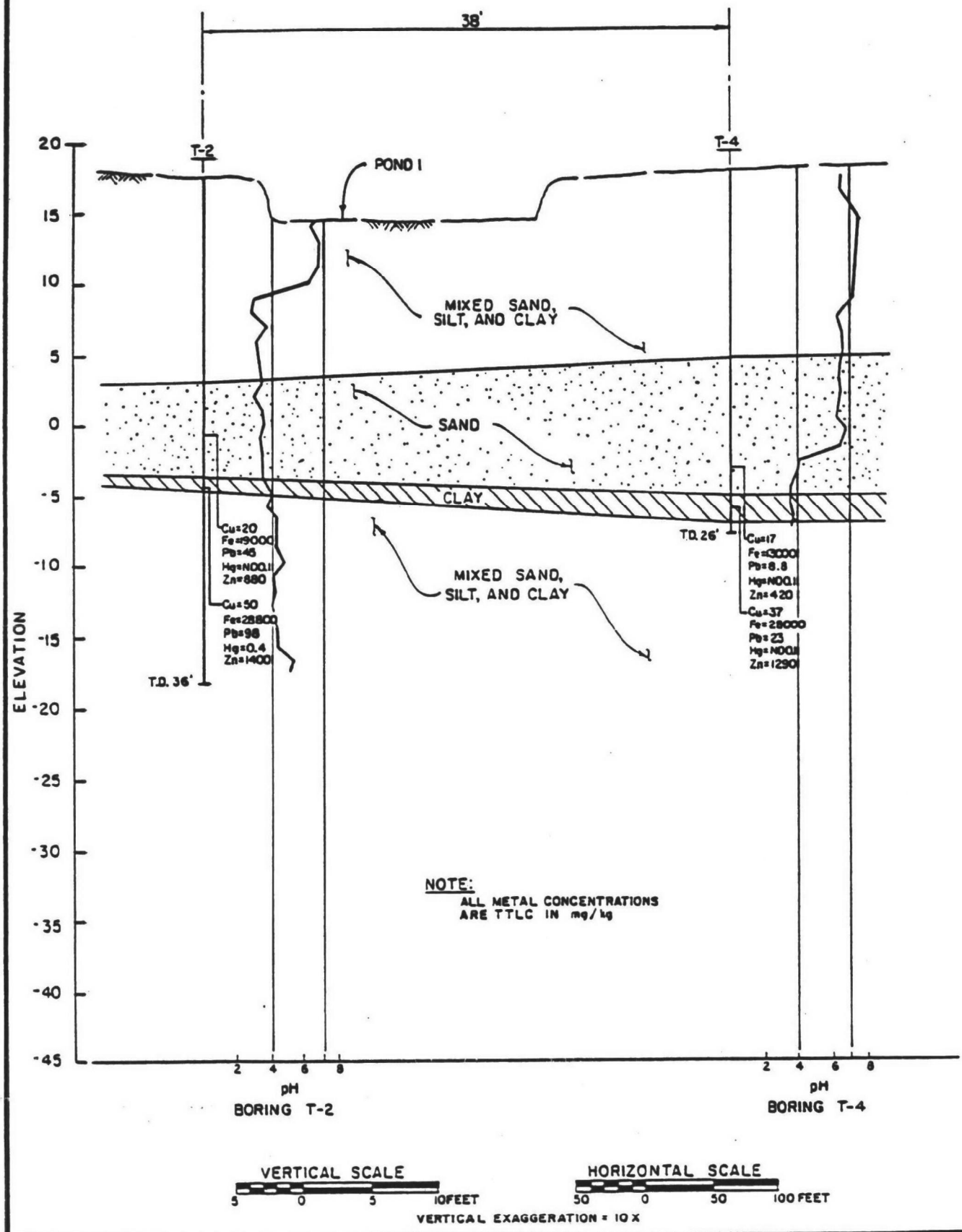
(3) ND X denotes none detected to a level of X.

(4) Silver and Cyanide were analyzed only in T-1 which is adjacent to the discharge point (Pond 2) for wastes containing silver and cyanide.

(5) Cyanide cannot be analyzed in an acidified sample.

From Canonie Environmental's "Kearney-KPF: Hydrogeological Assessment Report...", 1985.

(From Canonie Environmental's, "Kearney-KPF: Hydrogeologic Assessment Report...", 1986.



VERTICAL PROFILE OF pH AND METAL CONCENTRATIONS FOR DEEP BOREHOLES T-2 AND T-4

ENGINEERING ENTERPRISES, INC.

609-012-03 Figure 3

B. GROUND WATER

Two water supply wells and three monitoring wells are located on the Kearney-KPF property (see Figure 2). The shallow supply well ("Shallow Well") was completed between depths of 80 to 120 feet. The second supply well, referred to as the "Deep Well", extends to a depth of 230 feet. Three 2" SCH 40 PVC monitoring wells (Borings B1, B4, and B5) were installed as part of the hydrogeologic investigation at depths ranging between 55 and 60 feet. These wells were screened at the bottom 9 feet of each respective hole. Aquarium size silica sands and pea gravel were used to pack the wells. (Canonie Environmental, 1986).

Multiple groundwater samples have been extracted by Canonie Environmental from each well on site during 1985-86. Different sampling methods were used in each round of sampling. The initial water samples were collected with a bailer. These samples were not filtered and were analyzed for metals only. Two water samples were collected during the second round of sampling: one filtered and one unfiltered sample. These samples were collected with a bladder pump. Organic and metal constituents were analyzed. Tables 5 - 7 present the analyses of samples collected from both sampling rounds.

VII. FACILITY INVESTIGATION OFF SITE

An off site investigation program has not been conducted by Kearney-KPF as of this writing. Current emphasis still remains on the collection of adequate hydrogeologic information for the site itself. If groundwater contamination is documented, an

TABLE 5

SUMMARY OF WATER QUALITY DATA, FIRST SET-
SAMPLES NOT FILTERED OR ACIDIFIED IN THE FIELD

Analyte(s)	B-1 (2)	B-4 (3)	B-5	Shallow Well (3)	Deep Well (4)
pH	7.3	7.5	7.8	7.6	8.2
Copper	0.11	ND 0.05 (5)	0.05	ND 0.05	(1)
Cyanide	ND 0.05			ND 0.05	
Iron		16.6	46.0	0.21	ND 0.05
Lead	0.18	0.23	0.21	0.15	ND 0.1
Mercury	0.29	ND 0.001	ND 0.00	ND 0.001	
Silver	ND 0.02			ND 0.01	
Zinc	0.93	0.20	0.22	0.06	ND 0.05

Notes:

(1) Constituents that were not analyzed are left blank.

(2) Sample collected in January, 1986 during preliminary investigation.

(3) Sample collected in April, 1986 during detailed investigation. Cyanide and silver were not analyzed for in wells B-4 and B-5 because of the distance from the discharge point (Pond 2).

(4) Sample collected in June, 1985 for preliminary assessment for state. Only major metals analyzed.

(5) ND - I denotes none detected to a level of I.

From Canonie Environmental's "Kearney-KPF:Hydrogeologic Assessment Report...", 1986.

TABLE 6

(1)

SUMMARY OF WATER QUALITY DATA, SECOND SET
INCLUDES SAMPLES FIELD FILTERED AND ACIDIFIED

Analyte(s) (mg/l)

Well No./ Condition (2)	Copper (4)	Total Lead	Iron	Zinc	Mercury	Silver	Cyanide	Organic Lead
B-4/NF	ND 0.05	ND 0.005	26.0	0.07	ND 0.001	ND 0.005	ND 0.05	ND 0.1
B-4/F	ND 0.05	0.006	ND 0.05	ND 0.05	ND 0.001	ND 0.005	(3)	ND 0.1
B-5/NF	0.06	0.010	48.0	0.13	ND 0.001	ND 0.005	ND 0.05	ND 0.1
B-5/F	ND 0.05	0.006	0.08	ND 0.05	ND 0.001	ND 0.005	(3)	ND 0.1
B-1/NF	ND 0.05	ND 0.005	12.3	0.07	ND 0.001	ND 0.005	ND 0.05	ND 0.1
B-1/F	ND 0.05	ND 0.005	0.06	ND 0.05	ND 0.001	ND 0.005	(3)	ND 0.1
Shallow/NF	ND 0.05	0.005	0.07	ND 0.05	ND 0.001	ND 0.005	ND 0.05	ND 0.1
Shallow/F	ND 0.05	ND 0.005	ND 0.05	ND 0.05	ND 0.001	ND 0.005	(3)	ND 0.3
Deep/NF	ND 0.05	ND 0.005	ND 0.05	ND 0.05	ND 0.001	ND 0.005	ND 0.05	ND 0.1
Deep/F	ND 0.05	ND 0.005	ND 0.05	ND 0.05	ND 0.001	ND 0.005	(3)	ND 0.1

(1) Samples Collected in June, 1986.

(2) Wells designated NF were not filtered and acidified when sampled. Wells designated F were filtered and acidified when sampled.

(3) Cyanide cannot be analyzed in acidified samples.

From Canonie Environmental's "Kearney-KPF: Hydrogeologic Assessment Report...", 1986.

(4) ND X denotes none detected to a level of X.

TABLE 7
RESULTS OF ORGANIC ANALYSIS

ANALYTE(S) (MG/L)	WELL B-1 (2)	WELL B-4	WELL B-5	SHALLOW WELL	DEEP WELL	CALIFORNIA (3) DWAL
Bromodichloromethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Bromoform	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Bromomethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Carbon Tetrachloride	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Chlorobenzene	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Chloroethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
2-Chloroethylvinyl ether	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Chloroform	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Chloromethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Dibromochloromethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
1,2-Dichlorobenzene	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
1,3-Dichlorobenzene	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
1,4-Dichlorobenzene	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Dichlorodifluoromethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
1,1-Dichloroethane	ND 0.0005	ND 0.0005	0.0009	ND 0.0005	ND 0.0005	0.02
1,2-Dichloroethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
1,1-Dichloroethene *	ND 0.0005	ND 0.0005	0.03	0.0021	0.024	0.006
trans-1,2-Dichloroethene	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
1,2-Dichloropropane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
cis-1,3-Dichloropropene	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
trans-1,3-Dichloropropene	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
1,1,2,2-Tetrachloroethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Tetrachloroethene *	0.0005	ND 0.0005	0.0006	ND 0.0005	0.013	0.004
1,1,1-Trichloroethane	0.0017	ND 0.0005	0.027	0.0019	0.06	0.2
1,1,2-Trichloroethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Trichloroethene	0.0009	ND 0.0005	0.001	0.001	0.0031	0.005
Trichlorofluoromethane	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Vinyl chloride	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	
Methylene chloride	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	ND 0.0005	

(1) Analyzed using EPA Method 601 for Halogenated Volatiles.

(2) ND X denoted none detected at a level of X.

(3) Drinking Water Action Level.

(4) * - Exceeds DWAL.

From Canonie Environmental's "Kearney-KPF:Hydrogeologic Assessment Report...",1986.

expanded investigation by Kearney-KPF, including off site monitoring, will likely be required by the Regional Board (C. Williams, CVRWQCB).

VIII. DISCUSSION OF DISPOSAL WELL CONTAMINATION DATA

Data collected by Canonie Environmental for Kearney-KPF indicates that waste waters have migrated to vadose zone soils located below the industrial disposal well. Iron and zinc concentrations found in soils 18 ft. to 23 ft. below the well were the highest of those soils sampled. The pH of soils sampled near the well ranged from 2.9 at a depth of 9 ft. to 5.3 at a depth of 36 ft. below land surface (Canonie Environmental, 1986). Soils beneath Boring T-4 are also contaminated (see T-4 boring log). The pH of contaminated soils in T-4 ranged from 3.9 at a depth of 22 feet to 3.6 at a depth of 26 feet (total depth) below land surface (Canonie Environmental, 1986). Both boring samples appear to indicate that waste waters have migrated to the water table located 35 ft. below ground surface (see Figure 3).

Because Borings T-2 and T-4 are adjacent to Pond 1, soil contamination encountered in these borings cannot solely be attributed to the disposal well. Standing waters in the unlined pond most likely migrated into these same vadose zone soils.

Groundwater data collected from the two sampling rounds conducted on site are inconsistent. The first sample extracted from monitoring well B-1 (near the disposal well) in January of 1986 contained lead and mercury in concentrations exceeding EPA's National Primary Drinking Water Standards. These concentrations

included suspended and dissolved metals fractions. Iron and organic constituents were not analyzed in the sample.

The June 1986 samples collected from monitoring well B-1 consisted of a filtered and unfiltered sample. Unlike the first unfiltered sample extracted from B-1, the June 1986 unfiltered sample did not contain detectable concentrations of lead, mercury, and other metals. Iron, however, was present in the unfiltered sample at a concentration of 12.3 mg/l. This exceeds the EPA's Secondary Drinking Standard of 0.3 mg/l for iron. Significantly lower metal concentrations in the June unfiltered sample probably resulted from the change in sampling mechanism employed (bailer vs. bladder pump). Further sampling is planned by Kearney-KPF to resolve these discrepancies.

Iron, trichlorethene, and 1,1,1-trichloroethane were present in the filtered June 1986 sample. All constituents were detected below drinking water standards. All other inorganic and organic constituents analyzed were undetected in the sample.

Organic constituents encountered in other on site monitoring wells are: 1,1-dichloroethane, 1-1 dichloroethene, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. Of these, 1,1-dichloroethene, and tetrachloroethene exceeded California Drinking Water Action Limits (DWAL). Samples withdrawn from Well B-5 and the Deep Well contained more organic contaminants than other wells tested on site.

IX. ASSESSMENT

The vadose zone soils below the disposal well and Pond 1 contain elevated levels of heavy metal constituents. This contamination is directly attributable to the direct surface discharge of galvanizing waste waters. Soil contamination may also be attributed to the drainage of these waters into the disposal well. Depth discrete soil data near the disposal well indicate the probability that the galvanizing waste streams migrated to the water table via the disposal well. Further soil borings should be drilled to the water table near the disposal well and Pond 1 area. Soils should be sampled and analyzed for organic and inorganic parameters. Soils with contaminant concentrations exceeding recommended soil cleanup action levels should be excavated and hauled off site.

As of this writing, groundwater sampling data is inadequate to delineate the extent of subsurface contamination. As previously discussed, various water sampling collection methods and sample preservation techniques have been used to date. These variables make it difficult, if not impossible, to interpret the ground water analyses. Future water samples should be filtered and analyzed for metals and other priority pollutants identified in the process waste streams. Additional monitoring wells are needed on site. These wells will enable investigators to adequately establish aquifer characteristics and ground water quality beneath the site. Monitoring wells are especially needed in the Pond 1 area. These wells should be screened at multiple depth intervals. Additional monitoring wells will enable site

investigators to establish the depth specific quality of ground water below the disposal well area.

A conclusive assessment regarding the extent of contamination resulting from the disposal well cannot be made. Because the site investigation is in its early stages, soil and water quality information is limited.

Kearney - KPF's Hydrogeologic Assessment Report (HAR) was submitted to the Central Valley Regional Water Quality Control Board (CVRWQCB) and the California Department of Health Services (DOHS) in July of 1986. The recently created Toxic Pits Cleanup Act Unit of the CVRWQCB and the Toxic Substance Control Division of the DOHS have reviewed the report for conformance with California's Toxic Pits Cleanup Act of 1984. The CVRWQCB's Toxic Pits Cleanup Act Unit has been designated the lead reviewing agency (C. Williams, CVRWQCB). Numerous deficiencies in the Kearney - KPF HAR have been cited by the reviewing agencies. These agencies have recognized the disposal well area as a critical point of concern. Review comments suggest that Kearney - KPF should further assess the extent of soil and groundwater contamination in this area (Review of Kearney-KPF's HAR, CVRWQCB and the DOHS, 1986).

Immediate concerns were recently discussed in a meeting between Kearney-KPF and the state reviewing agencies. Additional groundwater sampling, soil sampling and waste stream character-

ization is planned (conversation with C. Williams, CVRWQCB). CVRWQCB's review of Kearney-KPF's site investigation will continue until the evaluation of soil and groundwater contamination is complete.

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Boring Log

PROJECT No. WCES-165
BORING No. T-4
PAGE 1 OF 4

PROJECT NAME Kearney-YPF
BORING LOCATION 5500.66 NORTH 5502.71 EAST SURFACE ELEV. 17.85
DRILLER Sierra Drilling - Russ DATE: START 4/3/86 FINISH 4/4/86

DEPTH	SAMPLE No	SAMPLE TYPE	SAMPLE INTERVAL FROM	SAMPLE INTERVAL TO	BLOW COUNT 0 6	BLOW COUNT 6 12	BLOW COUNT 12 18	RECOVERY IN FEET	% RECOVERED	ROD	pH	PROFILE	CONTACT DEPTH	SOIL DESCRIPTION AND REMARKS	PIEZO
1	1	SS	0	1	2	—					6.6	ML		Med. Stiff, slightly moist, dark brown-black SILT, trace VF sand some roots	
2	2	SS	1	2	6	6					6.5	ML		STIFF - Same	
3	3	SS	2	3	4	11					7.1	ML		V. stiff same with trace clay	
4	4	SS	3	4	10	20					7.5	ML		V Stiff Same	
5	5	SS	4	5	2	4					7.4	ML		med stiff grading to dry gray VF sandy clayey SILT.	
6	6	SS	5	6	7	6					7.4	ML		Stiff, dry, gray brown clayey SILT, trace VF to C Sand, Trace crystals, trace reddish brown staining	
7	7	SS	6	7	3	5					7.4	ML		Med Stiff, dry brown SILT, trace clay & VF to C sand, trace reddish brown staining	
8	8	SS	7	8	7	6					7.3	ML		Stiff, slightly moist, reddish brown SILT, trace VF to C sand	

6-35(

Canonie

Boring Log

PROJECT No. WC 85-165
BORING No. T-4
PAGE 2 OF 4

PROJECT NAME Kearney - KFF
BORING LOCATION 5520.66 NORTH 5502.71 EAST SURFACE ELEV. 17.85
DRILLER Sierra Drilling - Russ DATE: START 4/3/06 FINISH 4/3/06

DEPTH	SAMPLE NO	SAMPLE TYPE	SAMPLE INTERVAL FROM	SAMPLE INTERVAL TO	BLOW COUNT 0 to 6	BLOW COUNT 6 to 12	BLOW COUNT 12 to 18	RECOVERY IN FEET	% RECOVERED	ROD	pH	PROFILE	CONTACT DEPTH	SOIL DESCRIPTION AND REMARKS	PIEZO
9	9	SS	8	9	5	6					7.2	SM		med dense, slightly moist, reddish brown VF silty SAND trace F to C sand, trace orange stain	
10	10	SS	9	10	11	13					7.2	SM		med dense, dry, brown VF silty SAND, trace F to C sand, trace clay	
11	11	SS	10	11	4	7					6.3	SM		med dense dry brown VF silty SAND trace gray clay	
12	12	SS	11	12	9	15					6.6	SM/SC		med dense slightly moist, brown VF silty/clayey SAND, trace black and red stain.	
13	13	SS	12	13	5	11					6.7	SM		med dense, slightly moist brown VF silty SAND trace clay, trace black staining	
14	14	SS	13	14	11	12					6.5	SM		med dense. Dry gray brown VF silty SAND	
15	15	SS	14	15	4	5					6.4	SM		LOOSE, slightly moist, brown VF silty SAND.	
16	16	SS	15	16	5	6					6.5	SM		med dense slightly moist, brown VF SAND, some silt	

Canonie

Boring Log

PROJECT No. WC 85-165
BORING No. T-4
PAGE 3 OF 4

PROJECT NAME Kearney - KPF
BORING LOCATION 5500.66 NORTH, 5502.71 EAST SURFACE ELEV. 17.65
DRILLER Serra Drilling - Russ DATE: START 4/3/86 FINISH 4/4/86

DEPTH	SAMPLE No	SAMPLE TYPE	SAMPLE INTERVAL FROM	SAMPLE INTERVAL TO	BLOW COUNT 0-6	BLOW COUNT 6-12	BLOW COUNT 12-18	RECOVERY IN FEET	% RECOVERED	ROD	pH	PROFILE	CONTACT DEPTH	SOIL DESCRIPTION AND REMARKS	PIEZO
17	17	SS	16	17	5	5					6.4	SP		loose slightly moist, brown to red brown fine SAND, some silt	
18	18	SS	17	18	5	7					6.2	SP		med dense dry brown & gray fine SAND, trace silt	
19	19	SS	19	19	4	4					6.8	SP		loose, dry brownish gray VF to F SAND, trace silt & clay	
20	20	SS	19	20	5	7					6.4	SP		med dense slightly moist brownish gray VF to F SAND trace silt	
21	21	SS	20	21	4	4					4.1	SP		loose dry gray, fine SAND, trace VF to M sand	
22	22	SS	21	22	6	7					3.9	SW		med dense dry gray, fine to med SAND, trace coarse sand and fine gravel.	
23	23	SS	22	23	22	2					3.6	SW	23	med dense slightly moist gray fine to med. SAND trace coarse sand and fine gravel, trace orange staining	
24	24	SS	23	24	1	5					3.5	ML		Med. Stiff, top half inch asphalt then red brown VF sandy SILT, trace clay and f-c sand, trace red staining.	

Canonie

Boring Log

PROJECT No. WC 85-165
BORING No. T-4
PAGE 4 OF 4

PROJECT NAME Kearney - KPF
BORING LOCATION 5500 66 NORTH, 5502.71 EAST SURFACE ELEV. 17.85
DRILLER Sierra Drilling - Russ DATE: START 4/3/86 FINISH 4/4/86

DEPTH	SAMPLE No	SAMPLE TYPE	SAMPLE INTERVAL FROM	SAMPLE INTERVAL TO	BLOW COUNT 0 to 6	BLOW COUNT 6 to 12	BLOW COUNT 12 to 18	RECOVERY IN FEET	% RECOVERED	ROD	PID	PROFILE	CONTACT DEPTH	SOIL DESCRIPTION AND REMARKS	PIEZO
25	25	SS	24	25	7	9					3.8	ML		Stiff, slightly moist reddish brown SILT, trace VF to C sand trace white staining along veinlets	
26	26	SS	25	26	3	15					3.6	SW		med. dense slightly moist fine to C SAND, red brown and gray brown, some silt, trace fine gravel trace red staining.	
														Bottom of boring 26.0 ft	

Notes:
- Drill rig was a Mobile B-61
- 6 in dia hollow stem
- 1 3/8 in standard split spoon for sample collection
- Hammer weight was 140 lb with 30 in drop.
- Hole backfilled with cement grout, 5 bag mix.

This sample may have been incorrectly numbered. New person handled samples at end. I think this should be 22-23.

Canonie

Boring Log

PROJECT No. WCES-165
BORING No. T-2
PAGE 1 OF 5

PROJECT NAME Kearney - KPF
BORING LOCATION 5498.10 NORTH, 5464.32 EAST SURFACE ELEV. 17.5
DRILLER Sierra Drilling - Russ DATE: START 4/2/86 FINISH 4/3/86

DEPTH	SAMPLE No	SAMPLE TYPE	SAMPLE INTERVAL FROM	SAMPLE INTERVAL TO	BLOW COUNT 0 to 6	BLOW COUNT 6 to 12	BLOW COUNT 12 to 18	RECOVERY IN FEET	% RECOVERED	ROD	pH	PROFILE	CONTACT DEPTH	SOIL DESCRIPTION AND REMARKS	PIEZO
1	1	SS	0	1	1	2					7.7	OL		Soft, slightly moist, dark brown SILT.	
2	2	SS	1	2	2	2					7.2	OL		Soft, moist, dark brown SILT.	
3	3	SS	2	3	2	2					6.9	ML		Soft, Dry, dark brown SILT, trace VF sand, trace orange staining along root path.	
4	4	SS	3	4	3	3					6.2	ML		med. stiff, slightly moist, brown SILT, trace VF sand, trace gray clay with granular orange staining?	
5	5	SS	4	5	1	3					6.6	CL		Soft, moist, gray silty clay, trace VF sand, orange/red staining? along root paths (important ! ~ 30%)	
6	6	SS	5	6	4	5					6.6	CL		stiff, moist, grayish brown silty CLAY, trace VF sand, trace orange and brown stain	
7	7	SS	6	7	1	3					6.6	ML		Soft, moist brown clayey SILT, trace VF sand, vertical channel of red stain 3/4 inch wide	
8	8	SS	7	8	3	5					6.0 4.4	ML		med. stiff moist brown clayey SILT, trace VF. Sand, brown staining/ precipitate along root paths.	

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Boring Log

PROJECT No. WC85-165
BORING No. T-2
PAGE 2 OF 5

PROJECT NAME Kearney - KPF
BORING LOCATION 5405.10 North 4402 East SURFACE ELEV. 17.5
DRILLER Sunra Drilling - Pace DATE: START 4/2/86 FINISH 4/3/86

DEPTH	SAMPLE No	SAMPLE TYPE	SAMPLE INTERVAL FROM	SAMPLE INTERVAL TO	BLOW COUNT 0 to 6	BLOW COUNT 6 to 12	BLOW COUNT 12 to 18	RECOVERY IN FEET	% RECOVERED	ROD	PH	PROFILE	CONTACT DEPTH	SOIL DESCRIPTION AND REMARKS	PIEZO
9	9	SS	8	9	3	4					2.?	ML		mod. stiff - slightly moist, reddish brown SILT, trace clay and VF sand trace shiny crystals	
10	10	SS	9	10	7	8					2.7	ML		very stiff, slightly moist, reddish brown SILT, trace clay and VF sand, trace shiny crystals (like mica)	
11	11	SS	10	11	4	9					2.6	ML		stiff, slightly moist, reddish brown SILT, trace clay and V.F. Sand, trace shiny crystals and black stain	
12	12	SS	11	12	11	16					2.0	ML		Very stiff, Dry reddish brown SILT, trace clay and VF Sand, trace shiny grains and red/black stain along roots	
13	13	SS	12	13	5	9					2.1	ML/CL		Stiff Dry brown clayey Silt/Silty CLAY, trace shiny crystals, trace red and black stain along root paths	
14	14	SS	13	14	11	13					2.2	ML		V. stiff dry, grayish and reddish brown clayey SILT, trace red and black stain in pores, trace shiny crystals	
15	15	SS	14	15	16	8					2.3	ML		Stiff - Same as above with trace silty sand.	
16	16	SS	15	16	10	15					2.9	SM	CONTACT	med dense, moist, red and gray brown V.F. silty SAND, trace sandy Silt, red and black stain	

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Canonie

Boring Log

PROJECT No. WC85-165
BORING No. T-2
PAGE 4 OF 5

PROJECT NAME Kingsley - KPF
BORING LOCATION 540S.1' North 514W.92 East SURFACE ELEV. 17.5
DRILLER Sierra Drilling - Russ DATE: START 4/2/86 FINISH 4/3/86

DEPTH	SAMPLE No	SAMPLE TYPE	INTERVAL FROM	INTERVAL TO	BLOW COUNT 0 to 6	BLOW COUNT 6 to 12	BLOW COUNT 12 to 18	RECOVERY IN FEET	% RECOVERED	ROD	pH	PROFILE	CONTACT DEPTH	SOIL DESCRIPTION AND REMARKS	PIEZO
25	25	SS	24	25	9	13					4.2	ML		V stiff dry. reddish brown SILT, trace clay and crystals, one crystal 1mm long.	
26	26	SS	25	26	11	11					4.2	ML		V stiff dry reddish brown SILT, trace shiny crystals and fine to coarse sand, trace white stain and VF sand.	
27	27	SS	26	27	4	6					4.2	ML		Stiff slightly moist brown clayey SILT, trace red staining and crystals and V.F Sand.	
28	28	SS	27	28	7	11					4.6	ML		Very Stiff slightly moist brown clayey SILT with red stain in root paths, trace Gray stain and VF sand	
29	29	SS	28	29	10	17					4.0	ML		Very stiff, dry brown clayey SILT, trace red stain in pores, and abra laminations, trace crystals and VF Sand.	
30	30	SS	29	30	21	25					4.1	ML		Hard, dry reddish brown clayey SILT, trace red and gray staining and crystals	
31	31	SS	30	31	10	13					4.0	ML		Very Stiff-Same	
32	32	SS	31	32	19	25					4.2	ML		Hard - same with more white stain along vertical pores	

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Canonie

Boring Log

PROJECT No. WCBS-165
BORING No. T-2
PAGE 5 OF 5

PROJECT NAME Kearney - KPF
BORING LOCATION 6496.10 North 5464.82 East SURFACE ELEV. 17.5
DRILLER Sierra Drilling - Russ DATE: START 4/2/96 FINISH 4/3/96

DEPTH	SAMPLE No.	SAMPLE TYPE	INTERVAL FROM	INTERVAL TO	BLOW COUNT 0-6	BLOW COUNT 6-12	BLOW COUNT 12-18	RECOVERY IN FEET	% RECOVERED	ROD	pH	PROFILE	CONTACT DEPTH	SOIL DESCRIPTION AND REMARKS	PIEZO
33	33	SS	32	33	7	13					4.3	ML		Very stiff slightly moist reddish brown clayey SILT, crystals	
34	34	SS	33	34	24	30					4.3	ML		Hard In. red-brown V.F sandy SILT, laminated with harder granular layers, trace crystals and white stain in layers and vertical pores	
													34		
35	35	SS	34	35	8	8					5.2	SM		med dense dry, red-brown VF silty SAND, trace F to C. Sand, trace V.F Sandy, clayey silt	
													21.0		
36	36	SS	35	36	8	12					5.3	SM		med dense moist brown VF silty SAND, trace F to M sand, water	
														Bottom of Boring 36.0 ft.	
														Notes: - Drilling was Mobile B-61 - 6 in diam hollow stem - 1 3/8 in Standard split spoon used for Sample collection - Hammer Weight was 140 lb, with 30 in. drop. - Hole backfilled partly with 5 bag mix, sand cement grout. Remainder with cement from galvanize Plant	

UNDERGROUND INJECTION CONTROL PROGRAM
FILE INVESTIGATION REPORT

SECTION I - General Information

Name of Facility: Kearney - KPF

Address: P. O. Box 8485
Stockton, CA 95208

Telephone: (209) 464-8381

Owner Address and Telephone (if different from above):

Nature of Business: Silver plating, galvanizing operation in the manufacturing of electrical switches.

Use of Injection Well (s) (drainage, direct disposal, etc.):
Direct Disposal

Identification, Permit or EPA Number (s):

Injection Well (s) Location (township, range and section, latitude and longitude, verbal description, land marks, etc.):
T2N, R6E, Section 35. Hand dug, 22' deep. 17' East of Pond #1.

Type of Injection Well (s) -
Industrial Drainage:
Storm-runoff:
Other (specify): 1 5W-20, drains industrial waste pond.

Injection Well (s) Currently Operating: Yes _____ No X

If No, Last Date of Operation: January, 1986.

Date of Construction of Injection Well (s): 1972

Years Injection Well in Operation: 14 Yrs.

SECTION II - Hydrogeologic Information

Injection Formation - Name: River channel and flood plain deposits.

- **Description:** Alluvium
- **Extent of Injection Zone (s) Below Land Surface (or elevation above Mean Sea Level):** 22 feet deep
- **Minimum Distance from Injection Well to Underground Source of Drinking Water (U.S.D.W.):**

Location (depth below land surface, areal extent, etc.) and description (thickness, lithology, etc.) of Any Relatively Impermeable Strata (aquitard (s)) Present:

Possible permeable stratas below the site are:
River Channel: Flood plain deposits 0-25 feet thick
Victor Formation: 0-150 ft. thick
Laguna Formation: 0-400 ft. thick

Underground Sources of Drinking Water -

Confined:

Unconfined: Possible. Consultant contests that semi- confined to confined conditions exist.

Depth to Perched Water Table (if present):

Depth to Water: Approximately 35'

Saturated Thickness: Unknown.

Description and Characteristics:

San Joaquin Water Basin. Used extensively in northern half of basin.

Extent of Use of U.S.D.W. (extensive, moderate, municipal, domestic, potential, etc.): Extensive. Domestic, municipal, irrigative water supply.

Comments:

Attach the Following Information (note if unavailable) -

- X Map of Facility Grounds:
- X Well Log (s) for Injection Well (s):
- As-built Diagram of Injection Well (s):
- X Consultant Reports for Injection Well (s) and/or Site Hydrogeology:
- Monitoring Data for Injection Well:
- X Monitoring Well Data -
  - X Number of Monitoring Wells:
  - Location: Vertical and Horizontal Distance and Direction of Monitoring Well (s) From Injection Well:
  - X Depth of Completion and Sampling Interval:
  - X Chemical and Physical Analyses:
- Downgradient Water Supply Wells (within a one-quarter mile radius of the injection well) -
  - X Number of wells: 2 industrial water supply wells.
  - X Location: Vertical and Horizontal Distance and Direction of Supply Well (s) from Injection Well:
  - X Chemical and Physical Analyses:
  - X Status of Wells (operating, abandoned, etc.)
  - X Status of Any Nearby Surface Waters (possibly affected by injection well operation):

SECTION III - Operating Data

Injection Rate, Frequency, and Volume (drainage area, precipitation, etc.)

Oakite: 12.75 yrs. x 14,000 gal/yr ≅ 190,000 gal total.

Water rinse: 13.3 yrs. x 120,000 gal/yr ≅ 1,700,000 gal total.

Spent acid: 12.75 yrs. x 17,000 gal/yr. ≅ 200,000 gal total.

Description of Injection Operation (including brief history):

Galvanizing waste solutions were disposed of in pond 1. Standing "water" from Pond 1 was drained via a disposal well from 1972 to 1986.

Fluid Source:

Rinse waters and waste solutions from galvanizing process.

Fluid Composition/Characteristics (including any treatment process): Consitutents included:

1. Solium hydroxide
2. Sodium carbonate
3. Terpenes
4. Chelating agents
5. Muratic acid
6. Zinc chloride

Contaminant (s) and Potential Source (s) of Contamination:

Disposal well, Pond 1 and Pond 2 are potential contaminant sources on the Kearney - KPF property.

Method of Disposal (transport to well):

Surface drainage (gravity).

Previous Problems with Well (clogging, overflowing, etc.) -

No X

Yes _____ **Description of Problem:**

Operating Records Attached: Yes _____ **No** X

Injection Fluid Analyses Attached: Yes X **No** _____

SECTION IV - Prior Site Inspection Specifics

Name and Affiliation of Inspectors: Tom Vorster, CRVRWQCB
Dan Ward, CVRWQCB
Cam Williams _CVRWQCB. -
Charles McLoughlin, DOHS

Name and Affiliation of Facility Contact:

Date: **Time:**

Reason for Inspection: Inspect for compliance with the Toxic Pits Cleanup Act.

Number of Injection Wells: 1

Number of Injection Wells Inspected: 1

Site Conditions:

Inspection Comments:

Section 6.2.26

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Industrial Disposal Well Case Study: T.H.A.N. - Fresno, California
AUTHOR: (or INVESTIGATOR)	Engineering Enterprises, Inc. (Prepared for USEPA Region IX)
DATE:	December, 1986
FACILITY NAME AND LOCATION:	T.H. Agriculture and Nutrition Co. Fresno, California USEPA Region IX
NATURE OF BUSINESS:	Agricultural Chemical Formulation, Packaging, and Warehousing Plant
BRIEF SUMMARY/NOTES:	Designated Superfund site. Ten areas containing industrial waste contaminants have been identified. Industrial disposal wells and an industrial leach field were responsible for soil contamination at four locations. Groundwater contamination on and downgradient from the property is well documented. Injection ceased in 1983.

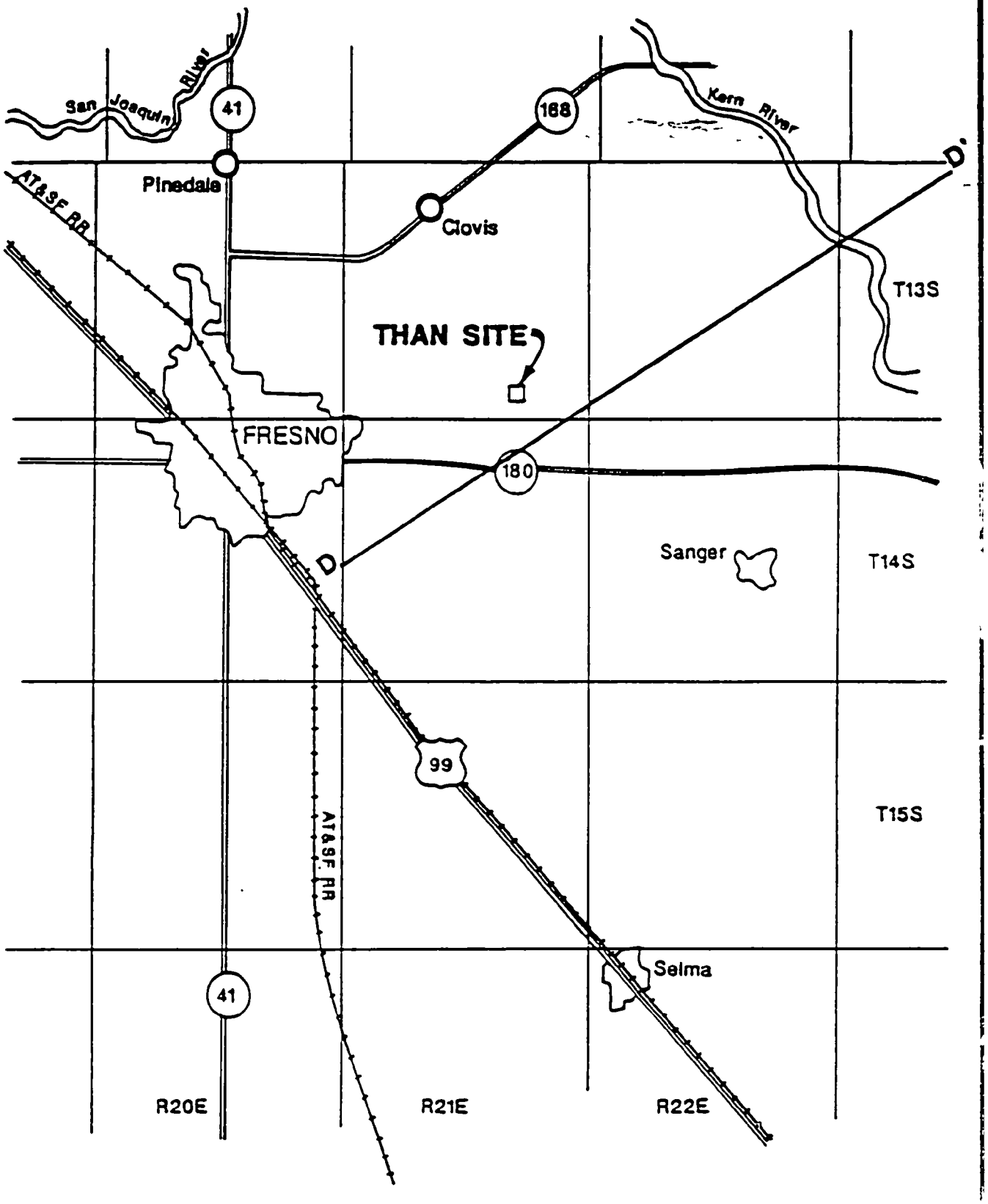
INDUSTRIAL DISPOSAL WELL CASE STUDY: THAN - FRESNO, CALIFORNIA

I. SITE BACKGROUND

"The T.H. Agriculture & Nutrition Company (THAN) is located at 7183 East McKinley Avenue in Fresno County, northeast of Fresno, California (refer to Figure 1). The property consists of approximately 25 acres, of which approximately five acres are under investigation by the Central Valley Regional Water Control Board and the California Department of Health Services to assess conditions related to historical industrial activities. The remaining 20 acres consist of orchards which surround the Site on its south, east and west boundaries. The areas beyond THAN's property consist of farms, orchards and low density residential developments.

The site was formerly utilized as an agricultural chemical formulation, packaging and warehousing plant which was operated between 1951 and 1981 by various owners, including Olin Corporation, Ciba-Geigy Corporation and THAN. The formulation and packaging of chemicals at this facility ceased in 1981. Subsequently, THAN removed all equipment and inventory in the summer of 1982, and the plant was closed completely in 1983", (Kennedy/Jenks/Chilton, July 1986).

THAN has worked with the Central Valley Regional Water Quality Control Board (CVRWQCB) and the California Department of Health Services (DOHS) since 1981. These state environmental agencies are of reviewing the remedial investigation conducted by



From USGS Report: "Geology ... in the Fresno Area", 1969.

AERIAL VIEW OF CROSS SECTION D-D'
THAN - FRESNO, CALIFORNIA

ENGINEERING ENTERPRISES, INC.

609-012-03 Figure 1

THAN. The purpose of THAN's investigation is to evaluate the extent of soil and ground water contamination resulting from THAN's past operations. Remedial action orders have been ordered by both agencies over the past five years. The site has been designated a Superfund site since the investigation began. THAN has recently submitted revised work plans for additional soil and groundwater characterization work required to complete the investigation. These plans are currently under review by the DOHS.

II. CHEMICALS HANDLED ON SITE

All chemicals apparently handled on site are listed in Tables 1 - 4. These tables were excerpted from Document F of the Remedial Investigation and Interim Remedial Measure Documents, (Kennedy/Jenks/Engineers, August 1986).

III. SITE GEOLOGY/HYDROLOGY

A. GEOLOGY

Geologic units in the Fresno area are classified into two general groups: consolidated and unconsolidated deposits. Consolidated rock in the Fresno area is largely referred to as the basement complex. This complex underlies all other deposits. The unconsolidated geologic strata which are present include the Tertiary and Quaternary continental deposits and Quaternary alluvial deposits.

From Kennedy/Jenks Engineers
"Remedial Investigation and Interi
Remedial Measure Documents,", 1985

TABLE 1

PESTICIDES APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Pesticide	Comments[b]
Acaraben	Resold
Agricultural Chemical Dust	-
Alar	Resold
Aldrin	-
Algaetrol	Resold
Amino Triazole	Resold
Amizine	Resold
Ansar	Resold
Aramite	-
Arasan	-
Atra Bor	Resold
Atrazine	Resold
Avadex BW	Resold
Avitrol	Resold
Azodrin	Resold
Bacillus thuringiensis[c]	-
Bacticin	Resold
Banvel	Resold
Barban	Resold
Basfapon	Resold
Benefin	-
Beam	-
Benfluralin	-
Benomyl	-
BHC-gamma	-
BHC Technical	-
Binapacryl	-
Biphenyl	-
Bolstar	Resold
Bromo - Kill D	Resold
Buctril	Resold
Butoxone	Resold
Captan	Resold
Carbaryl	-
Carbophenothion	-
Carbozan	-
Caumophos	-
Chem Hoe	-
Chloranil	-
Chlordane	-
Chlorea Granules	Resold
Chlorobenzilate	Resold
Chloropicrin	Resold

TABLE 1 (CONTINUED)

PESTICIDES APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Pesticide	Comments[b]
Chloropicrin	-
Chlorpropham	Resold
Chlorthal-dimethyl	-
Chor I.P.C.	Resold
Cidial	Laboratory agent
Ciovap Spray	-
Co-Ral 25 W	-
Comite	Resold
Contact Weed Killer	-
Copper	-
Copper Oxide	-
Copper Oxychloride	-
Copper Sulfate	-
Copro	Resold
Crotoxyphos	-
Cryolite	-
CS Tox	-
Cutrine	Resold
Cytrol	Resold
Daconate	-
Dalapon	Resold
Danex	-
Dasanit	Resold
DBCP	-
DD Soil Fumigant	Resold
DDD	-
DDT	-
Decco Salt No. 20	-
Ded Weed 40[d]	Resold
DEF	-
Defolate	Resold
Delmo	Resold
Delsan AD No. 3	-
Dessicant L-10	Resold
Devrinol	-
Diazinon	-
Dichlobenil	-
Dichlone	-
2,4-Dichlorophenoxy Acetic Acid (Weeder MCPA[d]; Weedone Brush-killer, 629 and 628[d])	Resold
Dichlorvos	

TABLE 1 (CONTINUED)

PESTICIDES APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Pesticide	Comments[b]
Dicloran	-
Dicrotophos	-
Dieldrin	-
Dimethoate	-
Dinide	-
Dinocap	-
Dinoseb	Resold
Dioxathion	-
Diphenamid	-
Diquat	Resold
Disulfoton	Resold
Dithane	-
Diuron 80 W	Resold
Durapon	Resold
Encap	Laboratory agent
Endosulfan	-
Endothall	-
Endrin	-
Eptam	Resold
Estonmite	-
Ethepon	-
Ethion	-
Ethylan	-
Ethylenedibromide	Resold
Fenac Granules	Resold
Fenthion	Resold
Folex	Resold
Galecron	Resold
Guthion	-
Heptachlor	-
Hexachlorobenzene	-
HiPar	Resold
Hyvar	Resold
Inject-A-Cide	Resold
Iso Octyl Ester Weed Killer	Resold
Karmex	Resold
Kelthane	-
Kem-Krab	Resold
Kern-Krab	-
Kola Dust	Resold
Kolo Spray	Resold
Kryocide	-

TABLE 1 (CONTINUED)

PESTICIDES APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Pesticide	Comments[b]
Lanstan	Resold
Livestock Spray Dip	-
M.C.P. Amine Weed Killer	Resold
Mag Chlor	Resold
Malathion	-
Maneb	-
Metasystox	Resold
Methoxane	Resold
Methoxychlor	Resold
Methylbromide	Resold
Mevinsphos	-
MH 30	Resold
MMH Seed Treater	Resold
Monitor 4	Resold
Monobar Chlorate	Resold
Monsanto 2,4-D Butyl E	Resold
Monsanto Field Clean	Resold
Morestan	Resold
MSMA	Resold
Naled	-
Nematocide	Resold
Nox Insex Bomb	Resold
Nudrin 1.8	-
Oil Spray	-
OMPA	Resold
Ovex	-
Oxycarboxin	-
Panogen	Resold
Paraformaldehyde	-
Paraquat	Resold
Parathion	-
Paratnion, ethyl methyl	-
Parathion, methyl	-
Pentachlorophenol	Resold
Phosalone	-
Phosmet	-
Phosphamidon	-
Phospho Dust	-
Phostoxin	Resold
Phygon XL	Resold
Phytar	Resold
Planavin	Resold

TABLE 1 (CONTINUED)

PESTICIDES APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Pesticide	Comments[b]
Pramitol	Resold
Prefar	Resold
Prometryne	-
Propanil	Resold
Propargite	-
Propoxur	Resold
Quintozene	-
Rabon	-
Rad E Cate	-
Randox	Resold
Ravap	-
Rodine	-
Rogue	Resold
Roneet	Resold
Rose & Garden Dust	-
Rothane	-
Round Up	Resold
Ryno-Tox	Resold
Sabadilla	Resold
Shed-A-Leaf	Resold
Simazine	Resold
Sinbar	Resold
Sodium Arsenate	Resold
Standard Leaf Arsenate	Resold
Strobane	Resold
Sulfur	-
Super Merge	Resold
Swimtrine	Resold
Systox	Resold
TDE	-
Tedion	-
Tepp	-
Terrazole	-
Tetrachlorvinthos	-
Tetradifon	-
TH Orchard Spray Oil	-
TH THIT	Resold
TH 604D	Laboratory agent
Thimet	-
Thiodan	-
Thiram	-
Topsin	Resold

TABLE 1 (CONTINUED)

PESTICIDES APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Pesticide	Comments[b]
Torbidan	Resold
Tordon	Resold
Toxaphene	-
Trichlorfon	-
Trifluralin	Resold
Triphenyltin hydroxide	Resold
Trithion	-
Unipar	Resold
Ureabor	Resold
VC-13	Resold
Vegadex	Resold
Vapam	Resold
Weed Hoe	Resold
Weed-E-Rad	Resold
Weedazol	Resold
Weed Killer A	Resold
Zerlate	-
Zineb	-
Zolone	-

NOTES:

a Refer to text for details of the scope and limitations of this list.
b Where "Resold" is indicated the chemical was only handled for resale to customers, according to the records review; it was not used as a raw material or formulated or repackaged at the site. "Laboratory" indicates that the chemical was only used in the laboratory.
c Live spores of a bacterium used as an insecticide.
d May contain 2,4-dichlorophenoxy acetic acid, which is already listed in Table 1. Other active ingredients, if any, have not been confirmed.

From Kennedy/Jenks Engineers, "Remedial Investigation and Interim Remedial Measure Documents", 1985.

TABLE 2

SOLVENTS APPARENTLY HANDLED AT THE THAN SITE[a] FRESNO, CALIFORNIA (K/J 4083)

Solvent	Comments[b]
Acetone	Laboratory agent
Acetonitrile	Laboratory agent
Agri Sol 50	-
Alfol 610 Alcohol	-
Amyl Acetate	Laboratory agent
Aromin 95	-
Avitrol (4-Aminopyridine)	-
Butyrolactone	-
Carbon Disulfide	Laboratory agent
Carbon Tetrachloride	-
Chloroform	Laboratory agent
Cyclohexanone	-
Deodorized Spray Base (Kerosene)	-
1,4-Dioxane	-
Dormant Oil	Resold
Elvanol 51-05	-
Elvanol 51-25 Regular	-
Ethyl Benzene	-
Ethylene Glycol	-
Formaldehyde	-
Habarsol	-
Helix Oil #5	-
Hexamine	-
Hexane	Laboratory agent
Isopropyl Alcohol	Laboratory agent
Isophorone	-
Kerosene	-
Methanol	Laboratory agent
Methylene Chloride	-
Methylisobutyl Ketone	-
Mineral Spirits	-
Monoethanolamine	-
Naptha Heavy Aroma	-
Oil #1	-
Oil 46-S	-
Oil Pine	-
Pac Base Oil	-
Paint Thinner	-
Panasol AN-2 Solvent	-
Pella Oil	-
Pet Ether	Laboratory agent
Propylene Glycol	-
Socal Solvent #3	-

TABLE 2 (CONTINUED)

SOLVENTS APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Pesticide	Comments[b]
Socal Solvent #25	-
Solvent 5X	-
Solvent B-170	-
Tedion 3684 Solvent	-
Tenneco 500-38 Solvent	-
Tricyclazole	-
Xylene	-

NOTES:

[a] Refer to text for details of the scope and limitations of this list.
[b] "Laboratory agent" indicates that the compound was only used in the laboratory according to the records reviewed. "Resold" indicates that the compound was only handled for resale to customers; it was not used as a raw material or formulated or repackaged at the site.

From Kennedy/Jenks Engineers', "Remedial Investigation and Interim Remedial Measure Documents", 1985.

TABLE 3

OTHER POTENTIALLY HAZARDOUS SUBSTANCES[a] APPARENTLY HANDLED AT THE THAN SITE FRESNO, CALIFORNIA (K/J 4083)

Chemical	Comments[b]
Acetic Anhydride	-
Aerosol OT/B	-
Agrimycin	Resold, Antibiotic
Amorphous Fumed Silica	-
Aminobenzoic Acid	Laboratory agent
Amitraz	-
Ammonium Chloride	-
Ammonium Sulfate	-
Aureomycin[b]	Resold Antibiotic
Baciferm[b]	Resold, Antibiotic
Biphenyl 50 W	-
Butoxone	-
Calcium Hypochlorite	Laboratory agent
Carbolic Acid (Phenol)	-
Carzol SP	Resold
Chel-Zinc "3"	Resold
Chlorine	Laboratory agent
Cutrine	-
Cyclocel	-
D & C Green No. 6	-
Derinol	-
Diphenylamine	-
Duponol	-
Epichlorohydrin	-
ESP	-
Ferrous Sulfate	-
Fertilizer NZN	Resold, Nutrient
Hydrochloric Acid	Laboratory agent
Hydrated Lime (Calcium Hydroxide)	-
KCL Soln	Laboratory agent
Leaf Green	-
Mag Chloride	-
Metso 60	Laboratory agent
N-FE-ZN	Resold, Nutrient
Neutro Cop 530	Resold
Nutra Spray Zinc 25 25	-
OTC	Resold, Antibiotic

TABLE 3 (CONTINUED)

OTHER POTENTIALLY HAZARDOUS SUBSTANCES[a]
APPARENTLY HANDLED AT THE THAN SITE
FRESNO, CALIFORNIA (K/J 4083)

Chemical	Comments[b]
Phos-FE-ZN Plus	Nutrient
Phos-FE-ZN	Nutrient
Phytomycin	Antiobotic
Potassium Hydroxide	-
Potassium Nitrate	-
Propionic Acid	Laboratory agent
Rhodamine Red Dye	-
Sequestrene Zinc Chelate	Resold
Soda Ash	Laboratory agent
Sodium Acid Pyrophosphate	-
Sodium Bicarbonate	-
Sodium Chlorate	-
Sodium Hydroxide (Caustic Soda)	Laboratory agent
Sodium Tri Polyphosphate	Laboratory agent
Sodium Sulfathiazole	-
Triton X-100	-
TSPP	-
Zinc Basic	-
Zinc Chelate	-
Zinc Manganese	-
Zinc Oxide	-
Zinc Sulphate	-
Zinc Tablets	Resold
ZTM Spray	Resold
ZM Spray	Resold

Notes:

[a] Defined as a substance listed in 22 Cal. Adm. Code 66680 or with an acute oral LD_{50} less than 5000 mg/kg (22 Cal. Adm. Code 66696). Refer to text for details of the scope and limitations of this list.

[b] "Laboratory agent" indicates that the compound was only used in the laboratory according to the documents reviewed. "Resold" indicates that the compound was only bought for resale to customers; it was not used as a raw material or formulated or repackaged at the site. The suspected use of some chemicals is also indicated.

From Kennedy/Jenks Engineers', "Remedial Investigation and Interim Remedial Measure Documents", 1985.

TABLE 4

OTHER UNCATEGORIZED SUBSTANCES APPARENTLY HANDLED AT THE THAN SITE[a] FRESNO, CALIFORNIA (K/J 4083)

Chemical	Comments[b]
Activate 3	Emulsifier
Activate Plus	Spreader, Resold
AG Foam	Resold
Agrem MP	Emulsifier
Agrimul 300	Emulsifier
Agrimul 70	Emulsifier
Agrimul A-400	Emulsifier
Agriwet	Wetting Agent
AL-50 Liquor Lignin	Wetting Agent
Alfonic 1012-60	Wetting Agent
Alfred Flake Coal Tar Dye	-
Alka Spred	Spreader, Resold
Alum Ammonia Pea	Nutrient, Laboratory agent
Aluminum Hydrated 31	-
Aluminum Sulfate	Nutrient
Amibtone	Laboratory Agent
Ammonium bicarbonate	-
Annatto Color Oil Soluble	-
Anti-Foam A	Resold
AP-78	-
Apple Pomace	-
Atlas A	Emulsifier
Atlox 3335	Emulsifier
Atlox 3403 F	Emulsifier
Atlox 3404 F	Emulsifier
Atlox 3406 F	Emulsifier
Atlox 3409	Emulsifier
Atlox 8916 P	Emulsifier
Atlox G 1186	Emulsifier
Brewers Yeast	-
Buffer X	Spreader, Resold
Calcium Carbonate	-
Carbon Black	-
Casein Spreader	Wetting agent
Celatom FP 4	Diluent
Celatom MN 47	Diluent
Celatom MP 80	Diluent
Celatom SP	Diluent
Celite	-
Chelated Iron	Nutrient, Resold

TABLE 4 (CONTINUED)

OTHER UNCATEGORIZED SUBSTANCES
APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Chemical	Comments[b]
Chevron Agent 236 - 64A	-
Chiastolith	Diluent, Laboratory agent
Chipman Wetter Water	Resold
Citric Acid	Resold
Clay Bardens	Diluent
Clay M-3	Diluent
Clay Pikes Peak	Diluent
Clay Pulgate	Diluent
Colloidal Z-1 Spreader	Spreader, Resold
Color Red Oil Dye	-
Darvan 4	Wetting agent
Daxad 21	Wetting agent
DeFoamer	-
Deslan AD #3	-
Dexox 35 WP	Resold
Diala X	-
Diammonium Phosphate	Nutrient
Diluex A	Diluent
Diphenyl Phthalate	-
Dipropylene Glycol	-
Dowfax 9N9	Emulsifier
Drivert	-
E-1670	Laboratory agent
Emcol H 490 Special	Emulsifier
Emery 3632	Emulsifier
Emery 3685	Emulsifier
Emery 916 Glycerine	-
Emgard 2016	Emulsifier
Emgard 2060	Emulsifier
Emgard Fish Oil	Emulsifier
Exel Granules 24/48	Diluent
Feed N Kleen	Nutrient, Resold
Fertilizer 16-20-0	Nutrient, Resold
Fertilizer 30-10-0	Nutrient, Resold
Fluorochemical	Laboratory agent
Formula 350	Resold
Formula 400	-
Frianite	Diluent
Fuller Earth Fly 16/30 AALV	-
GAFAC 510	Emulsifier
GAFAC RE-610	Emulsifier

TABLE 4 (CONTINUED)

OTHER UNCATEGORIZED SUBSTANCES
APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Chemical	Comments[b]
Gibberelic Acid Technical	-
Gibberellic Grape Fix	-
Glomax HE	Emulsifier
Glycerine	-
Granules 24-48 (Oxchem)	Diluent
Grid-White	Diluent, Resold
Gypsum	-
Hampene Iron Chelates	Nutrient
Hi Sil	Diluent
Hulls	-
Hydrite PX	-
Hyflo Super Cel	Diluent
ID-5008-1	-
ID-5008-2 Premix	-
ID-5008-2	-
Igepal DM 710	Emulsifier
Igepon T-77	Emulsifier
Industrial Fill #4 (Zonolite)	Diluent
Inject-A-Min	Nutrient, Resold
Kaolin #4	-
Labtone	Laboratory agent
Lightning Pitch Produce 335	-
Lignosol SFX	Wetting agent
Liquid Petroleum	-
Loamite Soil	Laboratory agent
Lomar D	Wetting agent
Lomar PW	Wetting agent
Lure-A-BEE	-
Magnesium Sulfate	-
Magox Magnesium Oxide 54%	-
Makon 10	-
Manganese Oxide	-
Manganese Sulfate	-
Maracarb N	-
Marasperse CB	Wetting agent
Marasperse N	-
Marsperse C-21	-
Micro Cel	Diluent
Minor Element Liquid	-
Mineral Mix	Nutrient
Mira Flo 400	Wetting agent
Moran D	Resold

TABLE 4 (CONTINUED)

OTHER UNCATEGORIZED SUBSTANCES
APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Chemical	Comments[b]
Neodol 23-6.5	Emulsifier
Neutralizer	Laboratory agent
Ninate 401	Emulsifier, Laboratory agent
Nopco Wax 22 DS	Wetting agent
Nutra Phos 10	Nutrient, resold
Nutra Phos 12	Nutrient, resold
Nutra Phos 3-15	Nutrient, resold
Nutra Phos FE	Nutrient, resold
Nutra Phos K	Nutrient, resold
Nutra Phos MG	Nutrient, resold
Nutra Phos N	Nutrient, resold
Nutra Phos Super K	Nutrient, resold
Nutra Plus 10 12 5	Nutrient, resold
Nutra Plus 17	Nutrient, resold
Nutra Spray 50 ZN	Nutrient, resold
Nutra Spray. Cu Bordon 22%	Nutrient, resold
Nutramin	Nutrient, resold
Oil Cotton Seed	-
Olancha Clay	Diluent
Opiwhite Pigment	Diluent
Orchard Starter Tablets	Nutrient
Organic Halogen Reagent	Laboratory agent
Orzan	-
Osmocote 18-6-12	Nutrient, Resold
Perlite	Diluent
Petro AG	Wetting agent
Petro BP	Wetting agent
Petro WP	Wetting agent
Ph 295	-
Phos Ammonium DI	Nutrient
Phos Soda Acid Pyro FG	-
Phos Soda Tri Poly	Nutrient
Phos Tri Calcium	Nutrient
Planting Tablets	Nutrient, Resold
Pollen	-
Ployfon O	Wetting agent
Polyfon D	Wetting agent
Polyfon F	Wetting agent
Polyfon G	Wetting agent
Polyfon H	Wetting agent
Prep Tank	Resold

TABLE 4 (CONTINUED)

OTHER UNCATEGORIZED SUBSTANCES
APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Chemical	Comments[b]
Pronon 201	Emulsifier
Pronon 201-50	Emulsifier
Pronon 505	Emulsifier
Propylene Glycol	-
Protox 7245	Emulsifier
Protox 7227	Emulsifier
Protox 7300	Emulsifier
Protox 7400	Emulsifier
Protox 7704	Emulsifier
Protox 7801	Emulsifier
Pyrolite	Diluent
Pyrophyllite	Diluent
Ray-Guard	Diluent, Resold
Rayplex FE	Nutrient
Repel	Resold
Retzloff PNS 249	Emulsifier
Rhoplex AC-33	-
Riboflavin 94-97%	Nutrient, Resold
Rust Arrester	-
Savol	Resold
Sellagen HR	Wetting agent
Sequestrene 138 FE	Nutrient, Resold
Sequestrene 330 FE	Nutrient, Resold
Sierra White Talc	Diluent
Silica Aluminate	-
Silicone Antifoam AF-60	Laboratory agent
Silipone	Wetting agent, Laboratory agent
Sodium Casinate	Diluent
Sodium Sulfate Anhyd	Nutrient
Sodium Tartrate Reagent	Laboratory agent
Sodium Xylene Sulfonate (Stepanate X)	Emulsifier
Sorba Spray CAB	Nutrient, Resold
Sorba Phix	Nutrient, Resold
Sorba Spray MIP	Nutrient, Resold
Sorba Spray Calcium	Nutrient, Resold
Sorba Spray CU	Nutrient, Resold
Sorba Spray FE	Nutrient, Resold
Sorba Spray MG	Nutrient, Resold
Sorba Spray MN	Nutrient, Resold

TABLE 4 (CONTINUED)

OTHER UNCATEGORIZED SUBSTANCES
APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (R/J 4083)

Chemical	Comments[b]
Sorba Spray Vitatone	Nutrient, Resold
Sorba Spray ZBK	Nutrient, Resold
Sorba Spray ZIP	Nutrient, Resold
Sorba Spray ZKP	Nutrient, Resold
Sorba Spray ZNP	Nutrient, Resold
Spencer Fertilizer	Nutrient, Resold
Sponto 80	Emulsifier
Sponto 830	Emulsifier
Spreader Activator	Spreader
Spreader Dry S 20	Spreader
Spreader Sticker	Spreader
Sticker Solution	-
Sugar	-
Sulfamethazine	Resold
Super D Spreader	-
Super D	-
Super Spray Gone	Resold
Super Phosphate Triple	Nutrient
Surfactant Spreader	-
Surfynol 82	Surfactant
Surfynol T.G.	Surfactant
T DET MC	Emulsifier, Resold
T-DET 1007	Emulsifier
T-DET 344	Emulsifier
T-DET AN 45	Emulsifier
T-DET Blend B	Emulsifier
T-DET DD	Emulsifier
T-Det N 5	Emulsifier
T-Det N 6	Emulsifier
T-DET N 828	Emulsifier
T-Det N 9	Emulsifier
T-Det N 9.5	Emulsifier
T-DET N-82080	Emulsifier
T-DET N8	Emulsifier
T-DET TDA 60	Emulsifier
T-DET TDA 65	Emulsifier
T-Mulz 0	Emulsifier
T-Mulz 121 N	Emulsifier
T-Mulz 1450	Emulsifier
T-Mulz IS Emulsifier	Emulsifier
T-Mulz 338	Emulsifier

TABLE 4 (CONTINUED)

OTHER UNCATEGORIZED SUBSTANCES
APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Chemical	Comments[b]
T-Mulz 339	Emulsifier
T-Mulz 404	Emulsifier
T-Mulz 495	Emulsifier
T-Mulz 63	Emulsifier
T-Mulz 650	Emulsifier
T-Mulz 8 Emulsifier	Emulsifier
T-Mulz 80	Emulsifier
T-Mulz A 02	Emulsifier
T-Mulz H	Emulsifier
T-Mulz L	Emulsifier
T-Mulz Mal 1S	Emulsifier
T-Mulz Mal 8	Emulsifier
T-Mulz S	Emulsifier
T-Mulz W	Emulsifier
Tablets Forest Starter	Nutrient, Resold
Tablets Blue Chip	Nutrient, Resold
Tablets Container	Nutrient, Resold
Tablets Orchard Starters	Nutrient, Resold
Tablets Planting	Nutrient, Resold
Taco Clay	Diluent
Talc	Diluent
Tamol 731	Wetting agent
Tamol N Granules	Wetting agent
Tamol S-N	Wetting agent
TAM Zircon Granules	Diluent
TH Compound SDJ	Laboratory agent
TH Silicone Antifoam 30 FG	Resold
Toximul NP	Emulsifier
Tri Sodium Phosphate	Laboratory agent
Tricalcium Phosphate	Laboratory agent
Triton B-1956	Emulsifier
Triton CF 32	Emulsifier
Triton N-101	Emulsifier
Triton X-114	Emulsifier
Triton X-155	Emulsifier
Triton X-171	Emulsifier
Triton X-193	Emulsifier
Turfguard 201	Resold
Tween 90	-
Uni Mix	Spreader, Resold
Upjohn 74-1	-
Urea 46%	Nutrient, Resold

TABLE 4 (CONTINUED)

OTHER UNCATEGORIZED SUBSTANCES
APPARENTLY HANDLED AT THE THAN SITE[a]
FRESNO, CALIFORNIA (K/J 4083)

Chemical	Comments[b]
Velvex	-
Vermiculate-Celite 30-70	Diluent
Vermiculite	Diluent
Vitatone Stabilized Iron	Nutrient, Resold
VLR Diluent	Diluent
VW&R Spreader No. 1	Spreader
Weychem 0506	Wetting agent
Weychem BD-50	Wetting agent
X-77 Spreader	Spreader, Resold
Zeolex 23	Diluent
Zeolex 7	Diluent
Zeosyl 10-3515	Laboratory agent

Notes:

[a] Refer to text for details of the scope and limitations of this list.

[b] Surfactant - indicates Surfactant or suspected surfactant.
Emulsifier - indiactes emulsifier or suspected emulsifier.
Spreader - indicates spreader or suspected spreader.
Wetting agent - indicates wetting agent or suspected wetting agent.
Diluent - indicates clay or suspected clay or other diluent.
Nutrient - indicates nutrient or suspected nutrient.
Laboratory agent - indicates that the substance was only used in the laboratory.
Resold - indicates that the substance was only bought for resale to customers; it was not used as a raw material or formulated or repackaged at the site.

1. Consolidated Deposits

"The hard tight rocks of the basement complex form an almost impermeable boundary of the groundwater basin (San Joaquin), but their deeply weathered surfaces and extensive joint systems permit yields of small quantities of water to wells" (USGS, 1969). A geologic cross section projected on a line extending roughly 2 miles southeast of the THAN site shows the basement complex to be 1600-1800 feet below land surface (Figures 1 & 2).

2. Unconsolidated Deposits

Unconsolidated deposits beneath the THAN site are derived from the hard crystalline bedrock of the Sierra Nevada. These unconsolidated strata were formed by small intermittent streams north of the Kings River. Poorly sorted sands and gravels as well as silt, clay, and clayey sand lenses are commonly encountered in the area.

A geologic study by Cehrs was conducted in the Fresno area in 1979. Cehrs reviewed electric logs, driller's logs and sample cores to define the local geology. Cehrs concluded that due to the geologic complexities discovered to exist in the area, general aquifer hydraulic properties could not be defined (Fresno WRMP, 1986).

a. Continental Tertiary and Quaternary Deposits

Unconsolidated deposits of Tertiary and Quaternary age below the THAN site consist of finer grain sediments and clay-silt lenses. This stratum is estimated to lie 300 to 400 feet below

GEOLOGIC CROSS SECTION D-D'
THAN - FRESNO, CALIFORNIA

From USGS Report: "Geology ... in the Fresno Area", 1969.

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Figure 2

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land surface at the THAN site and is approximately 1500 feet thick.

Most water wells within the Fresno-Clovis area do not penetrate the Continental deposits. Hydraulic properties of the geologic Continental layer in the Fresno area are not widely known.

b. Quaternary Deposits: Older Alluvium

The older alluvium of Pliestocene and probable Holocene age crops out at the THAN Fresno facility. The oxidized deposits are estimated to be 200-300 feet thick.

The older alluvium is generally coarser grained than underlying deposits, but changes in texture occur over short distances. Sediments within the older alluvium below the THAN site are estimated to be 20-33% coarse grained material. Yields to wells penetrating this water bearing zone range from 800 to 2000 gpm (USGS, 1969). Almost all wells southwest of the THAN facility are perforated in the older alluvium layer.

B. HYDROLOGY

Unconfined ground water beneath the site flows from the northeast to the southwest. Water levels measured in the on site monitoring wells confirm the presence of water roughly 25 feet below land surface. Hydraulic properties of the unconfined aquifer below the site are unknown. Horizontal velocities in coarser sediments have been measured to be as high as 0.61 feet per day in the Fresno area; however, average velocities are

probably much lower (Fresno GWRMP, 1986). Pump tests of on site and off site wells have been proposed by THAN to fully define the hydrogeology beneath and surrounding the site.

Water quality immediately upgradient from the THAN site is generally good. The following inorganic constituent concentrations were reported to exist in groundwater immediately upgradient from the THAN site (Fresno GWRMP, 1986).

Nitrates:	<15 mg/l (N_2)
Chloride:	<25 mg/l
Total Hardness:	100-200 mg/l

Widespread concentrations of 1,2-dibromo -3- chloropropane (DBCP) have been found in municipal groundwater supply wells throughout the Fresno area. Off site sampling programs conducted by THAN, however, have shown DBCP concentrations less than 1 ppb in upgradient water wells.

Current uses for groundwater in the general vicinity of the site are for domestic and irrigation purposes. Over 50 domestic wells used for drinking water are located within a one mile radius downgradient from the site. The San Joaquin water basin in the Fresno area has been designated a Sole Source Aquifer. Groundwater in the area, therefore, is protected under Section 1424(e) of the Safe Drinking Water Act.

IV. POSSIBLE ON SITE CONTAMINATING POINT SOURCES

Past employees of the THAN facility were interviewed by THAN in regard to former chemical handling practices and disposal operations at the site (Kleinfelder and Associates, November

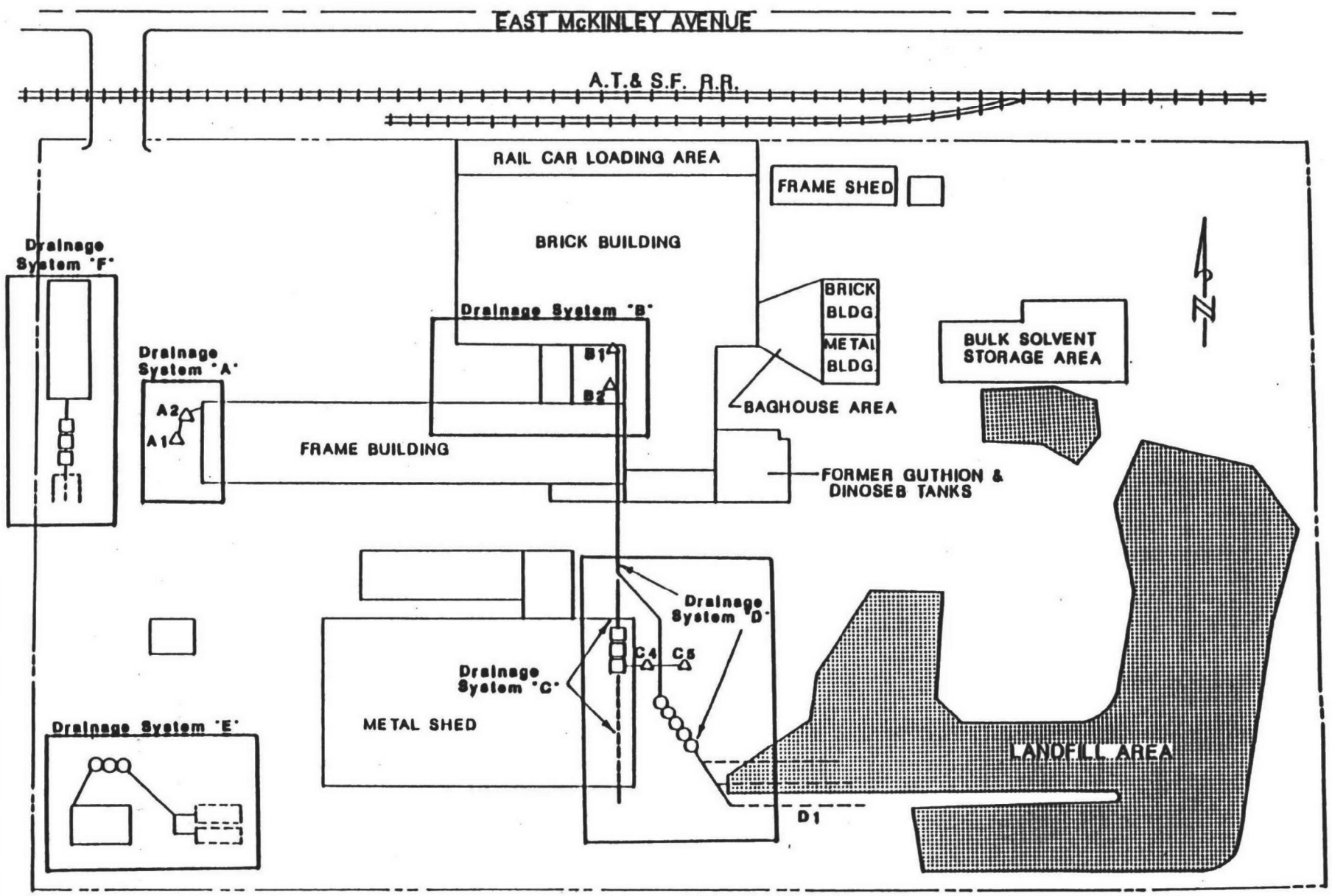
1984). Areas which were suspected to contain industrial waste contaminants were identified. Major excavation programs were conducted by THAN in 1984 and 1985 to delineate, and remove contaminated soils in these areas. After reviewing the extensive site information written by Kennedy/Jenks Engineers and Kleinfelder and Associates, the following possible contamination locations were identified by Engineering Enterprises, Inc. :

1. Landfill located in the southeast quadrant,
2. Bulk solvent storage area,
3. Baghouse area,
4. Dinoseb and Guthion Tank area,
5. Railcar loading area,
6. Drainage systems A through D,
7. Disposal well area southwest of sump.

(Refer to Figure 3 for the relative point source locations.

Pesticides, aromatic hydrocarbons, xylene and various other organic solvents were detected in soils beneath the locations noted "2" through "5" above. Soil contamination in these areas may have resulted from inadequate chemical handling practices. Chlorinated pesticides and organic solvents were also detected in soil and water samples collected from the general landfill area. Leachates from buried chemical containers, clean out clays, and plastic debris were detected in downgradient monitor wells (Kleinfelder and Associates, November 1984).

ON SITE CONTAMINATING POINT SOURCES
THAN - FRESNO, CALIFORNIA



Adapted from Kleinfelder & Associates' "Final Report; Drainage System Exploration Program", 1986.

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Figure 3

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V. DISPOSAL "WELL" SYSTEM DESCRIPTIONS

The following disposal system descriptions are summaries derived from discussions found in Kleinfelder and Associates' "Final Report: Drainage System Exploration Program" and "Status Report: THAN Remedial Program". Refer to Figure 3 for the locations of these industrial waste disposal systems on the THAN site.

A. INDUSTRIAL DISPOSAL WELLS A1 AND A2

Two industrial disposal wells (5W20) located west of the frame building served the laboratory on the THAN site. These cased, soil packed wells were excavated to a depth of 22 feet and removed from the site. Operational information is severely limited.

B. INDUSTRIAL DISPOSAL WELLS B1 AND B2

Disposal Wells B1 and B2 were formerly located between the wood and brick buildings. Disposal Well B1 was a 3.5 foot diameter by 5 foot deep steel cased disposal well located 10 feet north of disposal well B2. Disposal Well B2 was discovered to be a bottomless steel "55 gallon drum". Both disposal wells are theorized by THAN to have drainage lines leading to drainage systems C and D. The bottomless condition of well B2 somewhat contradicts THAN's proposed theory. At least 15 feet of vadose materials separated the reported discharge depths and the underlying ground water. These wells were excavated with surrounding soils and transported to a Class I landfill.

C. INDUSTRIAL DISPOSAL WELLS C4 AND C5

Drainage System C consisted of a septic tank servicing the metal building and two brick lined wells (C4 and C5). Operation of these disposal wells (C4 and C5) continued until 1970. Chemicals disposed of in Wells B1 and B2 were possibly allowed to flow into wells C4 and C5 via drain lines. Wells C4 and C5 are thus considered possible industrial disposal wells. Wells C4 and C5 are 3.5 foot diameter by 17 foot deep, brick lined gravel filled cisterns. "A four-inch diameter "orangeburg" pipe connects the two cisterns (disposal wells) with no apparent leach lines connected to either of the cisterns" (Kleinfelder and Associates, February 1986).

D. INDUSTRIAL DISPOSAL WELLS L1, L2, AND L3

Three industrial disposal wells (5W20) were inadvertently discovered southwest of the sump area during the landfill excavation phase. These disposal wells were approximately 2 feet in diameter and extended to a depth of 10 feet. Subrounded gravel was used to fill the well boreholes. All three wells were excavated and transported with landfill soils to a Class I landfill.

E. INDUSTRIAL DISPOSAL LEACHFIELD D1

A septic system was installed in 1970 southeast of the metal shed (refer to Figure 3) to replace Drainage System C. This septic tank system consisted of five concrete septic compartments (with steel lids) and a 4-inch PVC pipe leading to a leach field. Chemicals disposed of in Wells B1 and B2 were possibly allowed

to flow into this septic tank and leach line after 1970. Leach field D1 is therefore considered a possible industrial disposal system (SW20). The configuration of the leachline system, as shown in Figure 3, was inferred from construction records submitted to Fresno County in 1970. Since then, however, the existence of the leach line system has been confirmed by subsurface investigation.

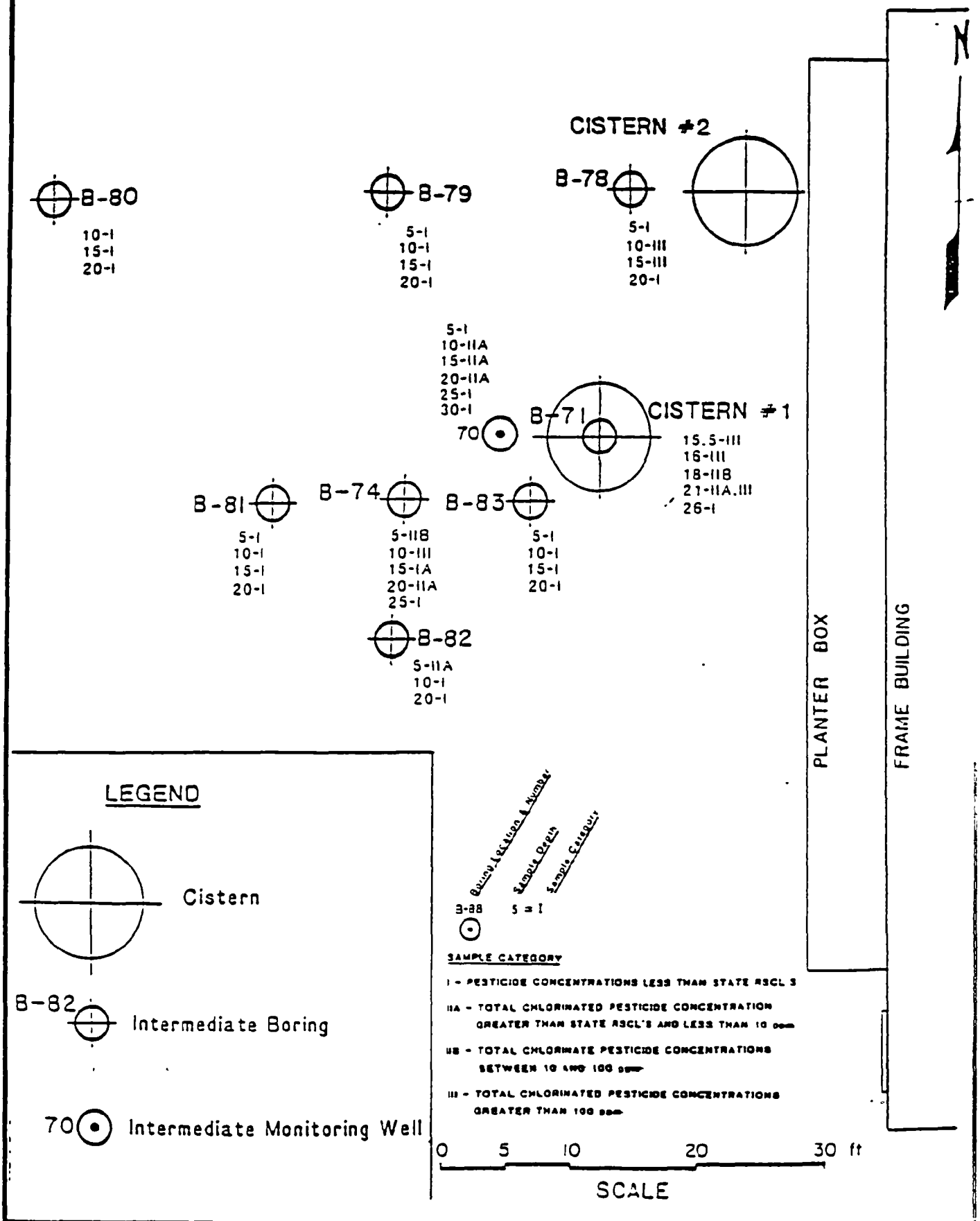
VI. FACILITY INVESTIGATION - ON SITE

A. SOIL INVESTIGATION

Subsurface soils have been sampled from four of the five industrial disposal systems located on-site. Chemicals present within these subsurface soils are believed to hold the potential to migrate into the underlying shallow groundwater. Below is a summary of the soil sampling work performed along with the analytical results of soils collected from each industrial disposal area.

1. Drainage System A

"A series of soil borings in the immediate area of cistern numbers 1 and 2 (Disposal Wells A1 and A2) were advanced to collect soil samples for subsequent chemical product residue analysis. Figure 4 shows the location of these borings and summarizes the results (analytical)", (Kleinfelder and Associates, November 1984). These soils were analyzed for organochlorine and organophosphate pesticides and DBCP. The results were reported in terms of total chlorinated pesticides because these compounds were generally the most concentrated of



CISTERN (1 & 2) BORING SOILS SUMMARY
THAN - FRESNO, CALIFORNIA

ENGINEERING ENTERPRISES, INC.

609-012-03 Figure 4

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those found in the site soils. All soils below Disposal Wells A1 and A2 were excavated to a depth of 23 feet and disposed of at a Class I landfill site.

2. Drainage System B

Two soil borings (B-134 and B-135) were originally drilled in the vicinity of Disposal Well B2. These borings were drilled and sampled every 5 feet to 25 feet below ground level. The samples were tested for pesticides, DBCP and volatile organic solvents (refer to Figure 5 for the results). "Samples from Boring 135 contained pesticide residuals above California's Recommended Soil Cleanup Levels (RSCL's) to a depth of 20 feet, and samples from Boring 134 contained pesticide residuals which were below the RSCL's", (Kleinfelder and Associates, November 1984). Xylene was detected in samples withdrawn from Boring 134 at 15, 20 and 25 feet below ground level. Xylene concentration ranged from 2262 to 2634 mg/kg.

Boring B-141 was later drilled adjacent to the newly discovered Disposal Well B1. Samples were collected every five feet until groundwater was encountered. These soil samples were tested for the presence of: chlorinated and phosphatized pesticides, dinoseb, DBCP, volatile organic compounds and extractable organic compounds. See Table 5 for contaminant concentrations detected in the B-141 soils mentioned above.

3. Drainage System C

"Four borings (B-142, B-143, B-146 and B-148) were advanced near and adjacent to the septic tanks (C1, C2, and C3) and the

DRAINAGE SYSTEM 'B' SOILS SUMMARY
THAN - FRESNO, CALIFORNIA

Adapted from Kleinfelder & Associates' "Final Report; Drainage System Exploration Program", 1986.

SAMPLE CATEGORY

I - Pesticide concentration less than State RSCL's
IIA - Total chlorinated pesticide concentration greater than State RSCL's and less than 10 ppm
IIB - Total chlorinated pesticide concentration between 10 and 100 ppm
III - Total chlorinated pesticide concentration greater than 100 ppm

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Figure 5

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Table 5 Soil Boring Analyses For Samples Collected During Drainage System Exploration Program
TIWM Site, Eastern Fresno County, California
(Concentrations ug/g)

Boring No.	141	141	141	141	141	141	142	143	143	143	143	144	144	144	144	144
Depth (ft)	5	10	15	20	25	30	30	15	20	25	30	5	10	15	20	25
Organochlorine Compounds																
Dicofol	ND	ND	ND	ND	ND	ND	48.35	ND	ND	ND	ND	ND	ND	ND	ND	ND
DDCP	ND	ND	0.01	0.01	0.02	0.02	0.03	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan Sulfate	ND	ND	ND	ND	ND	ND	59.31	ND	ND	ND	ND	ND	ND	ND	ND	ND
PP DDE	ND	ND	ND	ND	ND	ND	40.40	ND	ND	ND	ND	ND	ND	ND	ND	ND
OP TDE	ND	ND	ND	ND	ND	ND	131.93	0.08	0.08	ND	ND	ND	ND	ND	ND	ND
PP TDE	ND	ND	ND	ND	ND	ND	285.89	0.08	0.19	ND	ND	ND	ND	ND	ND	ND
PP DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toxaphene	ND	0.21	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Organophosphorous Compounds																
DEF	ND	ND	ND	ND	ND	ND	0.84	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethoate	ND	ND	ND	ND	ND	ND	0.17	ND	ND	ND	ND	ND	ND	ND	ND	ND
Malathion	ND	ND	ND	ND	ND	ND	0.08	ND	ND	ND	ND	ND	ND	ND	ND	ND
Volatile Organic and Base/Neutral/Acid Extractable Compounds																
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethyl Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

From Kleinfelder & Associates, "Final Report: Drainage System Exploration Program...", 1986.

Table 5 Continued

Boring No.	144	146	146	146	146	146	146	146	147	147	148	148	148	Detection	
Depth (ft)	30	5	10	15	20	25	30	35	10	15	5	10	15	Limit	RSCL's a/
Organochlorine Compounds															
Dicofol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	
DDCP	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	1.0
Endosulfan Sulfate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	
PP DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	1.0 b/
OP TDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	1.0 b/
PP TDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	1.0 b/
PP DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.10	ND	ND	0.05	1.0 b/
Toxaphene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	5.0
Organophosphorous Compounds															
DEP	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	
Dimethoate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	140
Malathion	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	160
Volatile Organic and Base/Neutral/Acid Extractable Compounds															
Benzene	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	0.7
Ethyl Benzene	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5	1400
Toluene	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	100
Xylene	1.0	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0	620

ND = non-detected at lowermost detection limit

All other constituents analyzed per EPA Methods 8010, 8080, 8140, 8240, and 8270 were non-detected, (see Appendix D for detection limits).

a/ Recommended soil clean-up levels (RSCL's) - available recommended cleanup levels established by State of California Department of Health Services (DHS) and Regional Water Quality Control Board (SFBRWQCB). Levels are based on Environmental Protection Agency (EPA) drinking water standards multiplied by a factor of 1,000.

b/ RSCL for sum of total DDT isomers

connecting brick-lined cisterns (C4 and C5) located beneath and east of the metal building, respectively, (see Figure 3). Boring B-142 was advanced through the center of cistern C5. One sample was obtained from a depth of 30 feet at this location. Gravels encountered from the bottom of cistern C5 (located a depth of 17 feet) to a depth of 30 feet, prohibited sample retrieval in this depth interval. Boring 143 was completed adjacent to cistern C4 and sampled at depths of 15, 20, 25, and 30 feet. Borings B-146 and B-148 were advanced and sampled at 5-foot intervals to depths of 35 and 15 feet, respectively", (Kleinfelder and Associates, 1986). These soil samples were analyzed for pesticides, DBCP, volatile organic compounds and extractable organic compounds. See Table 5 for contaminant concentrations present in these samples.

4. Drainage System D

Grab and soil boring samples were collected in the leach field area of Drainage System D. Grab Samples SL2 and SL3 were removed from soils directly underlying an exposed leach line. These samples were tested for chlorinated and phosphatized pesticides, volatile organic compounds and extractable organic compounds. The results from these tests are included in Table 6.

Boring B-147 was later drilled in the leach field vicinity to a depth of 15 feet. Analytical results for the two soil samples tested are presented in Table 6.

Table 6 +
Soil Analyses for Grab Samples Collected
Below Leachfield D1
THAN Site, Eastern Fresno County, California
Concentration (ug/g)

	Sample Number Soil Samples		RSCL
Organochlorine Compounds	SL2	SL3	
Aldrin	ND	ND	
Alpha BHC	ND	ND	
Beta BHC	ND	ND	
Gamma BHC (Lindane)	ND	ND	
Delta BHC	ND	0.05	
Chlordane	ND	ND	
Dicofol	0.09	0.08	-
Dieldrin	0.07	0.19	0.05
Alpha/Beta Endosulfan	ND	ND	
Endosulfan Sulfate	ND	ND	
Endrin	ND	ND	
Hepthachlor	ND	ND	
Heptachlor Epoxide	ND	ND	
OP' DDD	0.10	0.07	1.0*
PP' DDD	ND	0.14	1.0*
OP' DDE	0.47	0.58	1.0*
PP' DDE	ND	ND	1.0*
OP' DDT	0.42	0.31	1.0*
PP' DDT	1.02	3.13	1.0*
Toxaphene	ND	ND	
DBCP	ND	ND	
Dinoseb	ND	ND	
Organophosphorous Compounds			
Azinophosomethyl	ND	ND	
DEF	ND	ND	
Diazinon	ND	ND	
Dimethoate	ND	ND	
Diphenamid	ND	ND	
Ethion	ND	ND	
Malathion	ND	ND	
Parathion, Ethyl	ND	ND	
Parathion, Methyl	ND	ND	
Phorate	ND	ND	
Trifluralin	ND	ND	

* RSCL for sum of total DDT isomers.
+ Excerpted from Kleinfelder & Associates, "Final Report: Drainage Exploration Program", 1986

Table 6 (Continued)

(Concentrations in ug/g)

Volatile Organic Compounds	Sample Number Soil Samples SL2	SL3	RSCL
Carbon Tetrachloride	ND	ND	
Chloroform	ND	ND	
1,2-Dichloroethane	ND	ND	
1,2-Dichloropropane	ND	ND	
Tetrachloroethene	ND	ND	
1,1,1-Trichloroethane	ND	ND	
1,1,2-Trichloroethane	ND	ND	
Trichloroethene	ND	ND	
Base/Neutral/ Acid Compounds			
1,2,4-Trichlorobenzene	ND	ND	
1,3 Dichlorobenzene	ND	ND	
Napthalene	ND	ND	
Di-n-butyl phathalate	13	26	

ND = Non-detected at lowermost detection level

Note: All other constituents analyzed per EPA Methods 8040, 8080, 8140, 8240 and 8270 were non-detected, (see Appendix C for detection limits).

5. DISPOSAL WELLS L1, L2, AND L3

Boring samples of for soils underlying these disposal wells were not collected. These soils were excavated to a depth of 10 feet and transported to a Class I landfill.

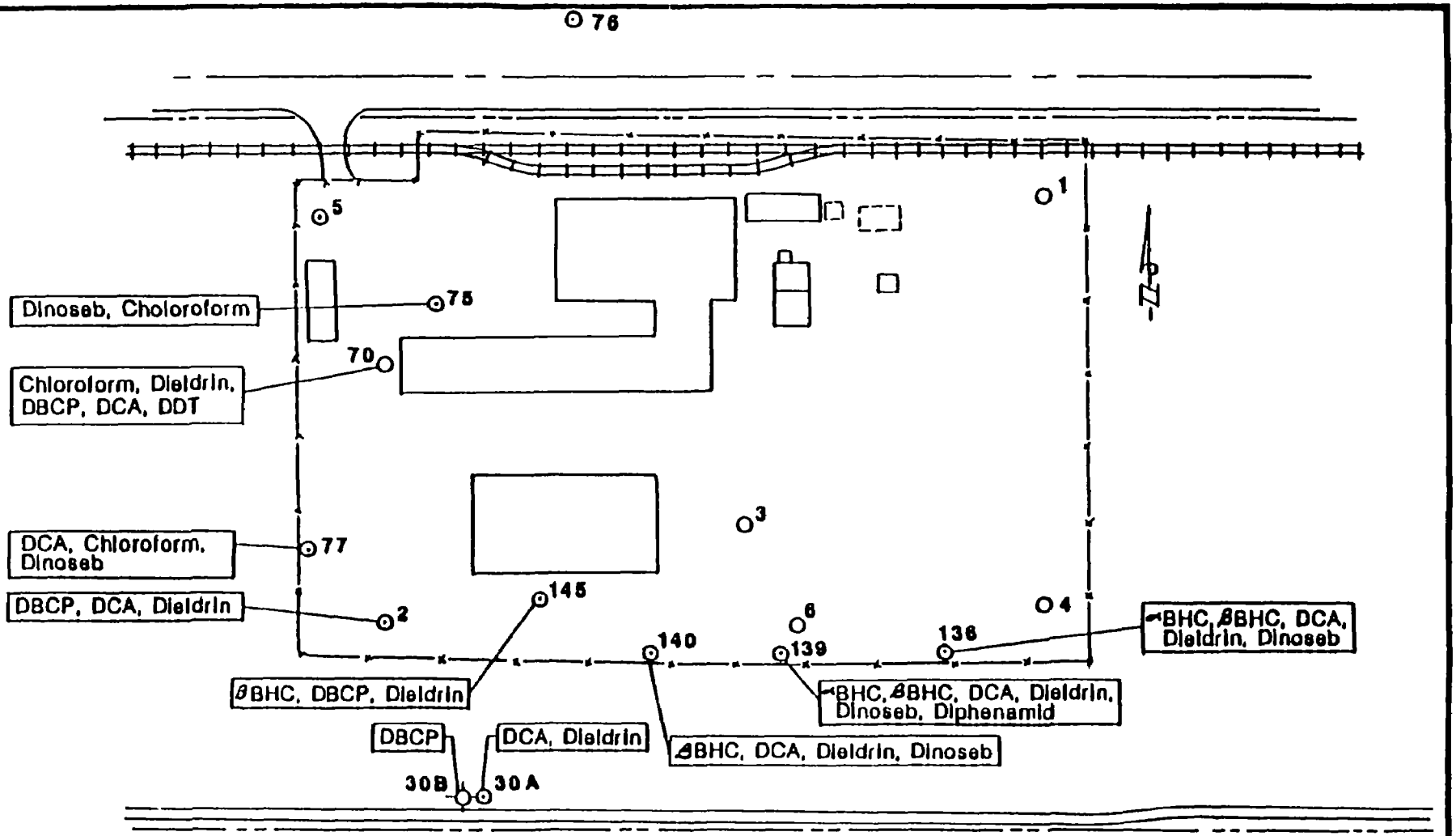
B. GROUNDWATER INVESTIGATION

This section has been taken directly from Kennedy/Jenks/ Chiltons', "Draft Feasibility Study, Tasks 1 and 2," July 1986, page 6.

"A total of 22 groundwater monitoring wells have been installed on-site between 1981 and 1985. Five of these wells have since been abandoned or destroyed due to site soil excavation or other activities. These on-site wells are predominantly shallow groundwater monitoring wells, with depths ranging from 30 to 50 feet. Four intermediate-depth wells (120 feet) have also been installed (refer to Figure 10 for well locations.)

The on site monitoring wells have been sampled quarterly since their installation. The wells have been analyzed for organochlorine and organophosphorous compounds, DBCP and volatile halocarbons. Elevated levels of chloroform, DBCP, Dinoseb and 1, 2 - DCA have been found in some of the on site wells. In addition, DDT, BHC (all isomers) and dieldrin have also been detected in some wells. The most significant levels of these chemicals were found to the west and southwest of the frame building in monitoring wells 70 (now abandoned) and 77 (refer to Figure 6). Elevated levels of chemicals were also detected in

CONTAMINANTS DETECTED IN ON SITE MONITORING WELLS
THE THAN - FRESNO, CALIFORNIA



Adapted from Kennedy/Jenks/Chilton's "Draft Freasibility Study", 1986.

LEGEND

- Existing intermediate monitoring well (120 feet, total depth)
- Existing shallow monitoring well (30-50 feet, total depth)
- Wells no longer in service

0 50 100
Scale in Feet

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609-012-03

Figure 6

[6-403]

monitoring wells along the southern site boundary. On site ground water monitoring well data collected to date for the main chemicals of concern are summarized in Figure 6. "THAN has proposed to construct three additional monitoring wells south of Well 139 on the property line. Screened intervals (5 feet) will be placed approximately 40, 70, and 110 feet below ground level."

VII. FACILITY INVESTIGATION - OFF SITE

Extensive off site groundwater sampling programs have been enacted by THAN since 1982. Domestic wells within one-half mile downgradient of the site were sampled three times a year in 1982 and 1983. Groundwater samples collected from these wells were analyzed for organochlorine and organophosphorous compounds, chloroform, DBCP, and volatile halocarbons. The off-site domestic well sampling program was later amended to include all wells located within a one mile radius downgradient of the site (Kennedy/Jenks/Chilton, July 1986).

In July of 1985, THAN proposed a drinking water sampling program. This program was designed to identify those domestic and agricultural wells downgradient of the site which were contaminated as a direct result from THAN's past operations. Fifty-seven domestic or agricultural wells were proposed to be sampled semi-annually. These samples were to be tested for DBCP, organochlorine compounds, and volatile halocarbons. The first samples were collected in December of 1985. The analytical results of these samples are summarized with previous sampling results in Figures 7 - 10. These wells will continue to be

DOMESTIC WELL CHLOROFORM CONCENTRATIONS
THAN – FRESNO, CALIFORNIA

California Drinking Water Action Level = 100 ppb

From Kleinfelder & Associates "Groundwater Analyses December Offsite Sampling", 1985

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Figure 7

[6-405]

DOMESTIC WELL
DBCP CONCENTRATIONS
THAN- FRESNO, CALIFORNIA

From Kleinfelder & Associates "Groundwater Analyses December Offsite Sampling", 1985.

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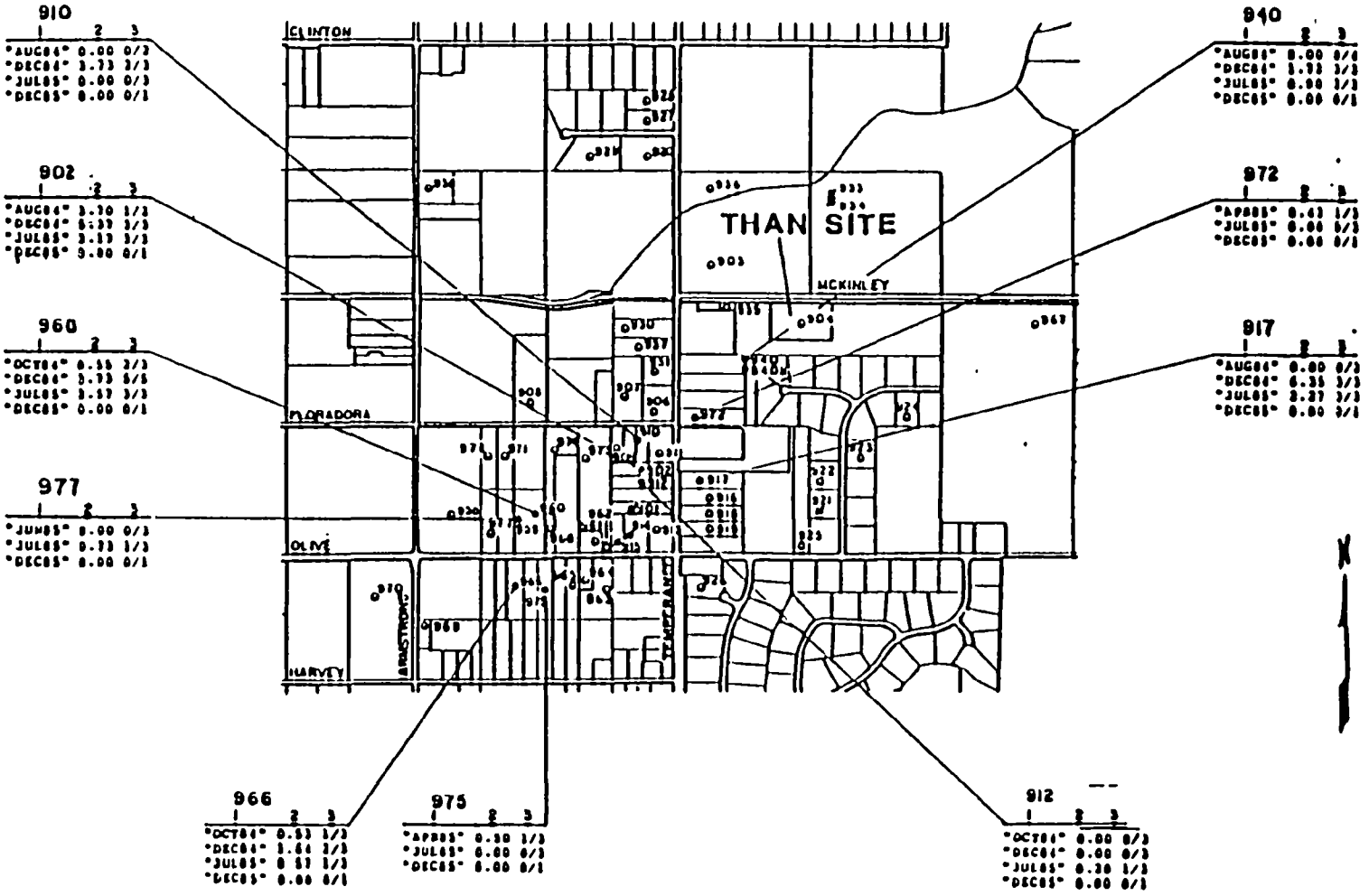
609-012-03

Figure 8

[6-4061]

DOMESTIC WELL
1,2 DICHLOROETHANE CONCENTRATION
THAN - FRESNO, CALIFORNIA



California Drinking Water Action Level - 10 ppb

From Kleinfelder & Associates "Groundwater Analyses December Offsite Sampling", 1985.

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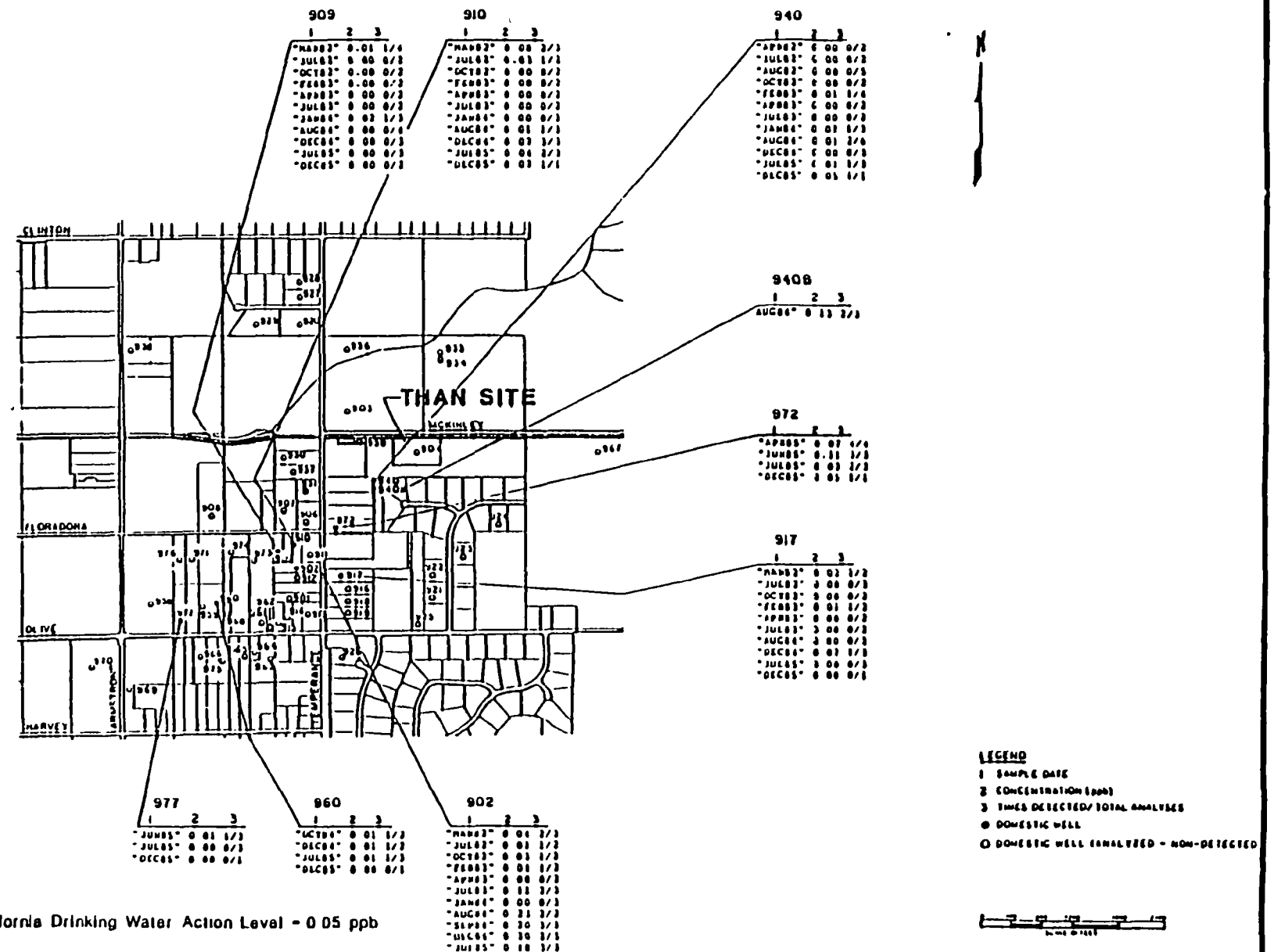
609-012-03

Figure 9

16-407

DOMESTIC WELL
DIELDRIN CONCENTRATIONS
THAN - FRESNO, CALIFORNIA



From Kleinfelder & Associates "Groundwater Analyses December Offsite Sampling", 1985.

ENGINEERING ENTERPRISES, INC.

609-012-03 Figure 10

[6-408]

sampled in June and December until a change in sampling protocol is warranted.

VIII. SUMMARY OF DISPOSAL SYSTEM CONTAMINATION DATA

A. SOILS

The following soil contamination summaries are presented with respect to their locations on-site (refer to Figure 3 for these locations).

1. Drainage System A

Soils within an approximate 10' - 15' radius of Industrial Disposal Wells A1 and A2 appear to have been contaminated from injection activities. Organochlorine pesticide concentrations were found to exceed California State Recommended Soil Cleanup Levels (RSCLs). Contamination was confirmed to extend to the water table (approximately 25 feet below land surface). These contaminated soils surrounding the disposal wells were excavated to a depth of 22 feet and hauled off-site.

2. Drainage System B

Soil contamination is evident in underlying soils adjacent to Disposal Well B-2. Chlorinated pesticide concentrations above California's RSCL's were discovered to depths of 25 feet below ground level. Soils near the newly discovered well B1 were not shown to be contaminated.

3. Drainage System C

High concentrations of organochlorine pesticides were discovered beneath Disposal Well C4 to a depth of approximately

30 feet. DDT isomer concentrations exceeded the California RSCL by a factor of over 400. A small concentration of toxaphene was detected in underlying soils adjacent to Disposal Well C4. This constituent, however, was found in minimal concentrations, and other contaminants were not detected. Samples from borings B-146 and B-148, located beneath the metal building, contained no detectible contaminants. Soils below Disposal Well C-5 appear to be the most extensively contaminated of those soils sampled in the Drainage System C area.

4. Drainage System D

Surface soils (0-3 feet) are most likely contaminated below leach field D1. Grab samples taken beneath an exposed leach line contained concentrations of DDT (and its isomers) above the RSCL. Subsurface soil contamination in this area has not been confirmed. Samples taken from two borings in the leach field area showed no evidence of contamination. These samples were withdrawn at five foot intervals to depths of 20 and 25 feet (two borings).

B. GROUNDWATER

Groundwater contamination has been well documented both on and down-gradient of the THAN property. Groundwater contaminants found in monitor wells located on site include: organochlorine pesticides, chloroform, DBCP, alpha BHC, gamma BHC, and organophosphate compounds. Refer to Figure 6 for the areal distribution of these contaminants found in groundwater below the site. Extensive contamination of groundwater downgradient from

the site has also been confirmed. (Kleinfelder and Associates, December 1985.)

Dieldrin, DBCP, alpha BHC, gamma BHC, heptachlor and DCA have also been detected in groundwater off-site. Of these contaminants, dieldrin, DCA, DBCP, and chloroform concentrations have exceeded RSCLs in off-site monitoring wells. Figures 7 - 10 show the areal distribution of these contaminants off-site. (Kleinfelder and Associates, December 1985.)

IX. ASSESSMENT

Ten areas containing industrial waste contaminants in soils have been identified by Engineering Enterprises, Inc. on the THAN site. Industrial disposal wells (5W20) and an industrial leach field (5W20) were responsible for soil contamination at four of these locations. Some contaminated soils (with concentrations above RSCLs) resulting from disposal well operations are still on site. These soils are located beneath the following areas:

- Disposal Well C5
- Drain System B near Boring B-135 (below 5')

Leachates from these soils may continue to threaten ground water. The aerial coverage of these contaminated soils is not extensive, however, and the potential threat posed by these soils to ground water cannot be assessed. The construction of monitor wells in the close proximity of these areas would be required to provide an adequate assessment.

Groundwater contamination on and downgradient of the THAN property is well documented. This contamination may have resulted from inadequate handling practices and waste disposal methods occurring throughout the eastern half of the site. For this reason, ground water contamination detected in the southern perimeter monitor wells cannot solely be attributed to upgradient disposal well activities.

Extensive chloroform contamination has been detected up to 1 mile downgradient of the THAN facility. Disposal Wells A1 and A2 (refer to Figure 3) are the suspected former chloroform discharge points. Additional upgradient monitoring wells would be required to confirm this suspicion. These disposal wells were used to dispose of laboratory wastes. Disposal Wells A1 and A2 were poorly designed and constructed. After reviewing construction and water elevation data, a vertical separation of 3 to 5 feet between the discharge depth and water table was inferred. Fluids disposed in these wells migrated this distance to the groundwater. Permeable underlying deposits, coupled with the soluble nature of chloroform, effected the extensive migration of chloroform off-site.

In summary, based on available evidence, the industrial disposal wells operated by THAN posed a high contamiantion threat to ground water. Shallow-occurring ground water, permeable upper soils, poor well construction features, and relatively soluble injectants were all conditions contributing to groundwater contamination.

Section 6.2.27

TITLE OF STUDY: (or **SOURCE OF INFORMATION**)	Refinery Waste Disposal Wells From Reporting on Class V Injection Well Inventory and Assessment in California, Draft
AUTHOR: (or **INVESTIGATOR**)	Engineering Enterprises, Inc. (Prepared for USEPA Region IX)
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Various refineries, California USEPA Region IX
NATURE OF BUSINESS:	Petrochemical refining
BRIEF SUMMARY/NOTES:	Three refinery waste injection wells have been located and investigated in California. Average injection volumes are approximately 40-50 million gallons annually. These high injection volumes, coupled with a variety of organic and inorganic constituents in the waste stream, make these wells capable of broad-scale contamination to USDW.

Well Purpose

Petrochemical refining is a complex process by which a variety of materials are produced. The waste stream generated as a result of these processes is similarly varied. Volumes of wastes generated at such facilities are typically large, totalling in excess of a million barrels per year per well for large refineries. An indeterminate portion of that volume is waste waters not associated with the refining process, such as laboratory wastes and sewage from facility office buildings. Produced water from surrounding oil wells may be also injected intermittently.

Two types of refinery waste disposal wells have been observed in California. The first type is located within the refining facility, and is owned and operated by the refinery. Disposal into these wells is generally continual and volumes of injectate are large, though they vary with refinery processes and activity levels. Operations are the responsibility of the refinery, and uninterrupted injection is necessary for continued refining operations. Hence, a large operational database is maintained by the refinery, and that data was made available for this investigation..

The second well type studied is privately owned refinery waste injectors. Operators of these wells are contracted by refineries to dispose of generated wastes. Disposal at these facilities is intermittent and dependent upon the frequency at which the refinery provides waste fluids, either by truck or

pipeline. Disposal volumes vary accordingly. Because wastes are transported to these facilities, and refining continues regardless of injection well status, operational monitoring is not the responsibility of the refinery. Private contractors do not typically maintain a complete operational database, hence less is known about these wells. This is reflected in the following assessment.

Inventory and Location

At the present time, three wells injecting refinery wastes are known to be operating in California. Two of these wells are located at the Texaco Bakersfield Refinery in Kern County (See Figure V-33). This facility is located within the Fruitvale oilfield, and is also within the limits of the City of Bakersfield. Both wells, the Red Ribbon Nos. 7 and 8, are owned and operated by Texaco USA, and were originally completed as production wells prior to conversion to injectors.

The other well inventoried as a refinery waste disposal facility is owned and operated by JMT Oil Company of Newhall, California. This facility is contracted by the Newhall Refinery to dispose of process waste water generated at the refinery. Wastes are trucked from the refinery to the disposal system. It is not known if the refinery uses any other disposal system at this time.

It has not been possible to identify any other Class V facilities that inject refinery wastes. It is known that several tens of petroleum refineries operate in California. In the

opinion of the authors, it is likely that there are more than three refinery waste injection wells in existence, but further investigation will be required to substantiate this.

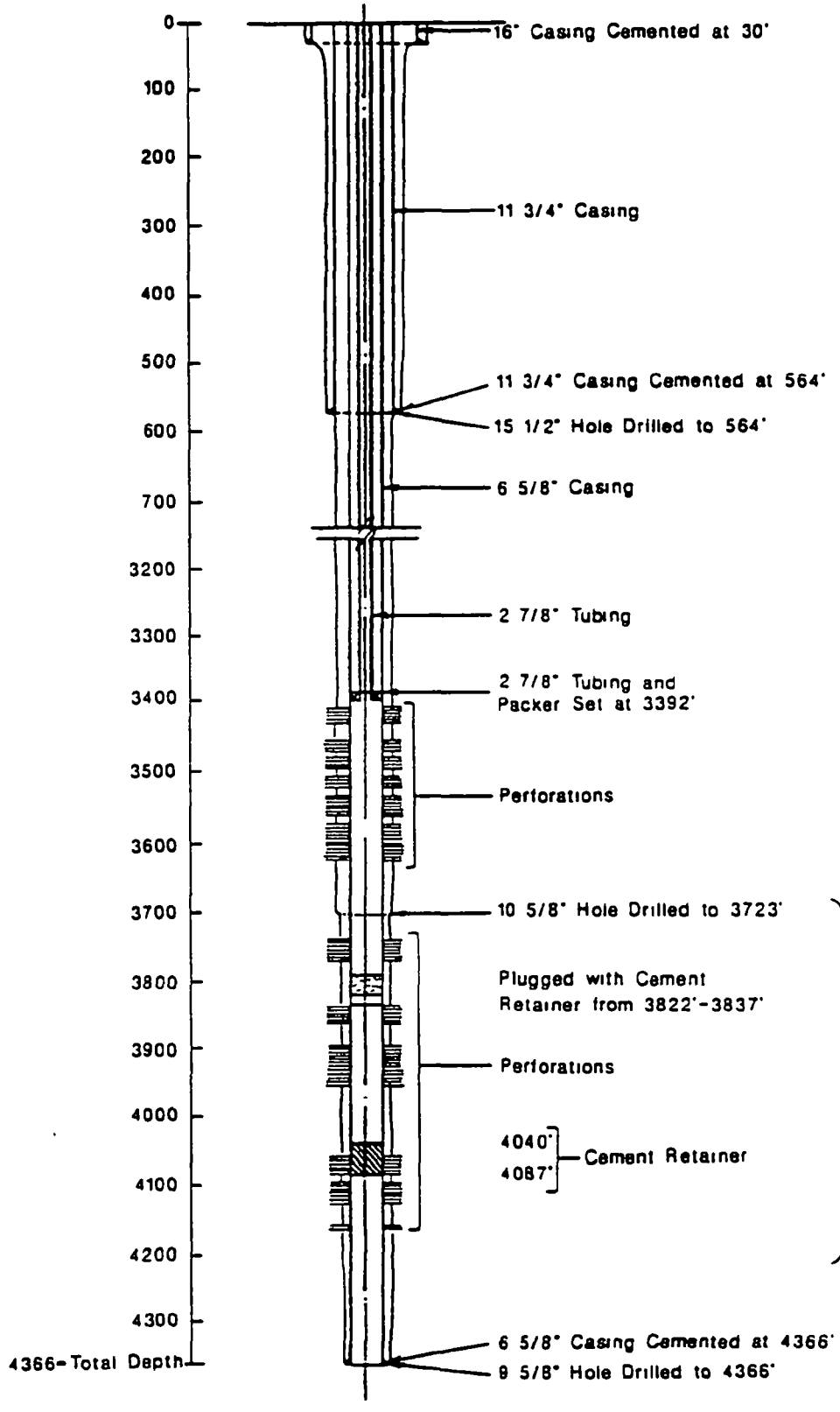
Construction, Siting, and Operation

Construction

A typical construction design for a refinery waste disposal well is presented in Figure V-52. Note that this well was originally productive of oil, but has been cemented back and recompleted as an injection well. This is true of all three refinery waste disposal wells inventoried for California.

The example presented in Figure V-52 displays 16-inch conductor casing cemented from surface to a depth sufficient to prevent hole caving during continued drilling. Also hung from the surface, 11-3/4-inch surface casing is used to protect shallow fresh water from drilling fluids. This string of casing is generally cemented back to the surface. Inside the surface casing, 6-5/8-inch injection casing is hung from the surface to total depth and cemented in place. The actual size and depth of various casing strings used, as well as depth of cement, varies from well to well. In general, casing programs of all refinery waste wells are similar to that presented in Figure V-52.

Injection wells of this type usually contain injection tubing and packers. Injection is into the formation through perforations rather than slotted liner. Cement plugs inside the injection casing prevent injection through the lower perfs. The



TYPICAL WELL CONSTRUCTION
FOR A REFINERY
WASTE DISPOSAL WELL

ENGINEERING ENTERPRISES, INC.

609.012.06 Figure V-52

overall design is to permit selective injection of relatively large volumes of waste fluid into one or several injection zones.

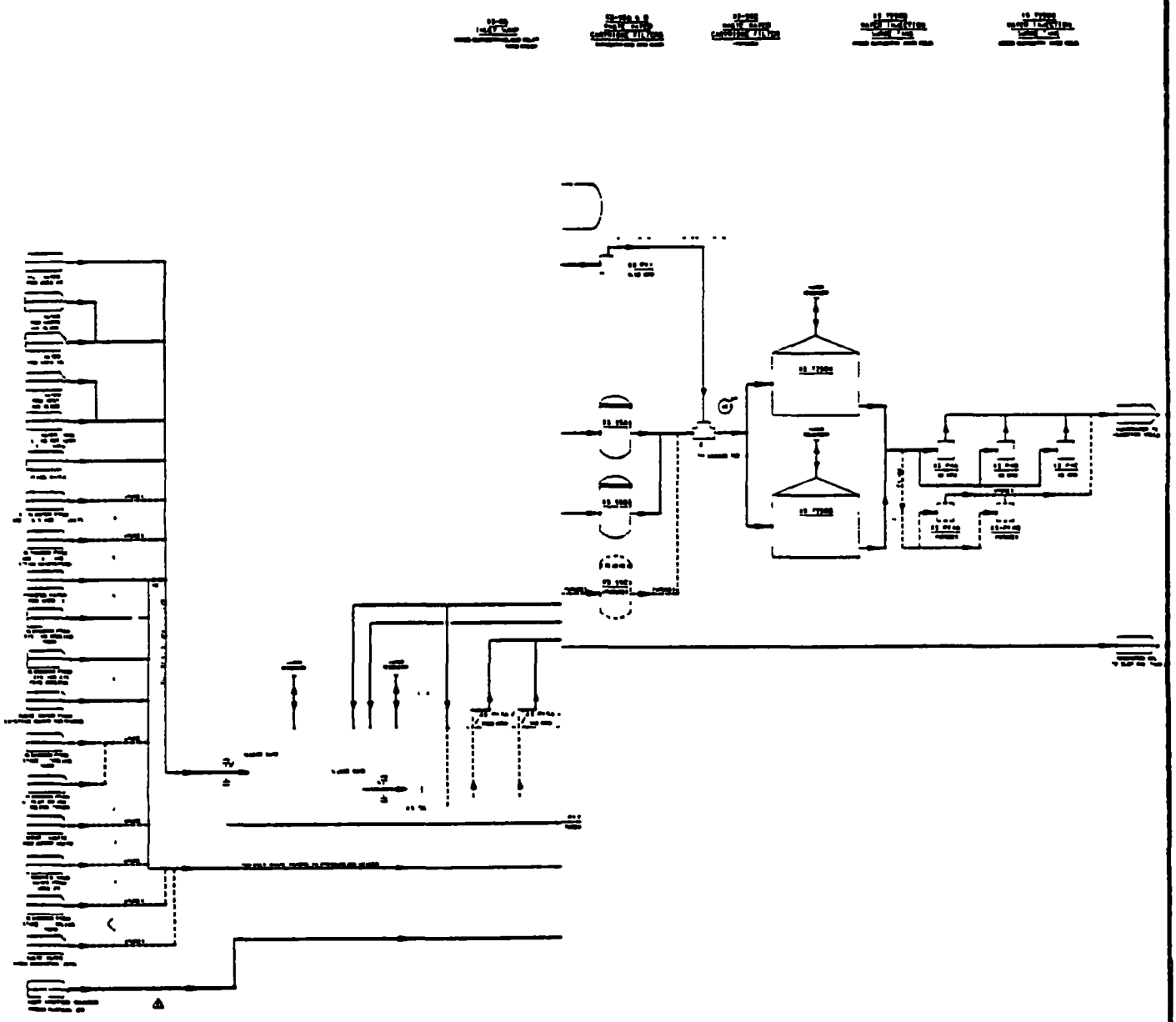
Wellhead assemblies and injection pump systems for these facilities are identical to other "hi-tech" Class V facilities studied in California. Injection pressures and volumes are typically monitored at the wellhead via pressure and flow meters. A typical refinery schematic is presented in Figure V-53 to illustrate the variety of sources that contribute to a refinery waste stream.

Siting

File investigations and inquiries conducted by the authors did not conclusively reveal a strategy for siting refinery waste injection wells. It is known that the Bakersfield wells were oil producers prior to conversion. Hence, their siting was made with respect to recovery rather than injection.

The injection wells at the Texaco Bakersfield Refinery are centrally located within the facility. These wells were converted to injectors after they became economically non-productive, and were never idle between production and conversion to injection status. It is believed these wells were converted as an economic measure preferable to drilling new injection wells.

The well history of the Thompson #2, JMT Oil Company's injector at Newhall is not totally clear. Apparently, this well was converted to injection status in 1982 to replace the Thompson



GENERALIZED SCHEMATIC OF A REFINERY SHOWING WASTE STREAM SOURCES

(Courtesy TEXACO,U.S.A.)

Figure V-53

#1, which had been used previously to dispose of the Newhall Refinery waste water. The Thompson #1 was originally a marginal producer at the down-dip limit of the Placerita Field. It is not known if the Thompson #2 was a producer prior to conversion, or dry and abandoned. It is known, however, that the well was not drilled and completed specifically for injection purposes.

Both case studies reflect that the conversion of pre-existing wells to injectors is preferable to drilling and completing new wells from an economic standpoint. As such, the strategy in siting the wells becomes one of finding adequate reservoir rocks, using existing well log and production data. An advantage to this approach is that reservoir parameters such as permeability and volume can be better understood from production history than from any other variable. The major disadvantage to this strategy is that less- than-optimum sites may be chosen as injection sites solely because a well already exists that can be used. It has not been concluded that this is the case at either Bakersfield or Newhall.

Operation

At the Texaco Bakersfield Refinery, the two injection wells operate continually, and as much as 50 million gallons of fluid can be injected annually per well. Flow rates and injection pressures are monitored continually at each well using circular recording charts. Mechanical integrity is demonstrated annually. A typical suite of MIT's consists of radioactive tracer, temperature, and spinner surveys. The purpose of these surveys

is to detect leaks in the casing or channeling of fluids through cement, both of which can contribute to the degradation of USDW's.

Referring back to Figure V-53, it will be noted that there are several sources of waste water within a refinery. All waters are combined and filtered prior to being piped into surge tanks. From the surge tanks, the waste stream enters the pump system, where it is distributed to the injection wells.

JMT Oil Company's well in Newhall is not part of the Newhall Refinery, but is the only known facility disposing of the refinery's waste by injection. The injection well is approximately one mile from the refinery, and all waste water injected has been transported to the site by JMT tank trucks. As a result, injection is intermittent, but average annual injection volume exceeds 30 million gallons.

Less is known about this facility, as it was not part of the original UIC inventory for Region 9. Most information regarding the operation of this injection well was obtained during an on-site investigation. It was learned that mechanical integrity tests are conducted annually, and generally consists of radioactive tracer and spinner surveys.

One aspect of the operation that may need further investigation is the use of dilute acids (KCl or HCl) to "acidize" the perforations. The goal of this procedure is to keep the perfs clean and unobstructed by adding the acid to

refinery waste as it is injected. According to the operator, up to 1,000 gallons of acid are used at one time. It can be assumed that the acid is further diluted to some degree by mixing with injectate, but this has not been quantified by the operator.

Character of Injected Fluids

Refinery wastes are the most diverse of all Class V injection fluids. This variation is due primarily to the many types of petrochemicals refined at these facilities, and the diverse chemical processes associated with refining. Secondary contributors are laboratory wastes, sewage from on-site facilities and excess produced water in some cases. As a result, a myriad of organic and inorganic constituents are potential elements of injected refinery wastes.

Injectate chemical analyses submitted by operators indicate that a variety of purgeable (volatile), acid, and base/neutral organics are present. Many of these constituents are classified by EPA as priority pollutants. In addition, a number of metals and other inorganic constituents are present due in part to contributions from processes unassociated with refining. Because of the potentially hazardous nature of this waste stream, the authors feel this type of well should be closely scrutinized.

Analysis of fluids from the Newhall Refinery is conducted by the refinery rather than the injection well operator. Analytical data submitted indicates that Primary Drinking Water Standards are being exceeded for cadmium, lead, mercury and selenium levels. Secondary standards for pH, TDS, chloride and fluoride

are also shown to be exceeded. Several priority pollutants, including dichloroethane, toluene, ethyl benzene, benzene and xylene were found to be present in levels near or above drinking water action levels established by the California Department of Health Services (DHS).

Similar analyses were provided by Texaco for the waste stream at the Bakersfield Refinery. Reported levels of chromium, lead, and selenium were found to exceed Primary Drinking Water Standards. TDS and iron levels exceed Secondary Drinking Water Standards and manganese was equal to the maximum secondary level. Priority pollutants present in amounts exceeding the DHS action levels include acrolein, acrylonitrile, benzene, dimethyl phenol, ethylbenzene, fluorene, napthene, phenol, toluene, trichloroethane, and xylene.

Because refining processes vary with time, it cannot be assumed that the analyses submitted represent a typical, or time-averaged characterization of the waste stream. It may be that other constituents are present at other times, or that some present in the analyses are typically not present. Any future analyses and subsequent legal or remedial action should address these possibilities.

Injection Zone Interactions

General

Two types of injectate-injection zone interactions are of concern in the Underground Injection Control Program. These are:

1. How will injection affect the ability of the rock media to accept fluids at the desired rates and pressures?

2. How will the injection fluid change the water quality of naturally-occurring fluids within the injection zone?

The first consideration is important in addressing the methods to be used in monitoring injection operations. In addition, type and frequency of mechanical integrity testing that are necessary will be dependent upon this consideration. Communication between the injection zone and other USDW's due to packer failures, formation fracturing and other casing or tubing failures could occur as a result of decreased injectivity.

The second point addresses potential degradation of USDW's resulting from injection of refinery wastes. This is a particularly complex problem when considering the extreme variety of chemical constituents found within refinery waste streams.

Effects on Injectivity

Injectivity can be decreased primarily by two phenomena. The first is the development of filter cake buildup at the borehole due to high suspended solids. This is perceived to be a relatively minor consideration with refinery wastes in that fluids pass through a complex filtering system prior to injection. As a result, most chemical constituents present within the refinery waste stream after filtering are dissolved in solution.

A second consideration, one that is more applicable in this case, is pore plugging due to precipitation of solids as the injectate moves through the rock media. It is known that concentrations of sulfate and calcium ions are elevated in refinery waste streams, primarily due to the introduction of excess produced water and other chemical by-products of refining into the waste stream. These ions readily combine to form calcium sulfate. Empirical data suggest this molecule is actually less soluble at higher temperatures (Nancollas and Gill, 1978; Vetter and Kandarpa, 1982). Because refinery wastes are held in storage tanks for indeterminate time periods prior to injection, it can be assumed that injectate is at or near ambient temperature when injected. Low temperature injectate that contacts higher temperature injection zone fluids should result in precipitation of calcium sulfate. The degree to which this occurs, and the influence it has upon pore plugging, will be site-specific and has not been empirically determined for either refinery waste disposal system studied.

A variety of reactions of this type can occur owing to changes in parameters such as temperature, pH and ion concentration. Ion concentrations and pH are particularly variable in refinery waste streams, and reactions causing precipitation of solids due to these parameters are extremely difficult to predict. Experiments using core samples demonstrate the greatest promise of predicting such reactions (Owens et al, 1978; Michels, 1983; Arnold, 1984). Pilot scale injectivity

testing should be conducted for each facility to enhance this predictability.

Effects on Injection Zone Water Quality

The influence of refinery waste on the quality of water within a USDW is unclear due to the extreme variety of constituents found in those wastes. It is known that injection at both inventoried facilities is into a zone productive of oil within the area. Water within both zones has been shown to be of USDW quality. Volumetrically, a large part of the waste streams is excess water produced with oil. The injection of this fluid will presumably affect the formation water, of roughly similar quality, very little.

TDS levels reported for samples of injectate at the Bakersfield facility average 1,350 mg/l, with maximum reported levels of 2,769 mg/l. This is approximately the same level for TDS found within the Fairhaven and Etchegoin zones, into which the refinery waste is injected. Because major ion composition is expected to be negligibly influenced by fluid-fluid and rock-fluid interactions, TDS levels of this magnitude can be considered as non-reactive parameters, and not a contributor to USDW pollution (Freeze and Cherry, 1979; Summers et al, 1980).

Analyses submitted for TDS levels in waste water from the Newhall Refinery show values as high as 6,000 mg/l. This is roughly 30 percent higher than average values found within the injection zones, the Lower Kraft and Modelo formations. Unless

the injectate is sufficiently diluted within the reservoir through natural recharge, it can be assumed that TDS levels within the reservoir will rise with continued injection. The quantitative influence of such rock-fluid and fluid-fluid interactions upon USDW pollution has not been defined, and deserves further analytical study.

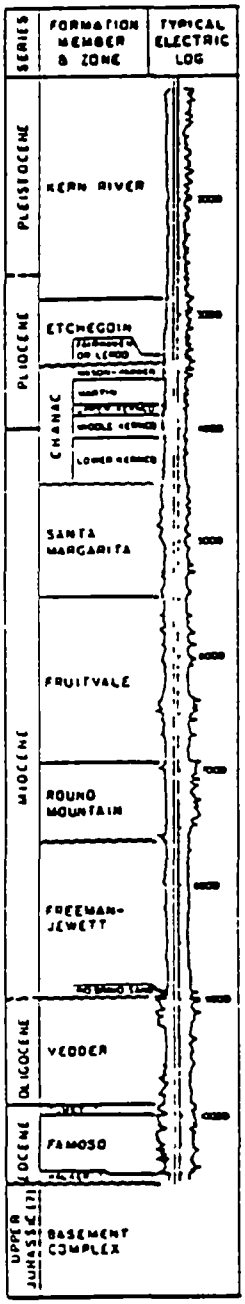
The influence of minor or trace elements and organic constituents (volatile, base/neutral, and acidic) is the area of major concern in assessing contamination potential of refinery waste injection. Fluid-fluid and rock-fluid interactions involving these constituents are adsorption-desorption, acid-base, solution-precipitation, oxidation-reduction, and ion pairing-complexation (Driscoll, 1986). Thermodynamic principles and chemical equilibria can be applied to dilute solutions at near earth surface conditions to estimate ion concentrations resulting from the above interactions. Experimental procedures like this should be conducted constituent by constituent on a site-specific basis to determine the role of each constituent in degrading USDW's. To date, research of this kind has not been found by the authors.

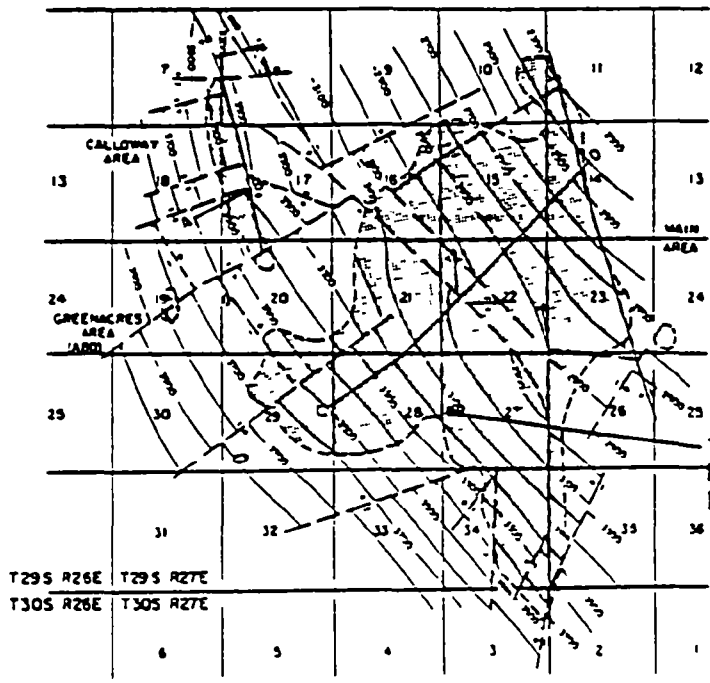
Hydrogeology and Water Use

Fruitvale Field-Kern County

The injection wells at Texaco's Bakersfield Refinery are located in Section 27, Township 29 South, Range 27 East (Figure V-54). This area is part of the Fruitvale oilfield, and is also located within the city limits of Bakersfield. This field is located within the Kern River groundwater storage unit (Davis et

FRUITVALE OIL FIELD





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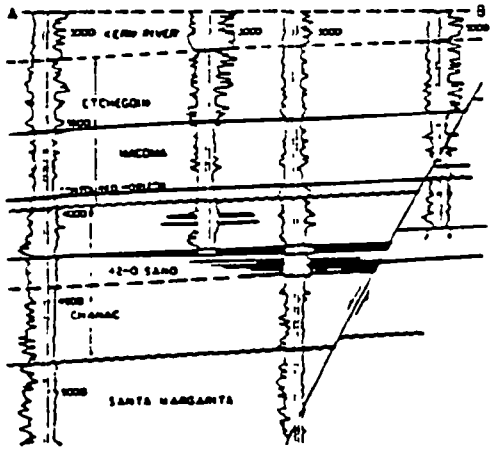

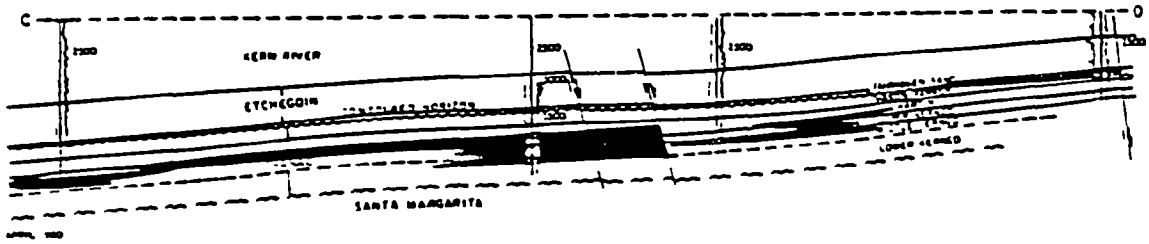

FRUITVALE FIELD: CONFIGURATION, REPRESENTATIVE CROSS SECTION, AND STRATIGRAPHIC COLUMN

(from CDOG Publication TR12, 1982)

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V-54

al, 1959) and is part of the San Joaquin Valley groundwater basin (DWR Bulletin 118). This is part of the "East Side" of Kern County, along with the Mount Poso, Poso Creek, and Kern River Fields discussed previously in the "Air Scrubber and Water Softener Regeneration Brine Disposal Wells" section.

The San Joaquin Valley is a broad late Mesozoic structural down-warp resting between the prominent Sierra Nevada and California Coast Ranges. The southern end of the valley, where the Fruitvale Field is located, represents a transition between structural styles of the two ranges (Davis et al, 1964). The resultant asymmetric valley floor slopes gently westward, and deposition onto the surface has been continual from Cretaceous time (late Mesozoic) to the present.

Valley margins consist of dissected uplands underlain by unconsolidated and consolidated sediments of continental origin. These slightly to moderately deformed sediments are of late Tertiary to Quaternary age (Davis et al, 1964). Low, relatively featureless alluvial plains border the dissected uplands along the east side of the valley. These typically clean, well-sorted gravels and sands are present as the result of perennial streams draining the Sierra. The lateral continuity of these deposits depicts a continually-shifting system of depositional centers.

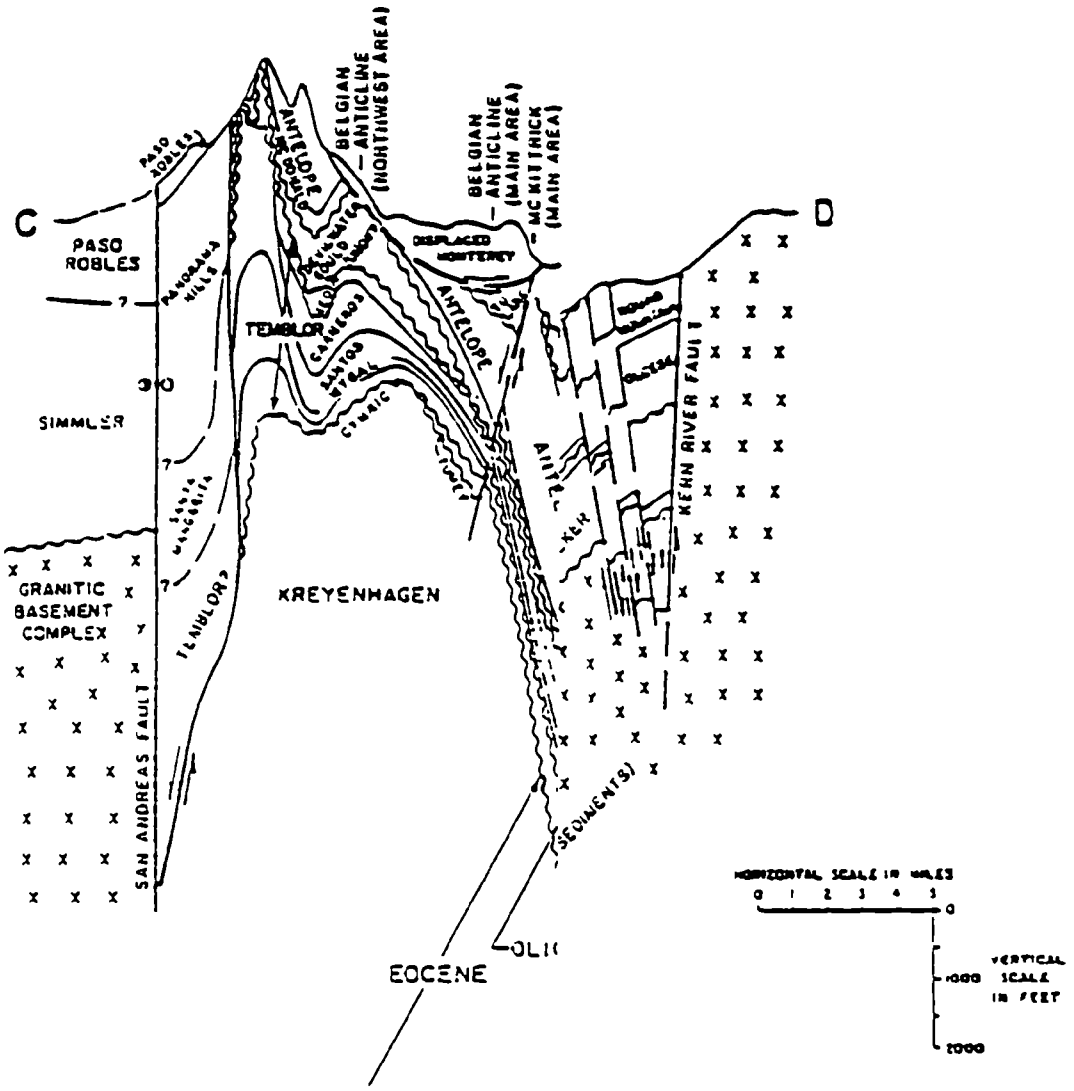
River flood plains and channels dissect the alluvial plains in areas along the Kern River within the valley trough. Because the valley has been poorly drained throughout much of its history, fluvial deposits are interfingered with extensive fine-

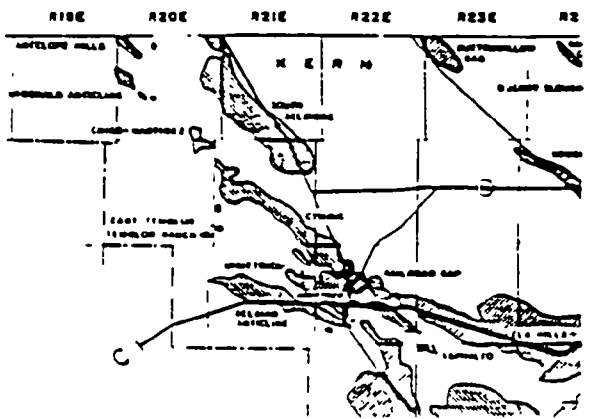
grained lake and swamp deposits along the east side. The most widespread lacustrine conditions occurred during Pliocene time, when the Corcoran Clay was deposited in thicknesses of up to 150 feet on the west side. The unit is generally absent in the area under consideration.

Total thickness of Tertiary and younger sediments in this portion of the San Joaquin Valley approaches 28,000 feet, as inferred from numerous seismic surveys. A generalized cross-section, oriented roughly east-west across the Valley, is presented in Figure V-55.

The southern San Joaquin Valley is characterized by an arid to semi-arid climate, with average annual rainfall slightly less than 5 inches (Rector, 1983). Because of such low rainfall, it is doubtful that any significant recharge to groundwater occurs due to that source.

Infiltration of water from stream channels, excess irrigation and unlined irrigation canals is believed to be the major source of groundwater recharge (Davis et al, 1964). On the east side, contribution to groundwater recharge by the Kern River can exceed 600,000 acre-feet in a year (Kern County Water Agency, 1982). In non-agricultural areas the chief source of groundwater recharge is due to seepage loss from intermittent streams draining the adjacent foothills. Estimates for recharge by this source to the south end of the east side average about 2,500 acre-feet/year (Rector, 1983).





GENERALIZED CROSS SECTION
SOUTHERN SAN JOAQUIN VALLEY
(from CDOG Publications TR12, 1982)

Figure V-55

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Under natural conditions, groundwater moves through confined and unconfined aquifers from recharge areas along the valley margins toward topographic lows in the central valley (Davis et al, 1964). Confined groundwater in the central valley moves generally northward along the trough axis. Flow of groundwater in the vicinity of the Fruitvale field, then, is generally west and north. As much as 200,000 acre-feet of groundwater moves into the Kern County portion of the basin annually (Kern County Water Agency, 1986). This actually tends to degrade the relatively fresh water of the east side due to influx of highly saline marine connate water from the west side.

Unconsolidated to semi-consolidated sediments of alluvial origin are the primary source of groundwater in Kern County (Davis et al, 1959). In general, these sediments are highly permeable relative to the consolidated basin margin rocks, which behave as barriers to groundwater movement.

Three distinct groundwater bodies have been identified for this portion of the San Joaquin Valley (Davis et al, 1959). Unconfined and semiconfined conditions exist in alluvial deposits that overlie the Corcoran Clay. Water within this zone is relatively fresh. Beneath the Corcoran Clay, a confined fresh water zone is present in the alluvial and lacustrine deposits of Plio-Pleistocene age. Much of the east side is not underlain by the Corcoran Clay. In these areas, the previously described zones constitute a single semi- and unconfined fresh water aquifer. The third groundwater body identified in this area is a

saline connate water of marine origin in mid-Pliocene and older sediments. This body underlies fresh water throughout the valley.

Most of the connate water found in the semi-consolidated and consolidated pre-Tulare deposits have TDS levels about 10,000 mg/l. Locally, these waters may be of USDW quality, but in general are considered to be a source of groundwater contamination to the uppermost confined fresh water aquifers (Rector, 1983). Groundwater found within the confined alluvial aquifer, and the semi- and unconfined aquifers above the Corcoran is generally USDW-quality, with notable local exceptions.

Because little to no outflow of groundwater occurs within Kern County, it can be assumed that the general groundwater quality within the basin is being degraded. New salts are imported with groundwater recharge supplies every year. Based upon this assumption, groundwater pumped for irrigation will become degraded as salts leach from crop root zones (Kern County Water Agency, 1986).

The primary use of water in Kern County is for irrigation purposes. In 1985, over 95 percent of the total water use in Kern County was for this purpose (3,178,700 acre-feet) (Kern County Water Agency, 1986). Municipal and industrial usage totaled 131,400 acre-feet. Groundwater extractions from Kern County aquifers for these purposes totalled 1,293,800 acre-feet (40 percent of total usage). The remaining water used was derived from the Kern River, State Water Project, and Central

Valley Project. Referring back to Figure V-33, it will be noted that as of a 1979 survey, no water wells existed in the immediate area of the Fruitvale Field. Because refining and oil production have continued since that time, it is assumed no new water wells have been drilled.

Field configuration, representative cross-sections and generalized stratigraphic column for the Fruitvale Field are presented in Figure V-54. Injection of refinery waste from the Texaco facilities is into the lower Etchegoin and Fairhaven formations. Note that in the region of the refinery (southwest portion of cross-section C-D), these units are not productive of oil. TDS levels for these zones, as reported by the operator, range from 3,000-6,000 mg/l. As such, both zones qualify as USDW's. The operator also reported TDS levels averaging 1,350 mg/l for injectate samples, with a maximum of nearly 3,000 mg/l.

If the above data is accurate, it can be concluded that injection will not adversely affect TDS levels within the injection zones. However, aquifer degradation can occur without an increase in TDS. This is probably occurring within the Etchegoin and Fairhaven Formations in the form of increased concentration of volatile, base/neutral and acid organic constituents from the refinery waste stream. It is relatively safe to assume these constituents do not occur naturally within those formations.

[6-434]

Shallow log data has not been obtained for the area in and around the Texaco facility, so the exact lithologic nature of the injection zones and surrounding formations is not clear. However, regional knowledge reflects that the overlying Kern River Formation is a thick sequence of alluvial sands and gravels interfingered with fine-grained lake sediments. Because the Corcoran Clay is absent throughout much of this area, it is concluded that alluvial sediments dominate, and lacustrine deposits are secondary. It follows that much of the Kern River Formation overlying the injection zones will display the relatively high permeability associated with clean alluvial sediments. The conclusion is that confinement above the injection zones has not been demonstrated.

Because of the lack of well log data, similar reasoning must be employed to delineate possible confinement below the injection zones. It is known that the lower limit of the Fairhaven is an erosional unconformity. This means that the underlying Mason-Parker sand (Upper Chanac) was exposed to surface conditions for an indeterminate period of time. One result of such exposure, under certain conditions, is the development of secondary overgrowths on sand grains due to diagenesis. This could reduce porosity and perhaps permeability within the sand unit as it was buried. While this reasoning does not conclusively demonstrate that low permeability rocks underlie the injection zones, a case can be made suggesting confinement occurs beneath the injection USDW's.

[6-435]

Placerita Field - Los Angeles County

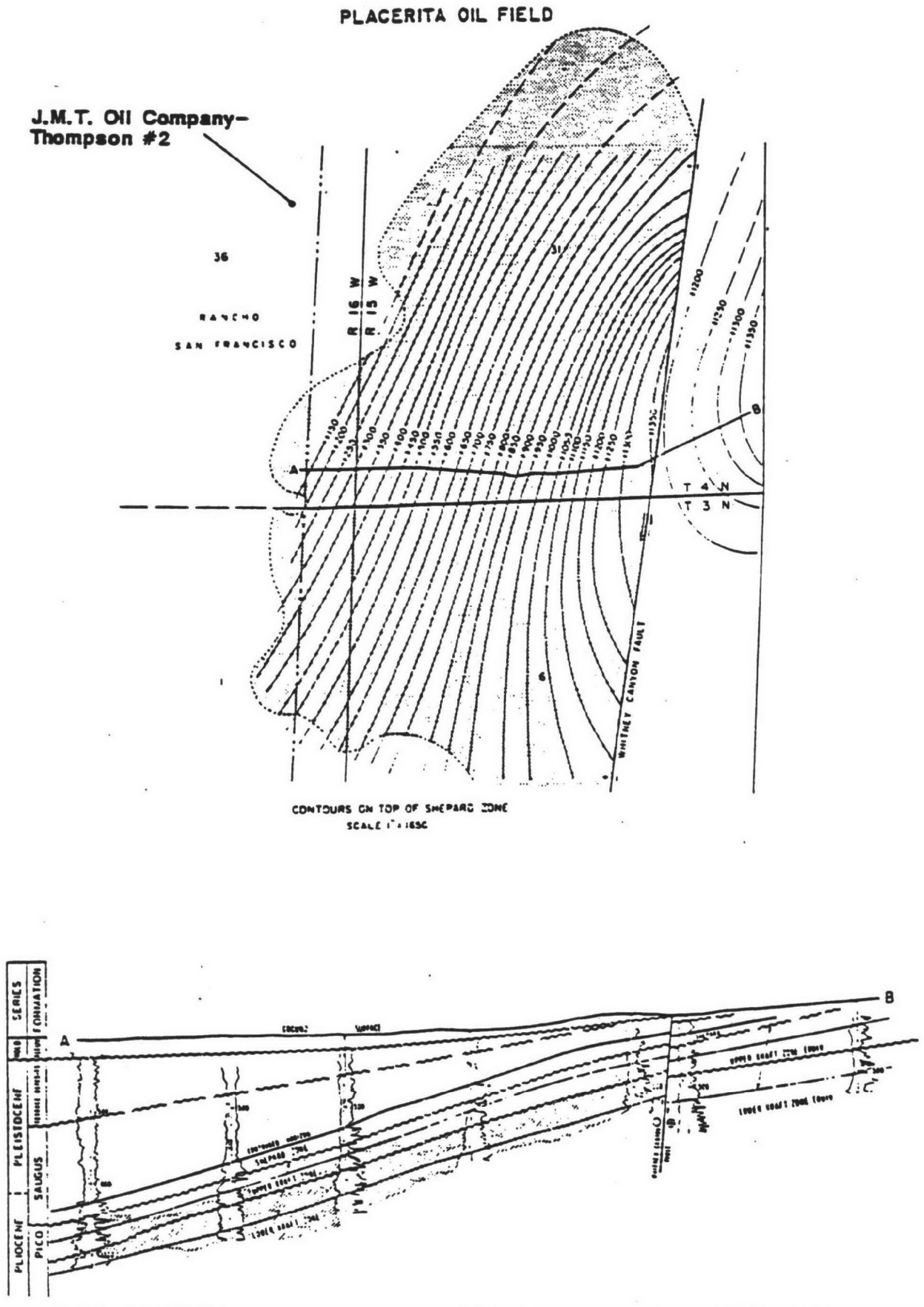
The JMT disposal facility is located at the eastern edge of the Placerita Field, in the south-central Transverse Ranges physiographic province. This area is near the headwaters of the Santa Clara River, and is part of the Santa Clara River Valley groundwater basin (DWR Bulletin 118). A map of Placerita Field, with representative cross-section and generalized stratigraphic column, is presented in Figure V-56.

Structurally, this region represents an interruption of the generally northwest-southeast fabric of the Coast Ranges. The east-west orientation of the range in this region, called the Transverse Ranges, is presumed to be related to the Murray Fracture Zone, traceable up to 1,800 miles westward into the Pacific Ocean (King, 1976).

Locally, the Placerita Field represents a break in structural styles. To the west, folding dominates the structural pattern, though minor faulting is evident. East of the area, high angle reverse faulting dominates, with the northern blocks typically upthrown. Both faulting and folding are late-Pleistocene or younger, as evidenced by the extensive section of folded Pleistocene sediments (Sharp, 1972).

The Transverse Ranges terminate abruptly a few miles east of the study area, owing to the presence of the San Andreas Fault. This presently active structural feature continually affects the geology of coastal and south-central California. In the vicinity of the Placerita Field, the Whitney Canyon Fault appears to be

[6-436]



PLACERITA FIELD: CONFIGURATION, REPRESENTATIVE CROSS SECTION, AND STRATIGRAPHIC COLUMN

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Figure V-56

a manifestation of the San Andreas Fault (Figure V-56). This feature provides a structural trap to hydrocarbon and water migration eastward.

The western Transverse Ranges are characterized by predominantly sedimentary rocks, whereas the eastern part is primarily igneous and metamorphic rocks. In general, the Santa Clara River Valley is characterized by enormous thicknesses (20,000 feet +) of mid- to late-Tertiary sediments overlain by a thin veneer of recent alluvium. The stratigraphy is extremely variable, representative of complex Tertiary and Quaternary structural activity along the continental margin. In general, pre-Pleistocene rocks are marine in origin, representing a variety of depositional environments, from abyssal to near shore shallow depths. Equal variation is noted for the Pleistocene continental sediments.

The study area is a typical semi-arid region, characterized by relatively low annual precipitation (10-15 inches). Presumably very little of this precipitation reaches the groundwater of this 336-square mile drainage basin, as the base of fresh water (less than 2,500 mg/l TDS) is reported as the ground surface (DWR, Bulletin 118). In the study area, subsurface flow of groundwater appears to be generally westward into the Santa Clara Valley drainage basin, though some southward flow into the Los Angeles Basin in anticipated.

As discussed, the lithologies present within the area vary widely, but it is believed USDW-quality water is present

[6-438]

throughout the section. The principal aquifer in use at the present time is recent valley fill alluvium. This unit varies locally, but is typically coarse to medium grained, poorly consolidated sand interfingered with clay lenses of fluvial origin.

Water quality of the alluvial aquifer is generally poor, and locally is extremely poor. In many areas, magnesium, sulfate, chloride, nitrate and TDS levels are too high for domestic use. In others, TDS, chloride and boron levels are excessive for irrigation purposes (DWR Bulletin 118). In the area immediately west of the study area, failing septic systems have degraded water quality to unusable levels. Overdraft and seawater intrusion are contributing to growing water availability problems in the Santa Clara Valley.

Because of these continuing water quality problems, most water used for domestic and agricultural purposes is derived from aqueducts of the Northern California Water Project. The nearest public water supply wells are three NCWD wells located 1-2/3 to 2 miles west of the facility in Sections 34 and 35, Township 4 North, Range 16 West. It is believed these wells are completed in the recent alluvium, but the actual use for this water is not known.

Injection of refinery waste water at the JMT facility is into the Lower Kraft and Modelo formations. The Kraft sands are productive of oil in the Placerita Field, and produced water from these zones is shown to be of USDW-quality (CDOG Publication

TR12). TDS levels for the Lower Kraft are reported as about 2,000 mg/l. Water quality for the Modelo, non-productive of oil in the region, has not been ascertained.

As discussed previously, water quality data for injectate was provided by the Newhall Refinery rather than the injection well operator. The most recent analysis was conducted in May, 1986, and was performed following the methods outlined in the California Assessment Manual (Title 22) for hazardous wastes and EPA manuals for solid and liquid wastes.

Results reported for this analysis indicate that the refinery waste water has TDS levels of around 6,000 mg/l. This is about three times the level reported for naturally-occurring formation water within the Lower Kraft. As expected, constituents associated with petrochemical refining such as oil and grease, ammonia, phenols, and sulfide are present in levels up to 100 mg/l. A variety of other organic compounds are present in trace amounts.

With respect to drinking water standards, cadmium, lead, mercury, and selenium present in the waste stream exceed Primary Standards. Fluoride, chloride, pH, and TDS levels exceed Secondary Drinking Water Standards. Constituents present in the waste stream found on EPA's Priority Pollutants list include dichloroethane, toluene, benzene, xylene and ethylbenzene.

Both the Kraft and Modelo sands are well developed clean sands with abundant interbedded shales, as determined from well

log data. Because of the depths injection occurs, it is believed waste water will tend to migrate up-dip (eastward) toward the Whitney Canyon Fault Zone. It can be concluded that migration toward the NCWD wells previously described will be minimal.

Total injection at the JMT facility averages more than 30 million gallons (100 acre-feet) per year, as reported by the operator. It is not known what volumes of recharge occur within the aquifers as a result of natural and artificial methods. It is believed that it is minimal, due to low rainfall and limited irrigation. If so, it can be concluded that the aquifers are being degraded to some degree by injection of refinery waste.

Summary of Contamination Potential

Three refinery waste injection wells have been located and investigated in California. Average injection into each of these wells is 40 - 50 million gallons (122-154 acre-feet) annually. Injection volumes this large, combined with a variety of organic and inorganic constituents within the waste stream, make these wells capable of broad-scale contamination to USDW's.

It has been shown that injection at both refinery waste facilities is into multiple zones. At least one of these zones at each facility is a USDW located above the uppermost oil-bearing horizon. At the Texaco Bakersfield Refinery, this zone is the Etchegoin-Fairhaven sequence. Water chemistry analyses reported by the operator for these zones indicates TDS levels of formation waters average 3,000-3,500 mg/l. At the JMT facility in Newhall, one of the injection zones is the Modelo Formation. This zone is

situated below the oil-bearing zones of the nearby Placerita Field.

In the opinion of the authors, both of these zones are potentially useable USDW's. The Etchegoin-Fairhaven sequence in the Bakersfield area is relatively shallow. Water chemistry indicates that sodium and chloride comprise up to 75 percent of the total dissolved solids within the formation fluid. Bicarbonate is the other major constituent. This is generally consistent with water chemistry data available for the Modelo Formation of the Placerita Field. Because of the general absence of organics associated with crude petroleum, treatment of these waters by desalination could make them potential drinking water supplies.

It has been shown that injection fluids at both facilities exceed certain National Primary and Secondary Drinking Water Standards. Typical Primary Standards exceeded include cadmium, chromium, lead, mercury and selenium. Secondary standards are exceeded for TDS, pH, iron, chloride and fluoride. Similarly a number of constituents present in refinery waste streams are found in 40 CFR Part 261, Subparts C and D. These constituents include dichloroethane, toluene, ethyl benzene, benzene, xylene, napthene, phenol and fluorene.

As discussed, injection volumes at refinery waste disposal facilities are typically very large. Similarly, concentrations of potentially hazardous constituents are high. Without direct

knowledge of how these USDW's attenuate the various constituents found in waste streams, it is difficult to assert that the USDW's are being degraded beyond Primary and Secondary drinking water standards. However, it is safe to assume that levels of substances found in 40 CFR, Part 261, Subparts C and D are increasing as a result of refinery waste injection.

In summary, it has been demonstrated that certain zones used for injection of refinery wastes in California are USDW's. The claim is made that these aquifers are of sufficient quality to be considered realistically usable as a drinking water supply, should significant advances in treatment technology be made. Fluids being injected are shown to contain constituents in excess of certain National Primary and Secondary Drinking Water Standards. Certain hazardous wastes, as defined in 40 CFR, Part 261, Subparts C and D, are present within the injectate. Because these substances have not been shown to exist naturally within the injection USDW's, it is concluded that levels of these wastes are increasing to some degree within the injection zones. Based upon these findings, it is concluded that injection of refinery wastes in California constitutes a high potential for contamination of existing USDW's serving as injection zones.

Regulatory Jurisdiction

Hazardous waste and waste discharge into injection wells in California has been subject to rules set out in the State Health and Safety Code, and the State Water Code. Assembly Bill Number 2058 (1985) has amended these codes to exempt injection wells

regulated by the California Division of Oil and Gas (CDOG) from the provisions set forth.

At the present time, regulatory responsibility for refinery waste injection wells is shared to some degree between two agencies. CDOG is apparently the lead agency in issuing permits and maintaining regulatory control over these wells. However, the Regional Water Quality Control Boards (RWQCB) in areas injecting refinery wastes are also actively involved in regulating this practice. While the present investigation has concluded these agencies work very well together, the discrepancy over primary responsibility has resulted in one problem of relatively minor significance. Operators appear unclear as to which agency should be initially contacted regarding permit application for refinery waste injection. The operators of these wells inventoried to date have made these initial applications to RWQCB.

The State Water Code previously mentioned has been established under the Porter-Cologne Water Quality Control Act (1985). While wells regulated by CDOG are technically exempted from these provisions, it is those provisions that are addressed in permits issued by both CDOG and RWQCB. Under California statutes, injected refinery wastes are considered hazardous substances, and agency requirements have become stringent.

Application for a permit to inject refinery waste involves the submittal of a comprehensive hydrogeological report. Area of review for this report varies with local geologic and water use conditions, but a minimum one-half mile radius is set forth in

the statutes. Parameters to be addressed in these reviews include injection zone character (lithology, permeability, dimensions, vertical and lateral confinement), regional groundwater flow rates and directions, and water quality of injected wastes and injection zone fluids.

Engineering and operational considerations in permit applications include drilling and completion details (casing, cement, tubing, and packer programs), formational testing, proposed injection volumes and pressures, and programs for future mechanical integrity testing. Frequencies for conducting MIT's are set forth, as well as the types of tests employed. Frequency for reporting injectate water chemistry is addressed, but is not specifically defined.

After permits are granted, and injection wells are completed or converted, operators have the option to inject at pressures prescribed by CDOG or conduct step-rate tests in an effort to establish a basis for higher injection pressures. Mechanical integrity tests are required annually, Typical tests for this purpose are spinner and radioactive tracer surveys, designed to determine at what point in the wellbore fluids are exiting the casing. Temperature surveys and injectivity tests are also prospective MIT's, but are not used typically for injection wells of this type.

Injection fluid water quality analyses are submitted annually, as a rule. Substances classified as hazardous by EPA

are analyzed for. In addition, a variety of organic constituents (volatiles, acid, and base/neutral) are tested for, as well as inorganics and metals. Physical properties of pH, specific conductivity, color, corrosivity and ignitability are reported. In general, the analyses reported by operators to RWQCB and CDOG are complete and adequately depict the waste stream.

Enforcement of regulations set forth in the Water Code, as well as remedial action and penalization, is a shared responsibility between CDOG and RWQCB. To date, a case involving penalization of a refinery waste facility has not occurred. As a result, this investigation has not revealed which agency would take the lead in such activity.

Aside from CDOG and RWQCB, two other agencies are involved to a lesser degree in permit review of some type. The Los Angeles County Public Works Department has issued a waste discharge permit to JMT Oil Company for disposal of the Newhall Refinery waste. The exact details of the permit were not ascertained, but conversation with the operator indicated these permit regulations are essentially the same as Water Code provisions.

The Department of Health Services is also involved in regulating injection operations of JMT and Texaco. This agency reviews hydrologic assessment reports (HAR's) submitted by the operator. The HAR's cover material similar to that described above for RWQCB and DOG submittals. Emphasis is placed upon water quality of injectate and formation waters in granting these permits.

[6-446]

Recommendations

Remedial or Corrective Action

It has been found that operators of refinery waste injection wells in California generally maintain operations in a professional and responsible manner. Waste stream analyses are submitted regularly, and annual mechanical integrity tests demonstrate that injection is into the desired zone or zones. In addition, operators have been extremely cooperative with the investigators during the data gathering phase of this assessment.

A large proportion of the fluids injected at each facility is into USDW's not productive of oil, although all wells are located at or near the margins of active oil fields. Both oil fields are characterized by multiple productive zones. The down-dip margins of each oil zone may be adequate injection zones for refinery wastes. The possibility of recompleting the presently used refinery waste injection wells in oil-bearing zones only (instead of USDW's) should be investigated. The oil zones may have adequate disposal capacity, but waste disposal into these zones may have other negative impacts on oil production.

A system of groundwater monitoring should be instituted immediately. Because many abandoned oil wells exist in both fields, two or three down-gradient wells should be re-completed for use as injection zone monitoring wells. This would result in an initial expense to operators, but the transmissibilities of certain waste stream constituents must be determined to

[6-447]

accurately define contamination potential posed by these Class V wells.

Best Regulatory Approach

One conclusion of this study is that both CDOG and RWQCB are conscientious in their regulatory control over refinery waste facilities. However, this duality in regulatory control has the potential for inherent inefficiency in corrective or remedial action, should such action become necessary. Because refinery activities are only indirectly related to petroleum production and enhanced recovery, it is the opinion of the authors that CDOG should play a secondary role to RWQCB in regulating these wells.

Injection into USDW's of relatively good quality, which occurs at both facilities, should be terminated immediately. Consideration should be given to injection into oil bearing zones, which the authors consider to be unusable as drinking water supplies, regardless of TDS levels. One possible regulatory approach would be to exempt oil-bearing USDW's, similar to regulatory jurisdiction involved with Class II wells.

It is the conclusion of this study that unless an oil-bearing zone can be used for injection, or some other non-treatable USDW can be found, refinery waste disposal should not be conducted using Class V wells. The nature of the waste stream, and volumes typically injected, indicate that Class I injection should be employed. Regulatory authorities should begin to move toward this goal.

[6-448]

A final point of concern is the lack of inventory data available for refinery waste injection wells. The authors feel that there are certainly more wells of this type in California, and it is essential that they be found and characterized with respect to injection volumes and chemistry. RWQCB and CDOG should immediately pool their resources, and question each refinery operator in California to determine the fate of their waste stream.

Air Conditioning Return Flow Wells (5A7)

Purpose

A heat pump is a temperature-conditioning device which transfers heat or thermal energy from one medium to another. An example of a heat pump familiar to everyone is an air-to-air heat pump or "air conditioner" which heats or cools by using air both as a heat source and a heat-receiving medium (heat sink). A groundwater heat pump may use groundwater as a heat source or heat sink. Groundwater temperatures remain very constant relative to the great variability of air temperatures in homes and buildings imposed by climatic conditions. A groundwater heat pump can be an effective air temperature-conditioning device whenever a significant differential exists between groundwater temperature and ambient air temperature in the space to be "conditioned". Water is an ideal medium for use in heat pumps because of all ordinary substances water has the greatest specific heat. Thus it can both absorb and yield much more heat in calories per degree change in the temperature of the medium than does an equal weight of air (Texas DWR, 1984).

[6-449]

Section 6.2.28

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	From Reporting on Class V Injection Well Inventory and Assessment in California (Draft)
AUTHOR: **(or INVESTIGATOR)**	Engineering Enterprises, Inc. (Prepared for USEPA Region IX)
DATE:	December, 1986
STUDY AREA NAME AND LOCATION:	California
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	Three tables contain information concerning industrial Class V wells in California. Information includes facility name, county, number of wells and status, description of wells, waste, and contamination potential.

TABLE

CLASS V DEEP[a] INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS (INACTIVE)	DESCRIPTION OF WELLS	TYPES OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
1. E.I. DuPont DeNemours[b]	Contra Costa	1	Injection well, approx. 6800' in depth, began operation in 1969, was capped and closed in 1982.	Wastes assoc. w/production of tetraethyl lead, comprised mostly of hydrocarbons which are gaseous at surface conditions, and partially liquified at well formation.	Various methods of waste disposal, incl. surface impoundments. Groundwater is contaminated w/chloroform, monofluoroethane, 1,2-dichloroethane, trichloroethane, chloroethane, and toluene. Site also contaminated with lead, >2000 ppm.
2. Rio Bravo Disposal Facility[b]	Kern	1	Deep well injection into old depleted oil well (Mary Anderson #1), 11,400' in depth. 1500-2000' of 3" steel transmission line xing under Hwy 43 from storage facility. Est. max. injection 420,000 gal/day.	Hazardous & non-hazardous, toxic, ignitable, corrosive wastes. Believed well began accepting spent solvents & pesticide rinse waters in May, 1984. WDR limits the 30 day avg discharge to 210,000 gal/day.	Groundwater contamination - unknown. Facility closed by DOHS 1/28/85 due to alleged violation of ISD permit. Groundwater is not being monitored.
3. Tosco Refinery - Now Texaco[b]	Kern	2	2 injection wells. Facility now closed.	Wastes associated with refinery. Facility claims that wastes were non-hazardous.	Injecting directly into an aquifer. Facility has recently been reclassified from Class IV to Class V.
4. Wheeler Well #5[b]	Los Angeles	1	Disposal well, improperly abandoned, under Operating Industries Landfill. Approx. 2000' deep.	Oil field brines & possibly hazardous wastes. Possible liquid hazardous wastes from landfill operation seeped into disposal well.	Operating Industries Landfill is #74 on State Superfund List. Shallow groundwater is being monitored in connection with Landfill.

(a) At least 100 ft below land surface
(b) (Toxic Assessment Group, 1985).

TABLE ___, continued
CLASS V DEEP[a] INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPES OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
5. Aerojet-General Corporation[b]	Sacramento	2			2 disposal wells, approx. 1600 ft. deep. Estim. with both wells in operation, 579,000 pounds of hazardous wastes are injected each year.	Toluene, Trichlorotrinitrobenzene, Diphenyl Oxide, Chloroform, Sodium arsenate, Ethylene dichloride, Formaldehyde, Misc. organics, still bottoms, Non-hazardous wastes also injected.	Groundwater contam. is due to chemicals other than those now injected at site. Well #1 operated 1962-68, 1975-1984. Inject well #2 began 1978. AGC makes explosives, fungicides, compounds used in manufac. of solid rocket propellants.
6. Beale Air Force Base[b]	Yuba	3			3 disposal wells, each approx. 1000' deep & in service since 1967.	Photographic wastes, incl. cyanide, silver, and bromine.	Groundwater contamination - unknown. Groundwater found at 75 feet.
7. Getty Refinery[b]	Kern	2			2 injection wells. No MDR.	Wastes associated with refinery. Facility claims that wastes are	Injecting directly into an aquifer. Facility has recently been reclassified from Class IV to Class V.
8. Texaco Bakersfield Refinery	Kern		2		Both wells previously oil producers; converted to injection status in 1977; total depths approx. 4400 feet.	Process wastewater from petroleum refinery; variety of inorganic & inorganic constituents (volatile, acid & base/neutral organics, also disposing of excess produced water from on-site production wells.	Average annual injection: 50 million gallons/well. Groundwater contamination unknown; injection into non oil-bearing shallow horizons.
9. JMT Oil Company	Los Angeles		1		Well completed in 1982 for disposal of waste from nearby Newhall Refinery. Total depth: 3600.	Typical refinery waste stream, including varied inorganic constituents (TDS approx. 5600 mg/l). Volatile, acid and base/ neutral organic fraction very high.	Groundwater contamination unknown; average annual injection: 35-40 million gallons; injection into & below shallowest oil-bearing zone.

(a) At least 100 ft below land surface
(b) (Toxic Assessment Group, 1985).

TABLE
CLASS V SHALLOW INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
1. Puregro-Bakersfield Facility	Kern		1		One well and concrete paved work pad. Consisted of 2 buried concrete chambers connected in series. Overflow pipe connected to 2nd chamber was cut several feet from disposal well. Temporarily abandoned.	Rinse water runoff and spillage of agriculture chemicals during material transfers.	Soil in immediate area of disposal well contaminated. No monitoring wells to water table completed on site. CVRWQCB currently reviewing PureGro's draft remedial action plan.
2. Kearney-KPF	San Joaquin		1		One uncased well constructed in 1972 to 22 feet below land surface. Backfilled with porcelain from foundary on site. Temporarily abandoned.	Drainage waters from silver plating process.	Soils below disposal well and drainage ponds are contaminated. Groundwater contamination is not established. CVRWQCB recently requested that additional groundwater sampling be performed. Groundwater appr. 35' below land surface.
3. Mefford Field	Tulare		2		-One two-baffled sump. Formerly connected to a disposal well. Temporarily abandoned. -Second sump measuring 2 ft. square by 4 ft. deep connected to disposal well. Temporarily abandoned.	Two-baffle sump and disposal well formerly disposed of rinse waters used to clean pesticide application planes. Second sump disposed of oils, solvents, and greases.	Water contamination detected in on site monitoring wells. Contamination has not been detected in water supply wells on or downgradient of the airfield. Groundwater 17-20' below land surface.
4. TIAH	Fresno		10		9 wells ranging in construction from endless 55 gallon drum to brick lined cisterns. Depths ranged from approximately 2 to 20 feet below land surface. 1 leachfield suspected of disposing of industrial and septic wastes.	Waste laboratory chemicals (chloroform) and various pesticides handled on site.	Groundwater contamination documented. Contamination resulted from negligent handling practices, an on-site landfill, and disposal well operations. Groundwater 15-25' below land surface.

(a) (Toxic Assessment Group, 1985).
(b) Unknown number.
(c) "Dry wells" which may or may not penetrate groundwater bearing strata.
(d) City of L.A. Bureau of Sanitation.

TABLE III, continued
CLASS V SHALLOW[c] INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
5. Rogers Helicopter	Fresno			1	1 well, 30 feet deep.	Biodegradable paint stripper.	Groundwater contamination unknown.
6. Upright	Fresno		1,1		One well has been converted to an industrial drainage well. Second well is temporarily abandoned.	Washwater from steam cleaning operation.	Sample from one former industrial well contained Dichloroethene, Trichloroethane above state action levels. CVRWQCB has requested Upright Harvesters to conduct a geotechnical investigation.
7. Columbia Showcase and Cabinet Company[d]	Los Angeles	2			Septic tank disposal well. Wells have been pumped out as ordered by L.A. Bureau of Sanitation.	Industrial wastes suspected to have been disposed with sewage.	Toluene Xylene detected in septic tank effluent. Groundwater contamination in San Fernando Valley suspected to have resulted from past operation of industrially owned septic tank systems.
8. Medal Tire Company, Inc.[d]	Los Angeles	1			Septic tank disposal well. Wells have been pumped out as ordered by L.A. Bureau of Sanitation.	Industrial wastes suspected to have been disposed with sewage.	Toluene detected in septic tank effluent. Groundwater contamination in San Fernando Valley suspected to have resulted from past operation of industrially owned septic tank systems.
9. Chapman Studio Equipment Company[d]	Los Angeles	1			Septic tank disposal well. Wells have been pumped out as ordered by L.A. Bureau of Sanitation.	Industrial wastes suspected to have been disposed with sewage.	Methylchloride, Tricloroethane, Parachloroethene, Trichlorethene detected in septic tank effluent. Groundwater contamination in San Fernando Valley suspected to have been caused by operation of industrially owned septic tank systems.

(a) (Toxic Assessment Group, 1985).
(b) Unknown number.
(c) "Dry wells" which may or may not penetrate groundwater bearing strata.
(d) City of L.A. Bureau of Sanitation.

TABLE [illegible], continued
CLASS V SHALLOW INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
10. McKenzie's Automotive[d]	Los Angeles	2			Septic tank disposal well. Wells have been pumped out as ordered by L.A. Bureau of Sanitation.	Industrial wastes suspected to have been disposed with sewage.	1,2-Dichlorobenzene detected in septic tank effluent. Groundwater contamination in San Fernando Valley suspected to have been caused by past operation of industrially owned septic tank systems.
11. R&R Four Slide Corp.[d]	Los Angeles	1			Septic tank disposal well. Wells have been pumped out as ordered by L.A. Bureau of Sanitation.	Industrial wastes suspected to have been disposed with sewage.	Xylene, Dichloroethene detected in septic tank effluent. Groundwater contamination in San Fernando Valley suspected to have been caused by past operation of industrially owned septic tank systems.
12. Remo, Inc.[d]	Los Angeles	1			Septic Tank disposal well. Wells have been pumped out as ordered by L.A. Bureau of Sanitation.	Industrial wastes suspected to have been disposed with sewage.	Trichloroethene, Toluene, Dichlorobenzene detected in septic tank effluent. Groundwater contamination suspected to have been caused by past operation of industrially owned septic tank systems.
13. Electro Coatings[a]	Alameda		1		Shallow well disposal. Operations began in 1963. From 1964-1965 disposal of chromic acid plating wastes into on-site shallow well.	Hydrochloric acid, sulfuric acid, copper sulfate, chromic acid, nickle sulfate. (Approx. 117,000 gal. of chromic wastes at 10,000 ppm are unaccountable.)	Identified abandoned site. State Superfund, 1985 ranked 177, 1984 ranked 90, 1983 ranked 59, 1982 1982 ranked 40.
14. Dow Chemical USA[a]	Fresno	2	9		11 dry wells in total, 9 of which are in bottom of ponds, sealed and never used. Remaining 2 wells receive wastes. Each well is approx. 10 feet deep.	Wash down from steam cleaning area and boiler blowdown.	Facility manufactures plastic film and bags. Groundwater contamination-unknown.

(a) (Toxic Assessment Group, 1985).
(b) Unknown number.
(c) "Dry wells" which may or may not penetrate groundwater bearing strata.
(d) City of L.A. Bureau of Sanitation.

TABLE III, continued
CLASS V SHALLOW[c] INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
15. Kearney Agricultural Field Station[a] (research station)	Fresno	b			Dry wells and seepage pits used to dispose of wastes.	Lab wastewaters and shop washdowns. Exact composition is unknown.	The facility pits and dry wells are still active though may no longer be be disposing of lab wastes in this manner. Groundwater contamination is unknown.
16. T.M.T. Chemical Company[a]	Fresno		1		Dry well, now abandoned, used to dispose of wastes since 1968. No longer in use.	Lab wastes, incl. sulfuric, hydrochloric, and nitric acids; sodium and ammonium hydroxides, and other reagents.	Ag. chemicals stored and formulated at the site. Groundwater contamination unknown.
17. A-1 Battery[a]	Kern		1		Disposal hole in asphalt and down metal pipe of unknown depth. No longer in use.	Wastewaters generated in process of charging and cleaning batteries. Lead Lead contamination between 130mg/kg to 6000mg/kg.	Company has been requested to clean up contaminated soil. Unknown if groundwater is contaminated.
18. Crop Management[a]	Kern			1	Dry well used to dispose of wastes.	Pesticide field rinsewaters from ground appplicator service.	Groundwater contamination-unknown.
19. Farm Flite Agricultural[a]	Kern	2			Exterior of planes and other equipment are rinsed off on wash pad and then discharged to two dry wells.	Pesticide rinsewaters.	Aerial application of ag chemicals. Groundwater contamination-unknown. Site was previously occupied by Lost Hills Flying Service for 5 years prior to Farm Flite Service, and possibly also utilized the dry wells.
20. Valley Helicopter[a]	Kern	1			Dry well connected to washpad.	Pesticide rinsewaters.	Company performs aerial application of pesticides. Groundwater contamination-unknown.

(a) (Toxic Assessment Group, 1985).
(b) Unknown number.
(c) "Dry wells" which may or may not penetrate groundwater bearing strata.
(d) City of L.A. Bureau of Sanitation.

TABLE III, continued
CLASS V SHALLOW[c] INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
21. Acton Site[a]	Los Angeles			1	Dry well, approximately 10' deep, used to dispose of waste waters over an unspecified period of time.	Wastewaters containing mercury.	Groundwater contamination-unknown. Identified as a result of citizen's complaint, 2/9/85, L.A. County.
22. BKK Landfill[a]	Los Angeles		b		Bore hole injection. Holes were approximately 80' deep into prism of trash within the Class I disposal area. Practice was halted in 1982.	Acids and other various chemical wastes.	Landfill ceased accepting liquid hazardous and non-hazardous wastes on 11/30/84. The landfill is ranked 56 on 1985 State Superfund List.
23. Basin By-Product[a]	Los Angeles		1		One injection well, approximately 40' deep, was in operation from 1964-1977.	Oil field waste, dilute acids and caustics, including hexavalent chromium. Est. quantity of wastes during years of operation, 504 million gal.	Groundwater contam-unknown. No groundwater monitoring. Aquifer is 75' deep. Large local pop. Site ranked 78 on 1985 State Superfund List.
24. Jones Chemical[a]	Los Angeles	1			Dry well, 5' in diameter, 34' deep, bricklined. Well has been utilized since 1969.	Neutralized wastes, incl. chlorides, sulfates, phosphates, nitrates, flourides, and ammonia derived from rinsing containers containing acids and alkalies.	Groundwater contamination is unknown. Though DOHS files indicate that RWQCB (LA) was notified of this site 4/12/82, RWQCB has no info on the facility.
25. Moen Foam Company (AKA Chemical Contour Co, Automation Industries, Pacific Urethane)[a]	Los Angeles		1		Past usage of 20' deep well for acid solution containment.	Wide variety of chemicals and compounds, including sulfuric, chromic, hydrochloric acids, and aluminum, titanium, magnesium, and thorium.	Groundwater contamination-unknown. Entire site has been paved over.

(a) (Toxic Assessment Group, 1985).
(b) Unknown number.
(c) "Dry wells" which may or may not penetrate groundwater bearing strata.
(d) City of L.A. Bureau of Sanitation.

TABLE ___, continued
CLASS V SHALLOW INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
26. Pacific Ocean Disposal Company[a]	Los Angeles		2		Two shallow disposal wells, 6' in diameter, 30' deep, used from 1963-1976. Now sealed.	Various acid wastes, incl. chromic, sulfuric, hydrochloric, nitric acids. Approx. 19 million gals. of wastes disposed of during their operation.	Groundwater not monitored, contamination unknown.
27. Baltimore Aircoil Company of California[a]	Madera		1		Dry well used for wastes from 1976-1981.	Chevron water solution oil. Approx. 110 gallons per year.	Groundwater contamination-unknown. Unconfined aquifer at 30'.
29. EIMAC-Division of Varian Associates[a]	San Mateo			2	Dry well used to dispose of wastes.	Approx. 600 gals. of various solvents. Monitoring well #3, located at dry well, shows various compounds, incl. Benzene (6ppb), Tetrachloroethene (280ppb), and Trichloroethene (12ppb).	Groundwater is contaminated, and is being monitored.
30. General Electric [a]	Santa Barbara		b		Dry wells used to dispose of wastes via transmission lines from buildings.	From 1974-80, approx. 600 gals. of 1,1,1-Trichloroethane was discharged into dry wells.	Groundwater contamination possible, no current investigations or remedial actions underway, though company has done some soil sampling. Company overhauls aircraft engines. Site is ranked 91 on the 1985 State Superfund List.
31. Fox Tool and Die Company[a]	Stanislaus			1	Dry well.	Cutting oil and water mixture.	Groundwater contamination-unknown.
32. Lyng Company[a]	Stanislaus	1			Dry well.	Rinsewaters from bean treating of captan fungicide is disposed of in dry well (10-15 gals. per rinse).	Groundwater contamination-unknown.

(a) (Toxic Assessment Group, 1985).
(b) Unknown number.
(c) "Dry wells" which may or may not penetrate groundwater bearing strata.
(d) City of L.A. Bureau of Sanitation.

TABLE ___, continued
CLASS V SHALLOW[c] INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
33. BASF Wyandotte Corporation[a]	Tulare	1			Exact description unavailable. Final rinse waters to "subsurface disposal." Believed to be dry well.	Pesticide container rinsewater.	Groundwater contamination-unknown.
34. CAN Chemical[a]	Tulare		1		Dry well, approx. 42' deep, used to dispose of wastes.	Insecticide and defoliant production rinsewaters, incl. organophosphates, organochlorides, carbamates, organic metals, dinitrophenols, petroleum oils, tetrahydrophalamide, sulfur, sodium chlorides.	CAN manufactured and formulated insecticides and defoliants. Site has been identified by DOIS as an Identified Abandoned Site. Site. Groundwater contamination-unknown.
35. J.R. Simplot/ Oxychem[a]	Tulare		1		Dry well connected to wash pad, no longer in use.	Pesticide rinsewaters. Though initial sampling of dry well and wash pad revealed significant concentrations of DDT, Toxaphene, Kelthane, and DDE, later sampling showed no detectable levels.	Oxychem stores and sells packaged pesticides and operated herbicide spray rig. Groundwater contamination unknown.
36. Porterville Municipal Airport[a]	Tulare		1		15' x 15' cobbled pit of unknown depth used to dispose of wastes from rinsing off of equipment.	Possibly pesticides.	CVRWQCB (Fresno) requested that the well be removed. Unknown if any testing occurred to determine if contamination existed at the site.
37. Puregro Company-Pixley[a]	Tulare		1		Dry well, approx. 35' deep, connected to wash pad.	Pesticide rinsewaters.	Ag. chem. storage and application. Groundwater contamination unknown. At this location since 1966, Puregro proposes to seal off the opening of their closeddrywell with concrete or bentonite as suggested by CVRWQCB.

(a) (Toxic Assessment Group, 1985).
(b) Unknown number.
(c) "Dry wells" which may or may not penetrate groundwater bearing strata.
(d) City of L.A. Bureau of Sanitation.

TABLE [illegible], continued
CLASS V SUBTYPE INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
38. Lawrence Livermore Lab. Site 300	San Joaquin		13,1		14 dry wells, rock filled, connected to various buildings by drain lines. Wells no longer in use. Methods of closure are unclear. All but one well are permanently abandoned.	Photo Rinsewaters; paint rinsewaters; acid dip rinsewaters; wastes associated with automotive cleaning	LLL Site 300 facility is a D.O.E. Class II-1 disposal site. Groundwater is contaminated with TCE.
39. BMC Corporation	Tulare		4		Unknown	Unknown	Unknown
40. Puregro Company Leaf Life Division	Tulare		1		Unknown	Unknown	Unknown
41. Support Terminal Services, Inc.	Imperial		1		1 well constructed of precast concrete. Well was 12' long.	Received water from oil/water separator.	Groundwater contamination-unknown.
42. Lawrence Livermore-Livermore	Alameda		2		Temporarily abandoned dry wells.	Unknown.	Groundwater contamination unknown.
43. American Box Division	Fresno	3			Dry wells.	Two wells receive air compressor condensate and dessicant brine. One well receives continuous boiler blowdown from steam generation.	Groundwater contamination-unknown.
44. Biological Science Research Center	Stanislaus	6			Unknown.	Unknown.	Unknown.
45. Southern Pacific Transport Company	Sacramento		2		Operated until February of 1986. Injected for appr. 30 years.	Unknown.	Groundwater contamination-unknown. Study pending.

(a) (Toxic Assessment Group, 1985).
(b) Unknown number.
(c) "Dry wells" which may or may not penetrate groundwater bearing strata.
(d) City of L.A. Bureau of Sanitation.

TABLE __, continued
CLASS V SHALLOW INDUSTRIAL WASTE DISPOSAL WELLS

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
16. Lilly Labs	Fresno		2		Both dry wells are 4 ft. in by 20 ft. deep. Both drywells abandoned in 1969.	Waters from a chemical wash pad and chemical storage room sink.	Groundwater contamination-unknown. CVRWQCB has requested a proposal for a soils and groundwater investigation at the site from Lilly Labs.
47. FMC	Fresno		b		Some extend to 30 feet below land surface.	Sanitary and laundry wastes.	Pesticide contamination. Other disposal areas on site. Additional construction of monitoring wells is planned.

(a) (Toxic Assessment Group, 1985).
(b) Unknown number.
(c) "Dry wells" which may or may not penetrate groundwater bearing strata.
(d) City of L.A. Bureau of Sanitation.

TABLE ___
CLASS V INDUSTRIAL WASTE DISPOSAL WELLS OF UNKNOWN DEPTH[b]

FACILITY	COUNTY	STATUS			DESCRIPTION OF WELLS	TYPE OF WASTE DISPOSED IN WELLS	GROUNDWATER CONTAMINATION OR ADDITIONAL INFORMATION
		ACTIVE	INACTIVE	UNKNOWN			
1. Lyco Chemical	Kern		a		Liquid wastes, incl. runoff, disposed in several holes, 3-4' in diameter, drilled ground, of unknown depth. Operated early 1950s to early 1970s.	Parathion; Malathion; Hydrochloric, Sulphuric acids. Amount of wastes generated is unknown.	Groundwater contamination - unknown, but domestic wells within 1000' of site; depth of unconfined aquifer 320-340'. Lyco made rust remover, repacked parathion & malathion. State Superfund List ranked 153 in 1985, 67 in 1984.
2. Mather Air Force Base	Sacramento		1		Disposal hole with removable cap, 10" in diameter, unknown depth. Disposal hole used 1958-1966, for various wastes. Exact location of disposal hole is unknown except for general area.	TCE; transformer oil possibly containing PCB's; waste engine oils; Carbon Carbon tetrachloride; Antifreeze. Est 1,350 gals of transformer oil disposed of in this well.	Groundwater is contaminated. TCE in AC&W water well, & also this disposal hole is suspected source of the TCE in family housing wells at the airforce base. Site is candidate for EPA National Priorities List.
3. Chatham Brothers	San Diego		1		Water well used to dispose of volatile organic compounds.	Volatile organic compounds, incl. TCE, 1,1-Dichloroethane; 1,1-Dichloroethane 1,1,1-Trichloroethane.	Groundwater contamination in wells adjacent to resident areas. Aquifers at great depth may be threatened. Wastes poured down one well seeped into on/off site wells. State Superfund ranked 67 in 1985, 49 in 1984, 16 in 1983.

(a) unknown number
(b) (Toxics Assessment Group, 1985)

Section 6.3

Gasoline Service Station Disposal Wells Supporting Data

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	"Subsurface Injection of Service Bay Wastewater is a Potential Threat to Groundwater Quality," From Proceedings, International Symposium on Class V Injection Well Technology, Sponsored by UIPC.
AUTHOR: **(or INVESTIGATOR)**	Basavaraj "Raj" Mahadevaiah and Lorraine C. Council, Engineering Enterprises, Inc.
DATE:	September, 1987
STUDY AREA NAME AND LOCATION:	Long Island, New York USEPA Region II
NATURE OF BUSINESS:	Automobile Service Stations
BRIEF SUMMARY/NOTES:	Fluid and sediment samples of Service Bay Wastewater (SBW) were collected from catch basins and disposal wells at eight automobile service stations in Nassau and Suffolk Counties, New York. Analytical results of the SBW samples indicated the presence of several USEPA Priority Pollutants that exceeded New York State water quality limits. The preliminary results have led to a conclusion that the subsurface injection of SBW poses a continued threat to groundwater quality of the upper glacial aquifer on Long Island, New York.

SUBSURFACE INJECTION OF SERVICE BAY WASTEWATER IS A POTENTIAL THREAT TO GROUNDWATER QUALITY

by

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This paper has not been subjected to review and comment by the USEPA and, therefore, does not necessarily reflect the views and policies of the agency. No official endorsement should be inferred. Also, mention of trade names or commercial products does not constitute endorsement or recommendations for use.

ABSTRACT

As a result of its potential to contaminate groundwater, injection of service bay wastewater (SBW) to the shallow subsurface is now being extensively investigated by many regulatory agencies. The USEPA Region II and Engineering

Enterprises, Inc. recently performed one such investigation to assess the impact of SBW injection in Long Island, New York.

In the first phase of the investigation, liquid and sediment samples of SBW were collected from catch basins and disposal wells at eight automobile service stations in Nassau and Suffolk Counties. Analytical results of the SBW samples indicated the presence of many USEPA Priority Pollutants that were highly in excess of New York State water quality limits. Based on the preliminary findings a more detailed investigation, Phase II, is now under consideration, where additional SBW samples will be collected and further characterized.

The preliminary results and other findings have led to a conclusion that the subsurface injection of SBW poses a continued threat to the groundwater quality of the underlying upper glacial aquifer in Long Island, New York. A nationwide survey conducted by the USEPA indicated the presence of this Class V injection well type in at least 16 states in the U.S. The injection of SBW to the subsurface is, therefore, a potential threat to human health and the environment in many parts of the country.

INTRODUCTION

Injection of wastewater into the shallow subsurface through Class V disposal wells, is currently being examined by some regulatory agencies. Of the many Class V waste sources, one type of wastewater is comprised of waste antifreeze fluids, waste petroleum products (oil, grease, etc.), floor washings (including detergents, sediments, etc.), and miscellaneous wastes which originate from service bays at gas stations and auto dealerships. This type of wastewater will be called Service Bay Wastewater (SBW) in the following discussion. SBW typically is disposed of by three general methods: discharge to sanitary sewers, discharge to the subsurface by injection, and disposal by other methods such as storage or hauling of waste to an off-site disposal or recycling facility.

Engineering Enterprises, Inc. (EEI) in Norman, Oklahoma was retained as a contractor by USEPA to provide technical assistance to the Underground Injection Control (UIC) program. In a work assignment for Region II, EEI conducted sampling and analysis of SBW at automobile stations in Nassau and Suffolk Counties, New York. This paper presents the findings of this preliminary investigation including recommendations for further detailed analysis of the problem.

Also included in this paper is a brief discussion on the current inventory of automobile service station disposal wells on a nationwide basis and recommendations for inventory building efforts, regulatory considerations, and necessary remedial

actions. The national information was obtained while EEI was assisting USEPA Office of Drinking Water (headquarters) compile the "Report to Congress, Class V Injection Wells" (USEPA, 1987, draft under preparation) under another related work assignment. Several State reports were reviewed and collated to prepare the Report to Congress.

WELL CONSTRUCTION AND OPERATION

SBW originates from service bays at automobile service stations and auto dealerships. During our investigation in Long Island, New York it was discovered that SBW is disposed by numerous techniques as illustrated in the Flow Chart, Figure 1.

The effluent originating from service bays at many of the sites EEI investigated passed through a pretreatment system before being discharged into a disposal well. Such pretreatment systems include grease pits, oil water separators, or catch basins. Figure 2 is an illustration of a catch basin sampled in New York.

The SBW is then disposed by three general methods: discharge to sanitary sewer, discharge to the subsurface by injection, and disposal by other methods such as storage and hauling of the waste to an off-site disposal or recycling facility.

A great number of automobile service stations in Long Island, New York have been in existence for many years, when there was no sanitary sewering in the area. Sanitary sewering is now being undertaken in Nassau County and some parts of Suffolk

County in Long Island, New York. Also, many service stations have not resorted to storage and hauling of SBW to an off-site disposal or recycling facility.

As a result of these investigations, it was found that the injection of SBW to the subsurface was most popular at many facilities. One method of waste injection involves discharge of wastewater through disposal wells or dry wells which exclusively receive wastewater from service bay drains. For the purpose of identification in the following sections, these wells will be called single purpose wells. The other method of injection involves discharge of SBW through cesspools, septic tank systems, or storm water drainage wells. These discharge systems will be called multi-purpose systems as they receive wastes both from service bay drains and sewage or storm water runoff. In the cases where SBW is disposed through septic tank systems, the waste may ultimately be discharged to the subsurface through cesspools, dry or disposal wells, drainfields or other disposal methods. Hence, SBW may be injected to the subsurface through any of the above mentioned disposal devices, all of which are regulated under the UIC regulations.

As discussed before, wastewater from service bays may be discharged through single purpose or multipurpose wells. Construction of multipurpose wells is similar to the construction of septic tank systems or storm water drainage wells. Single purpose wells designed to discharge only service bay wastewater and some multipurpose wells are typically completed at shallow

depths using standard precast cesspool rings as illustrated in Figure 3. At some sites, depending on the volume of waste discharged and the geology, a series of standby wells may also be constructed. Injection of SBW is not continuous and the entire injection operation takes place by simple gravity flow from the service bay to the end point (discharge to the subsurface).

FIELD INVESTIGATIONS AND SAMPLING TECHNIQUES

PROCEDURES

In September 1986, EEI conducted inital inspections of the sample points at selected automobile service stations to ensure safety and site accessibility and notified the owners of the sampling program. The wellhead at each site was tested for the lower flammable limit, oxygen level, hydrogen sulfide concentration and trace gas levels. Although the site posed no significant respiratory or contact safety concerns, EEI opted to use disposable safety gloves (Silver Shield) during sampling to ensure maximum skin protection.

The second step entailed in-depth site inspections and sample collection. Before obtaining samples, the depth to fluid, depth to oil/water interface, and total depth of the wells were recorded. Liquid samples were grab-sampled at the catch basins. At the disposal wells, liquid samples were collected using a teflon bailer. Sediment samples at the bottom of one disposal well were collected employing a bottom dredge. After the samples were collected, an aliquot of each sample was tested in the field

for temperature, pH, and conductivity. The chain of custody and other documentation procedures were completed in the field and the samples were delivered to the laboratory at the end of each day of sampling. The entire sampling was performed employing all applicable quality assurance and quality control (QA/QC) procedures.

PROBLEMS

One of the primary problems encountered in the sampling program was the identification of the actual disposal wells. The owners of many inspected facilities were not able to identify the exact location of the disposal wells. By visual observation, it was apparent that some of the catch basins were possibly connected to the sewer system. As suggested by USEPA Region II, EEI obtained only liquid samples at the catch basins at such facilities.

CHARACTERISTICS OF THE INJECTION FLUIDS

Samples were collected at eight facilities in Nassau and Suffolk Counties, Long Island, New York (Figure 4). Nine liquid samples, of which one was a blind duplicate sample, and one sediment sample were collected from catch basins and disposal wells.

PARAMETERS SELECTED FOR ANALYSIS

Due to the composition of the waste fluid matrix, the samples were tested for three field indicator parameters, nine heavy metal (total) priority pollutants, one non-volatile organic compound, and 33 volatile organic compound (VOC) priority

pollutants. In all, a sum of 46 parameters were tested in fluid samples obtained from five catch basins and three disposal wells at eight service stations, including one blind duplicate sample. In addition, one sediment sample from a service station disposal well was also analyzed for all the selected parameters except the three field indicator parameters.

Rationale for Collecting Unfiltered Samples for Metal Analyses

The gasoline service station disposal fluids originate from the station service bays and pass through catch basins (on many sites) and into disposal wells or the sewer system. The disposal fluids are comprised of both suspended sediments and dissolved particulates. These fluids are being discharged to the subsurface or the sewer system in their entirety, i.e. without any kind of pre-filtration. Hence, in order to obtain maximum information on the characteristics of the disposal fluid matrix, it is necessary to collect and analyze unfiltered samples. Such an unfiltered sample is fully representative of the total amount of contaminants that are being disposed into the subsurface. A filtered sample, on the other hand, is representative of the dissolved particulates alone. Such filtered samples would provide misleading data on the actual composition of the disposal fluid. Also filtered samples do not account for contaminants that might potentially desorb or leach from the residual suspended sediments in the waste stream. It is also very important to note that the National Primary and Secondary Drinking Water Regulation standards for metals are based on total metal concentrations (NJDEP, 1986).

LABORATORY ANALYSIS AND QA/QC PROCEDURES

An EPA certified lab, in Long Island, New York, was chosen to conduct analysis of the samples. All analyses were performed following the guidelines recommended in the Contract Laboratory Program Protocol (C.L.P.) (USEPA, 1986b). The C.L.P. procedure was used to ensure that the data produced could be used in possible enforcement initiatives. Guidelines and procedures presented in the USEPA Region II "Draft Underground Injection Control Quality Assurance Project Plan" were also followed as necessary.

METHODS USED FOR EVALUATION OF LABORATORY ANALYSES

The entire analytical data obtained in this investigation were stored in the computer disk for further evaluation. The blind duplicates were compared with their corresponding samples to find the Percent Relative Differences (PRDs) as defined in the Underground Injection Control Quality Assurance Project Plan Draft (USEPA, 1986a). This comparative assessment served as a check on the sampling technique and the lab analytical procedures. In addition, VOC field blanks that were included with samples gathered during each of the four sample days were checked for diffusion of VOCs.

On completion of the initial data evaluation discussed above, the analytical data was checked against New York State groundwater quality and effluent limitation standards (New York State Department of Environmental Conservation, 1978), and New York State drinking water standards and guideline levels (Harris

and Andreoli, 1984). This evaluation identified several disposal fluid samples that exceeded the standard for various parameters.

Error in Field Sampling or Laboratory Analytical Techniques

Duplicate samples may show Percent Relative Differences which have large variations. One reason for such variations may be due to the presence of both suspended sediments and dissolved particulates in a sample. The sample volume, container, and method of sampling cause a random distribution of solids in the waste stream and the sample, resulting in non-homogeneous sample collection each time an aliquot of the sample is taken. This non-homogeneous segregation is heavily influenced by the specific gravity, size, and shape of the suspended sediments. Berg (1982) details procedures to minimize such sampling errors experienced both in the field and in the laboratory. Such procedures were not used in this study since this was not in the scope of the work assignment. In any event, such non-homogeneous samples desorb contaminants into sample solution causing large variations in different aliquots of the same sample.

According to the UIC Quality Assurance Project Plan, estimates of Percent Relative Differences of two separate aliquots (duplicate samples) are found employing the formula:

$$PRD = \frac{x_1 - x_2}{\frac{(x_1 + x_2)}{2}} \times 100 \leq 50\%$$

PRD = Percent Relative Differences

x_1 & x_2 = Respective values obtained during duplicate sample analyses

CHEMICAL CHARACTERISTICS OF FLUID SAMPLES

Field Indicator Parameters

Conductivity, pH, and temperature are considered to be contamination indicator parameters and are usually measured in the field during sampling. In this study it was found that the pH of the disposal fluids ranged from 4.6 to 10.8 units (Table 1). One service station appeared to be disposing very alkaline waste fluids into a disposal well. The pH in the disposal well was found to 10.8 units (Sample #4). The operator at the facility indicated the floor washings, that contained plenty of soap solution, were the major cause of the high pH.

The conductivity of the samples ranged from 900 to 7,000 umhos/cm at an average temperature of 20° centigrade. The wide range of conductivity values observed is typically found in composite samples that have randomly distributed, dissolved, and suspended sediments. Hence, the conductivity values obtained appear to have been influenced both by suspended sediments and dissolved particulates.

Heavy Metal Priority Pollutants

Heavy metals are typically found in waste petroleum products and are expected to be present in the SBW. Table 1 summarizes the sample concentrations of the nine heavy metal priority pollutants analyzed for this study. These priority pollutants are believed to endanger human health and the environment, as demonstrated in laboratory experiments. Long term investigation

of groundwater contaminated with these priority pollutants are known to cause many health effects including intestinal, skin, lung, and nerve tissue injuries (Forstner and Wittmann, 1979). All the samples exceeded water quality standards for heavy metals.

Three of the six service station catch basin samples had total heavy metal concentrations that range from 50,000 ppb to 70,000 ppb as illustrated in Figure 5. One disposal well sample (Sample #7) had a concentration of 50,000 ppm of heavy metal (total) priority pollutants. Lead and zinc levels were noticeably very high in most samples. Two of the six service station catch basin fluid samples (Samples #2 & #6) had total lead levels that range from 30,000 ppb to 50,000 ppb as illustrated in Figure 6. A sample from one disposal well at a service station (Sample #7) had lead (total) levels in excess of approximately 30,000 ppb. Also two service station catch basin samples (Samples #2 & #6) and one disposal well sample (Sample #7) had approximately 20,000 ppb of total zinc (Figure 7).

In general, total cadmium levels in all the samples were in excess of water quality standards, ranging from 16 ppb to 700 ppb, whereas none of the samples exceeded the silver standards. Total selenium levels were below the sample detection limit. Only one sample (Sample #7) exceeded the barium (total) standards. Arsenic (total) levels ranged from below 10 ppb to 300 ppb with only two catch basin service station samples and one disposal well sample exceeding water quality standards. Although

30% of the samples exceeded total mercury levels, the levels were only slightly in excess of water quality standards. Of the eleven samples, 55% were in excess of chromium levels ranging from 20 ppb to 2000 ppb.

Finally, one blind duplicate sample (Sample #9) collected at a service station revealed errors in field sampling methodology and/or lab analytical techniques. Although PRDs for individual heavy metals varied from 12% to 48%, the mean PRD for metals was approximately 20%. The samples can be therefore considered representative of the waste matrix considering the relatively simple techniques used for preliminary sampling.

Ethlyene Glycol

Ethlyene glycol is a primary compound found in coolants and antifreeze liquids. Most service stations dispose waste antifreeze and coolants in the repair bay waste stream. This compound is not classified as a priority pollutant by the USEPA. However, according to Verschueren (1985) a single oral dose of approximately 1.4 ml/Kilogram of body weight is lethal to human beings. Ethylene glycol was tested for in nine samples taken at eight service stations including one blind duplicate sample. High levels of ethylene glycol ranging from 80 ppm to 40,000 ppm were found in these samples. Waste fluids sampled at four of the eight service station catch basins had ethylene glycol levels ranging from 20,000 to 40,000 ppm (Figure 8). One sample out of a disposal well had 1000 ppm while the other two disposal well samples had approximately 80 ppm of the compound.

VOC Priority Pollutants

Waste petroleum products present in the SBW predominantly contain VOCs. Some samples out of service station disposal wells had VOC concentrations in excess of water quality standards. Benzene, carbon tetrachloride, chloroform, 1-4 dichlorobenzene and vinyl chloride were some of the compounds found in the samples that are tentatively classified as known or suspected, human or mammalian carcinogens (The Bureau of National Affairs, 1986). Other USEPA priority pollutants that were found in excess of water quality standards include ethylbenzene, 1, 1, 1-Trichloroethane, and Toluene. The analytical results for 33 volatile organic priority pollutants are listed in Table 2.

Benzene, a known human carcinogen, was found in a very large concentration in one sample (Sample #5) from a service station catch basin. The benzene level was 3,500 ppb (Figure 9) in sample #5, while the levels in all the other samples ranged from 5 ppb to 210 ppb. Although carbon tetrachloride, chloroform and vinyl chloride were identified in the sample, the contaminant levels were found to be individually less than 200 ppb. Also, as much as 610 ppb of 1,4-dichlorobenzene was found in a service station disposal well sample (Sample #7) while contaminant levels in the rest of the samples were below 300 ppb (Figure 10). Ethylbenzene levels ranged from 5 ppb to 1,400 ppb where Sample #5 had the highest contaminant level (Figure 11). As much as 9,300 ppb of toluene was reported at a service station disposal well sample (Sample #1) (Figure 12). Also, one catch basin

disposal fluid sample (Sample #5) had as high as 8,900 ppb of toluene while the rest of the samples were reported to have contaminant levels ranging from 3 to 2,500 ppb of Toluene.

In general, various contaminants exceeded water quality standards by a range from 8 to 100%. One blind duplicate sample (Sample #9) collected at a service station served as a check on sampling and analytical techniques. The PRDs for this sample ranged from 40 to 100% for benzene, trans-1,2-Dichloroethylene, ethylbenzene, tetrachloroethylene, 1,1,1-trichloroethane, toluene, and 1,2-dichlorobenzene. This type of variation is typical in liquid samples containing both dissolved particulate and suspended sediments that are undergoing physical-chemical processes. The rest of the 26 parameters appear to have a PRD of 67%, but the sample concentrations are below quantitation limits.

VOC Cross Contamination in the Laboratory

The Contract Laboratory Program (CLP) Quality Assurance/ Quality Control procedures include checks for interferences from the analytical system (especially VOCs) by running lab reagent blanks (also known as method blanks or instrument blanks). The sample analysis methods used for this project followed this procedure and found some compounds such as 1,1,1-Trichloroethane, Benzene, and Toluene in the instrument blank. However, this phenomenon did not cause a significant impact on the analytical results for the samples collected, due to the very low concentration found in the blanks.

Diffusion of VOCs

A field reagent blank (also known as field blank or trip blank) was carried through the sampling and handling activities as required by QA/QC procedures. This procedure served as a check against diffusion of volatile organics.

Seven compounds, benzene, chlorobenzene, ethylbenzene, methylene chloride, 1,1,2,2-Tetrachloroethane, 1,1,1-Trichlorethane, and Toluene, were detected in the field blanks in small amounts of less than 10 ppb. Many researchers (Wilson, et al, 1983; and Mahadevaiah and Miller, 1986) have experienced similar diffusion of volatile compounds through the teflon lining of the screw caps.

All the elements of the diffusion phenomenon are yet to be studied in order to make suitable corrections on the raw data. However, since the diffusion detected in the field blanks was considerably low for the scope of this project, its effect was neglected in the final data evaluation.

CHEMICAL CHARACTERISTICS OF THE BOTTOM SEDIMENTS

As many as forty-three parameters involving nine inorganic heavy metal priority pollutants, thirty-three volatile organic priority pollutants and one organic compound were tested in one bottom sediment sample.

It was possible to collect bottom sediments at only one of the three service station disposal wells. Sediment samples were not collected from one service station disposal well (Sample #4)

since there were large amounts of organic debris (leaves and twigs) that rendered the bottom dredge inoperative for sampling. Bottom sediments were not collected from the other disposal well due to sampling equipment malfunction. At the five other service stations, disposal wells could not be located.

The bottom sediments collected at the service station disposal well were found to contain both heavy metals and volatile organics highly in excess of the initial contaminant threshold levels recommended by the USEPA (Bolton, 1985). These contaminant threshold levels serve as indicators of potential toxicity to the biota. Many scientists have discovered that adsorption is one of the primary reasons why bottom sediments are highly contaminated with many hazardous organic compounds and heavy metals. These contaminants may slowly and eventually desorb or leach and migrate through the subsurface and finally reach drinking water sources in the vicinity.

Heavy Metal Priority Pollutants

Heavy metal priority pollutants were found in the bottom sediment samples in levels ranging from less than 10 mg/Kg to 1000 mg/Kg. High levels of lead, zinc, barium, and arsenic were detected in concentrations of 1030 mg/Kg, 340 mg/Kg, 260 mg/Kg, and 80 mg/Kg respectively. Other heavy metals such as cadmium, chromium, mercury, selenium and silver were found in comparatively low levels.

Ethylene Glycol

Fifty mg/Kg of ethylene glycol was also found in the sediment sample collected (Table 1). The ethylene glycol level was lower in the sediment sample than in fluid sample from the well, due to the high solubility of ethylene glycol compared to VOC's and heavy metals.

VOC Priority Pollutants

Among the five VOCs that are tentatively classified as known or suspected human carcinogens, chloroform was positively identified at 0.003 mg/Kg, whereas carbon tetrachloride, 1,4 dichlorobenzene, and vinylchloride were less than 1 mg/Kg (sample detection limits for these compounds were 1 mg/Kg). Benzene, a known human carcinogen was found in levels of 0.28 mg/Kg in the sediment sample. Nine VOCs were found in very large amounts in the bottom sediment sample, ranging from 1 mg/Kg to as high as 150 mg/Kg. Dibromochloromethane, 1,1-Dichloroethylene, 1,2-Dichloropropane, 1,1,2,2-Tetrachloroethylene and 1,1,1-Trichloroethane were found in concentrations ranging from 1 mg/Kg to 3.8 mg/Kg, whereas, 12 mg/Kg of 1,1,2,2-Tetrachlorethene and as high as 95 mg/Kg of 1,1,1-Trichloroethane were positively found in the sample. Toluene and ethylbenzene were found in the sample at the highest levels, 150 mg/Kg and 140 mg/Kg respectively. Nearly 9.5 mg/Kg of a compound found in the sample contained primary ions of chlorobenzene but was not identified by standard library spectral search. The rest of the eighteen VOCs were either below quantification limits or less than the water quality standards. The analytical results for VOCs are tabulated in Table 1.

CONTAMINANT FATE AND TRANSPORT

Predicting the transport and fate of pollutants from point source pollution is a difficult, if not impossible, task when limited data exists. The following discussion concerns the contamination potential of the SBW to groundwater quality. This evaluation will be updated when additional data is generated by future studies.

FLUID INJECTION

At most sites, waste fluids enter the unsaturated subsurface zone by gravity flow, seeping through slots and openings of the disposal well. Waste fluids migrate vertically downward in the unsaturated (vadose) zone by force of gravity. In this process, the fluids may leave behind residual contamination in the well and in the flow path through the vadose zone, due to adsorption or absorption. The residue potentially may leach or desorb contaminants to the subsurface for long periods of time.

HYDROGEOLOGY AND WATER USE

Wastewater from service bays typically is injected into the shallow subsurface through disposal wells. In Long Island, New York, some of the disposal wells which were sampled have injection zones as close as 5 feet to within a few hundred feet above the upper glacial aquifer. Immediately underlying the upper glacial aquifer is the Magothy aquifer which is a major source of drinking water to the residents of Long Island, New York. The Magothy aquifer, which is located less than a quarter of a mile

below the disposal wells, is also hydraulically connected with the upper glacial aquifer except in the south, where they are separated by a confining unit.

The Long Island aquifer system has been designated as a "sole source" aquifer by the USEPA. At many sites, the injection well discharge zones may be in or near shallow aquifers. Shallow aquifers are highly vulnerable to contamination regardless of their location with respect to injection zones since contaminants in SBW may eventually reach the aquifer. Most gas station service bays are located in populated areas that may have many additional sources of pollution (See Figure 13). Some residents in the area may obtain their drinking water from wells completed in shallow aquifers in the general area. Contaminants entering the shallow aquifers may migrate through the groundwater and, eventually, contaminate drinking water wells in the vicinity.

In some areas where shallow aquifers are non-potable, water wells may be completed in deeper aquifers. Contaminants from SBW disposal wells may still migrate down to the deeper aquifer, depending on the hydrogeological connection between the upper shallow aquifer and the deeper aquifer. Improperly abandoned or poorly constructed and maintained water wells may also contribute to connectivity of shallow and deep aquifers.

CONTAMINATION POTENTIAL

Based on the rating system described in the "Report to Congress, Class V Injection Wells," (USEPA, 1987) automobile service station waste disposal wells are assessed to pose a high

potential to contaminate groundwater. These wells typically do inject into or above fresh water aquifers. Typical well construction, operation, and maintenance would allow fluid injection or migration into unintended zones. Injected fluids typically have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. Furthermore, many of the fluids are likely to exhibit characteristics or contain constituents listed as hazardous as stated in the Resource Conservation and Recovery Act (RCRA) Regulations. Based on injectate characteristics and possibilities for attenuation and dilution, injection occurs in sufficient volumes or at sufficient rates to cause groundwater degradation beyond the facility perimeter. This conclusion is reaffirmed by some State Class V well inventory and assessment reports, including New York, Utah, and Iowa, that rate these disposal methods as those that pose a high contamination potential.

As discussed above, discharge of such contaminants to the subsurface has an immediate or potential impact on the groundwater quality and, thereby, poses a threat to human health and the environment. The impact on groundwater quality is influenced by the transport and fate of the injected fluids in the subsurface.

As mentioned by Keeley, Piwoni, and Wilson (1986), there are many natural processes that affect the transport and fate of pollutants (Table 3). They are divided into physical, chemical,

and biological processes. These processes may, in many instances, reduce the contamination potential. Nevertheless, these contaminants have the ability to eventually degrade the groundwater quality depending on the volume, persistence, mobility, and toxicity of the injected contaminants. Investigations that study the transport and fate of contaminants can be both costly and time consuming but are essential. Such investigations become more complicated (especially in densely populated residential and industrial areas as in the case of the Long Island, New York study) as different sources of contamination contribute to the gross contamination plume.

A thorough investigation of the various factors mentioned above is necessary to understand the severity and extent of the groundwater contamination potential of SBW injection.

CURRENT REGULATORY APPROACH

Automobile service station waste disposal wells are authorized by rule under Federally-administered UIC programs (USEPA, 1987). Currently, gasoline station disposal wells are not actively regulated by the USEPA or by many State systems. One reason is that some States do not believe that such disposal practices exist. Also, many other States believe that multipurpose wells like septic tank systems and storm water/industrial drainage wells (that also discharge waste from service bays) do not meet the definition of "Automobile Service Station Disposal Wells".

Some States, however, are beginning to recognize the impact of these injection practices. For instance, according to Patton (1987), Connecticut has barred any discharge of wastewater to the subsurface from gasoline station service bays. All facilities, old and new, are required to dispose of such wastewater only through the sewer system or other means where the waste is removed from the area. Operators are required to obtain necessary permits in this regard. Facilities that do not follow these requirements have been asked to immediately seal off such drains. Other States, including Wyoming, Wisconsin, New Jersey, and New York, are taking effective steps to mitigate these injection practices. Some States, like Texas, are now requiring permits for these discharges, and have classified the wells as Class I wells (Musick, 1986).

USEPA reported the presence of 98 automobile service station disposal wells in the Report to Congress (USEPA 1987) on Class V injection wells. Figure 14 illustrates the nationwide distribution of this well type. It is very important to note that this tabulation is not complete as many States have not yet recognized this well type. Table 4 is a synopsis of the State reports (as compiled in the Report to Congress) on the inventory and regulatory programs for automobile service station waste disposal wells. As listed in the Table, 13 states reported inventory information for this well type and three states confirmed their presence but no numbers.

SUMMARY AND CONCLUSIONS

This Phase I study served as a preliminary assessment of the impact of fluids disposed/injected into the upper glacial aquifer in Long Island, New York. The type of disposal fluids examined originate from automobile service station repair bays. The field investigations involved site inspection and sampling of disposal fluids and bottom sediments at eight service stations. The sample analysis indicated the presence of heavy metal priority pollutants and VOC priority pollutants that were highly in excess of water quality standards. However, this investigation was comprised of a single round of sampling at selected sites. A more detailed time-series sampling would be required to better determine the composition of the waste fluids.

USEPA Region II is currently reviewing a work plan for the Phase II investigation which will include additional sampling and sample sites. Based on the characteristics of the waste fluid observed in Phase I investigation, the second phase of the investigation will consider modified sampling methods and analytical techniques. These techniques will yield representative and statistically valid samples which will be tested to determine the waste fluid's potentially hazardous nature. Appropriate regulatory measures will then be implemented to help alleviate the contamination potential due to the injection of SBW.

Based on findings of this initial study, the construction, operation, and maintenance of automobile service station disposal wells allow migration of toxic organics and heavy metal priority

pollutants present in the SBW into unintended zones in the subsurface. These contaminants may possibly degrade the groundwater quality of the underlying aquifers. Based on these findings, it can be concluded that subsurface discharge of SBW presents a high potential to contaminate USDW in many areas of the country where they are known to exist. The problem is predominantly found in populated areas that depend, in many instances, on groundwater as a source of drinking water. The injection of SBW to the subsurface, therefore, is a potential threat to human health and the environment.

RECOMMENDATIONS

As discussed previously, subsurface injection or discharge of potentially hazardous and toxic fluids from service bays at gasoline stations and car dealerships is a threat to human health and the environment.

According to Utah, communities with a water reclamation system commonly prohibit oil and grease discharges to their sewer. Consequently, some operators decide to discharge wastewater to dry wells as a "loophole" to the environmental regulations. In a situation like this, local building code and sewer pretreatment inspections could be used to locate these wells.

The following recommendations should help achieve better goals in the control and abatement of groundwater contamination due to SBW injection practices.

NATIONWIDE INVENTORY

An inventory of SBW disposal systems on a State level and, eventually, on a national basis is vital. This inventory information can be employed in making an assessment of the contaminant mass loading and detrimental effects on the subsurface water quality. Unsewered areas, such as in areas of Long Island, New York, may have large concentrations of SBW subsurface disposal facilities. Therefore, it may be appropriate to begin inventories in these unsewered areas and gradually work outward.

REGULATORY NEEDS

There is an immediate need to develop guidelines for construction, operation, and overall regulation of these disposal practices. The guidelines must be based on actual inventory and assessment studies. These guidelines should include classifying subsurface discharge as single purpose and multipurpose discharge systems. Such a classification allows the regulating agencies to properly permit and regulate any present or future discharges. All past discharges and abandoned or improperly plugged discharge systems should also be investigated. Necessary corrective or remedial actions may need to be implemented, based on such investigative findings.

The next step in this regard would be permitting of all existing and new discharge systems. The State of Iowa suggests requiring the permittee to include information on construction features, a plan to utilize separators and holding tanks, and a plan to sample and analyze the injection fluids.

The State of Utah suggests educating the local government staff who conduct building and environmental inspections. This training will help locate those operators who violate the regulation and thereby lead to appropriate regulatory measures.

REMEDIAL MEASURES

One way of avoiding further contamination is to curb the problem at the source by choosing other disposal alternatives such as: 1) collection and disposal at an approved hazardous waste landfill; 2) adopting suitable pretreatment techniques before discharge to the subsurface; and 3) discharge to a municipal treatment facility as per regulatory requirements.

With regard to the wells in Long Island, New York, several remedial alternatives are available to restore the groundwater quality of the already contaminated aquifer. A thorough investigation conducted as a result of joint effort between Nassau County Department of Health and Dvirka and Bartilucci, consulting engineers, included a list of remedial techniques associated with such cleanup efforts. Since the aquifers of Long Island have been contaminated by many other unidentified sources as discovered by other regulating agencies, a remedial investigation and feasibility study should ideally be initiated in cooperation with the related regulatory agencies in the general area.

According to Utah, these wells can be corrected by providing underground holding tanks (total containment) for the waste oils/

fluids. These tanks would require regular off-loading to waste oil reclaimers. In Utah, there is economic incentive for a service station to sell waste oil to a reclaimer. The management of these wells would be accomplished at the local government level because they already enforce their building and sewer ordinances. Any inspections by state or federal staff would be a duplication of effort.

In conclusion, if the discharge of SBW to the subsurface is the only viable disposal alternative, such discharges should be carefully and reasonably monitored under appropriate regulatory programs. However, if future studies determine that SBW is hazardous or dangerous to human health or the environment, alternative disposal practices should be used.

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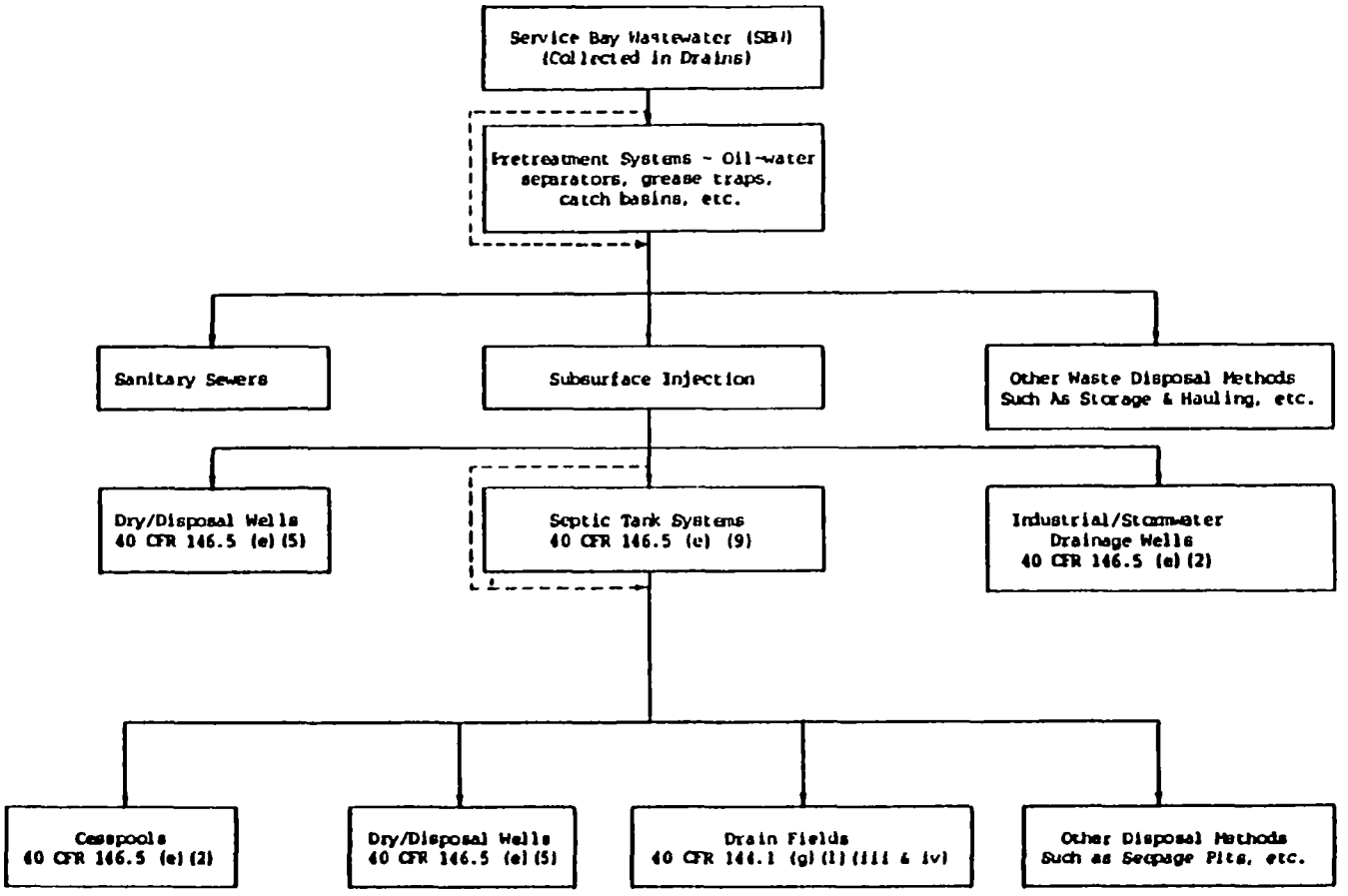
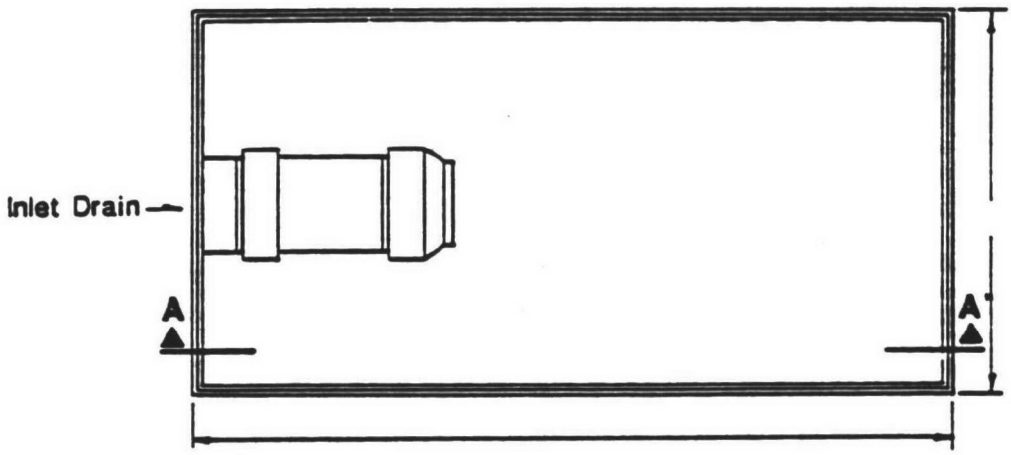
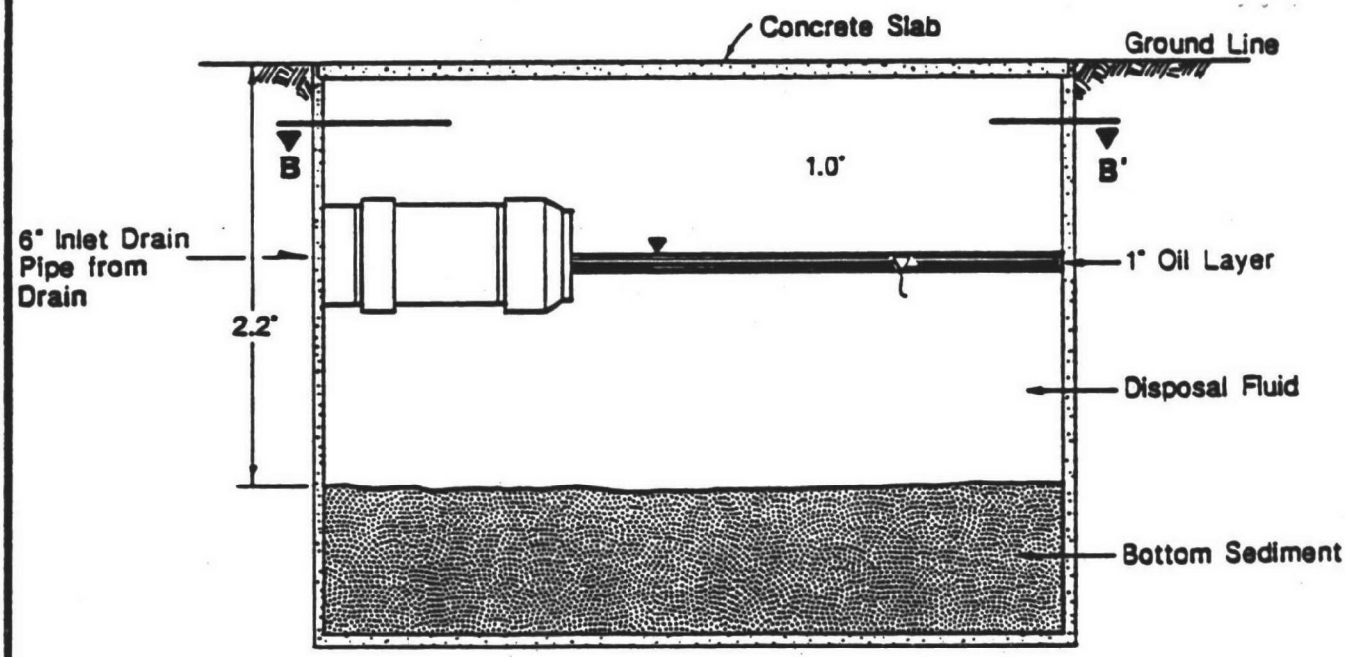


Figure: 1 Typical disposal methods employed by gasoline service stations and car dealerships that discharge service bay wastewater (SBW)



PLAN VIEW (B-B')

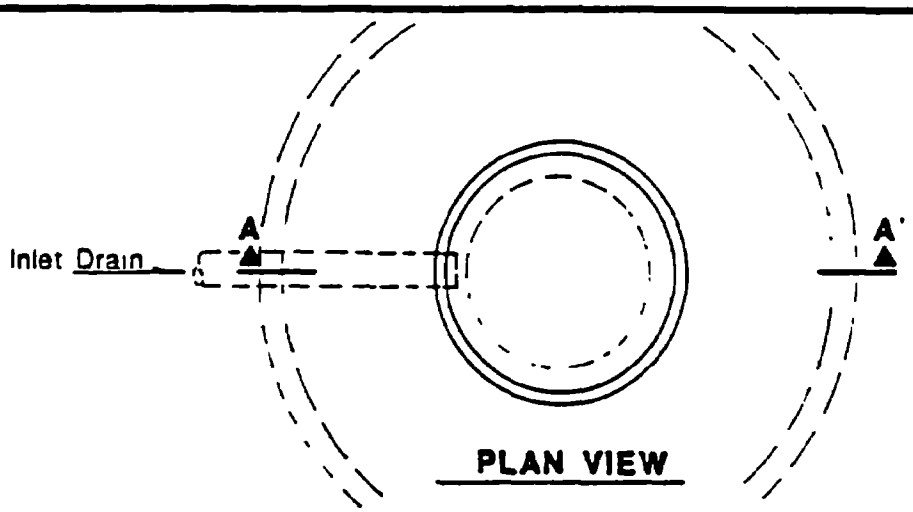


CROSS-SECTIONAL VIEW (A-A')

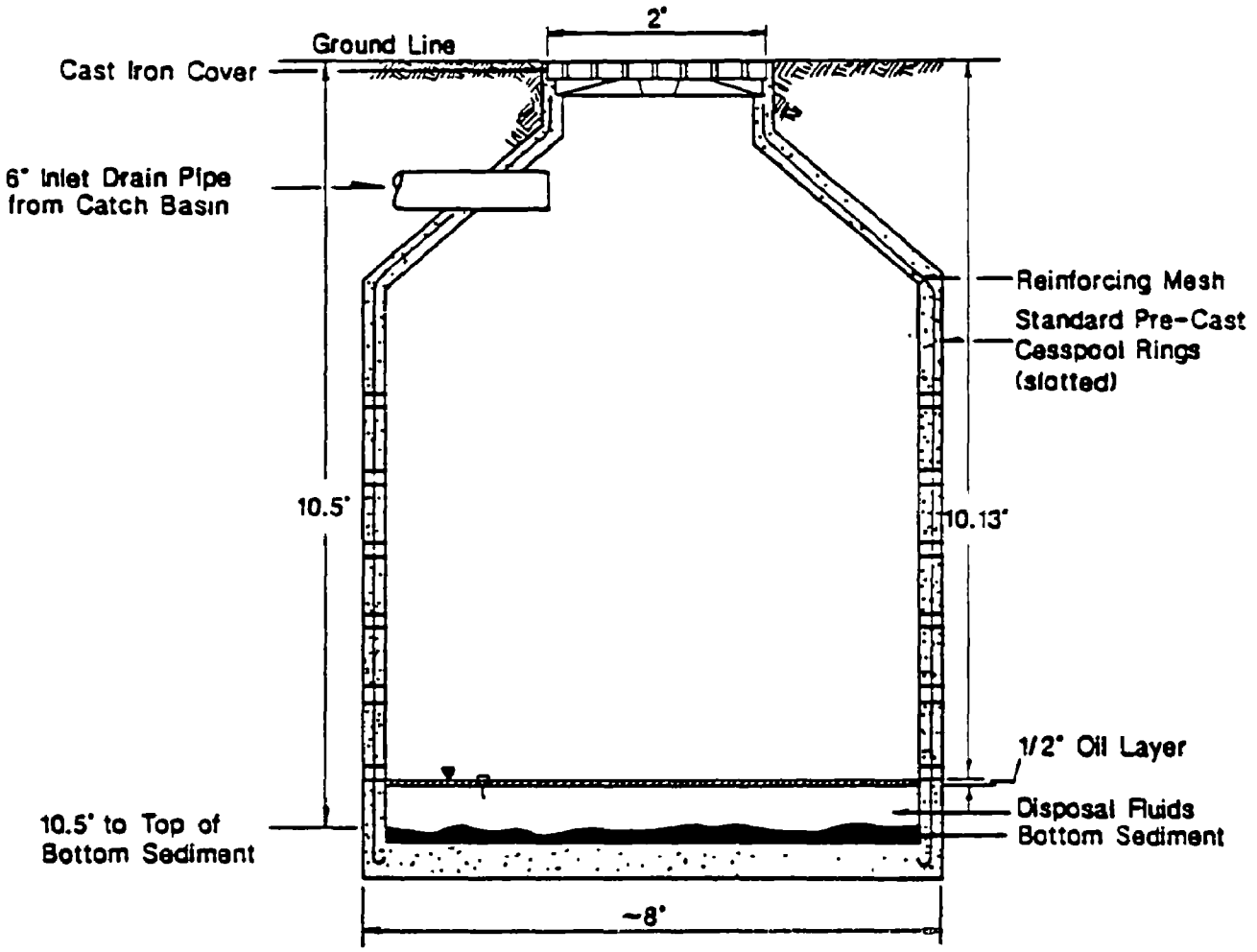
DETAIL OF A CATCH BASIN
SAMPLED AT A GASOLINE SERVICE STATION
LONG ISLAND, NEW YORK

EEI ENGINEERING ENTERPRISES, INC.

700.005.01 Figure 2



PLAN VIEW

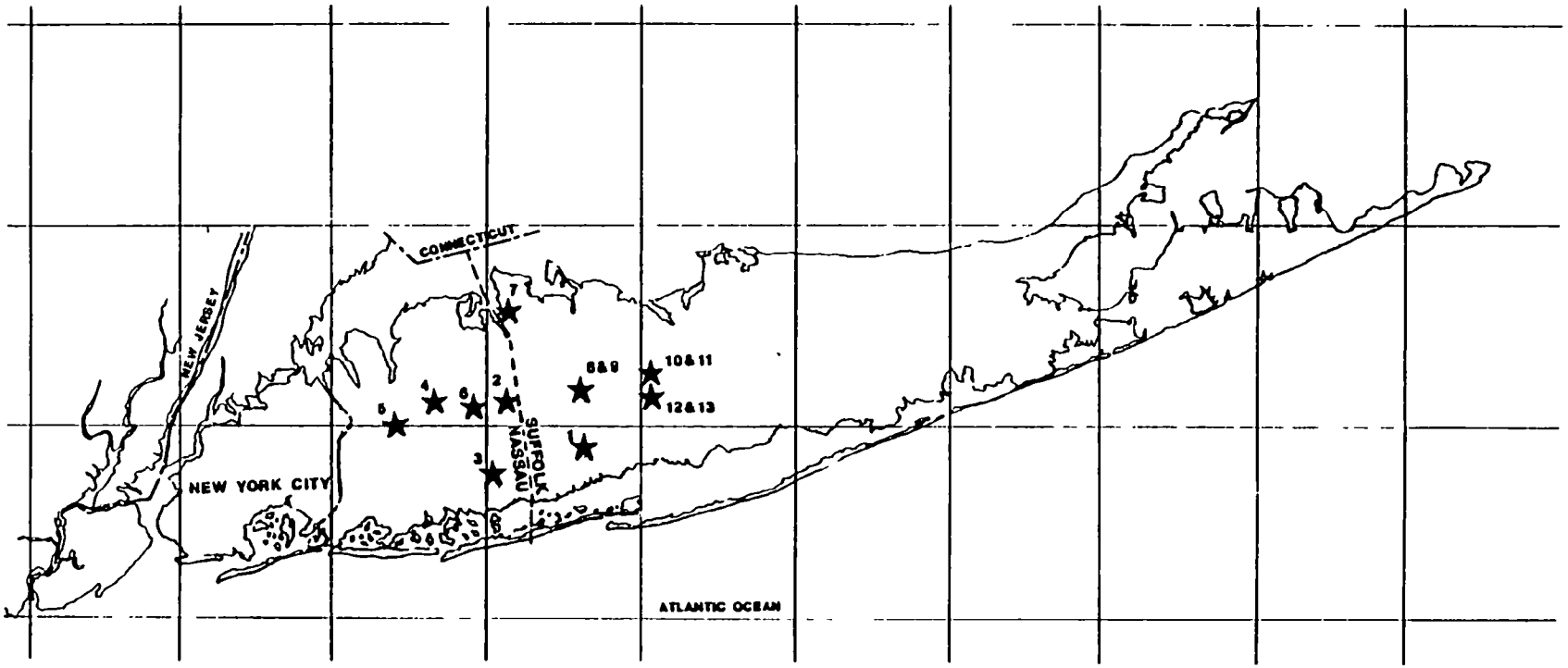


CROSS-SECTIONAL ELEVATION (A-A')

DETAIL OF A DRY/DISPOSAL WELL
SAMPLED AT A GASOLINE SERVICE STATION
LONG ISLAND, NEW YORK

ENGINEERING ENTERPRISES, INC.

700.005.01 Figure 3

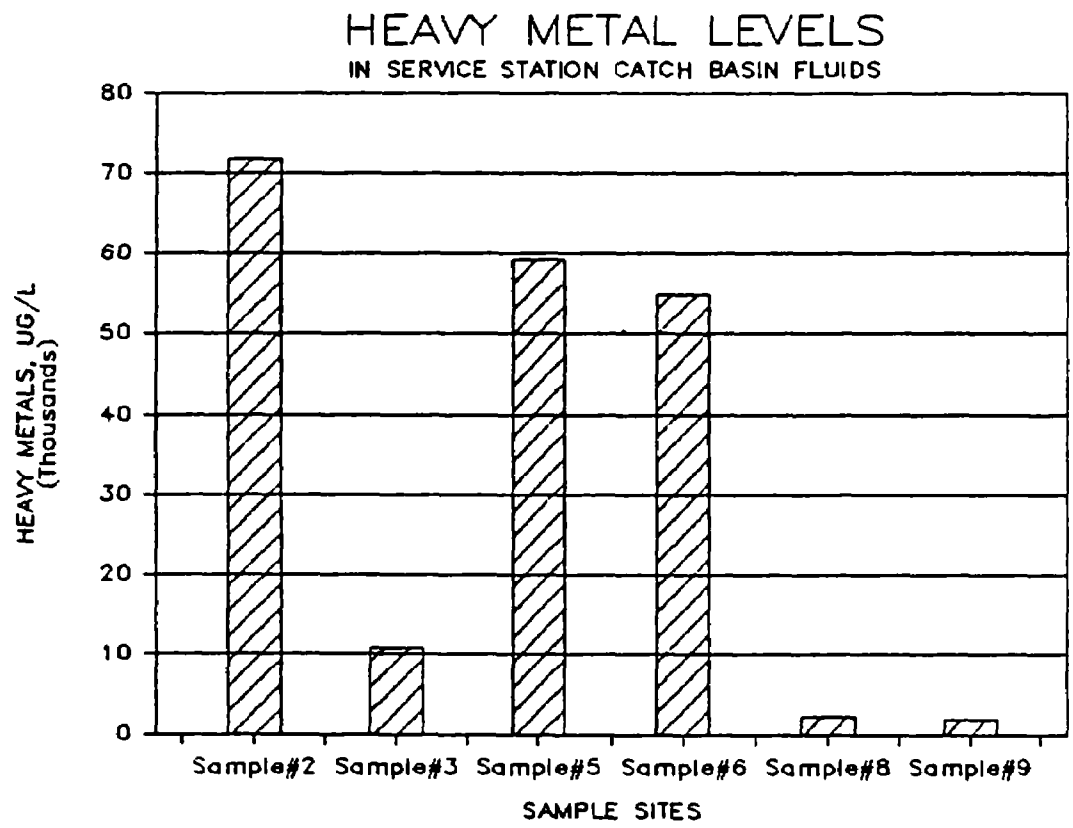


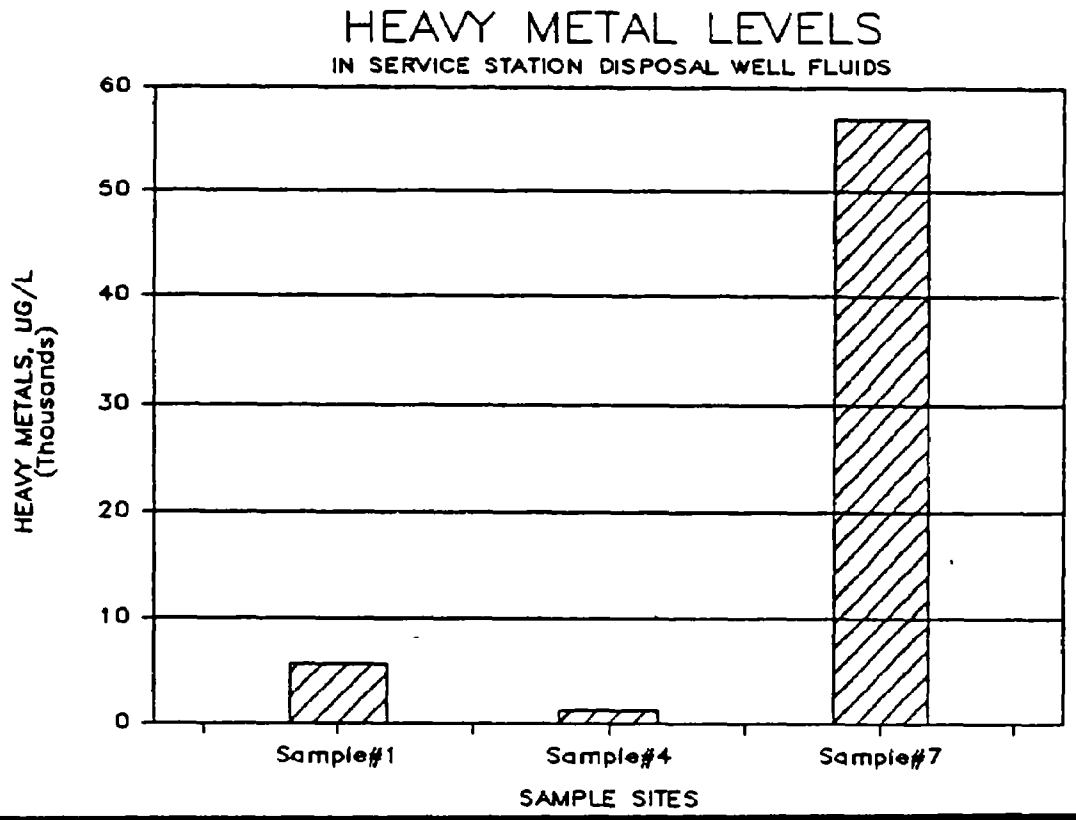
LONG ISLAND
Sample Locations

Figure 4

EEI ENGINEERING ENTERPRISES, INC.

602 006 01

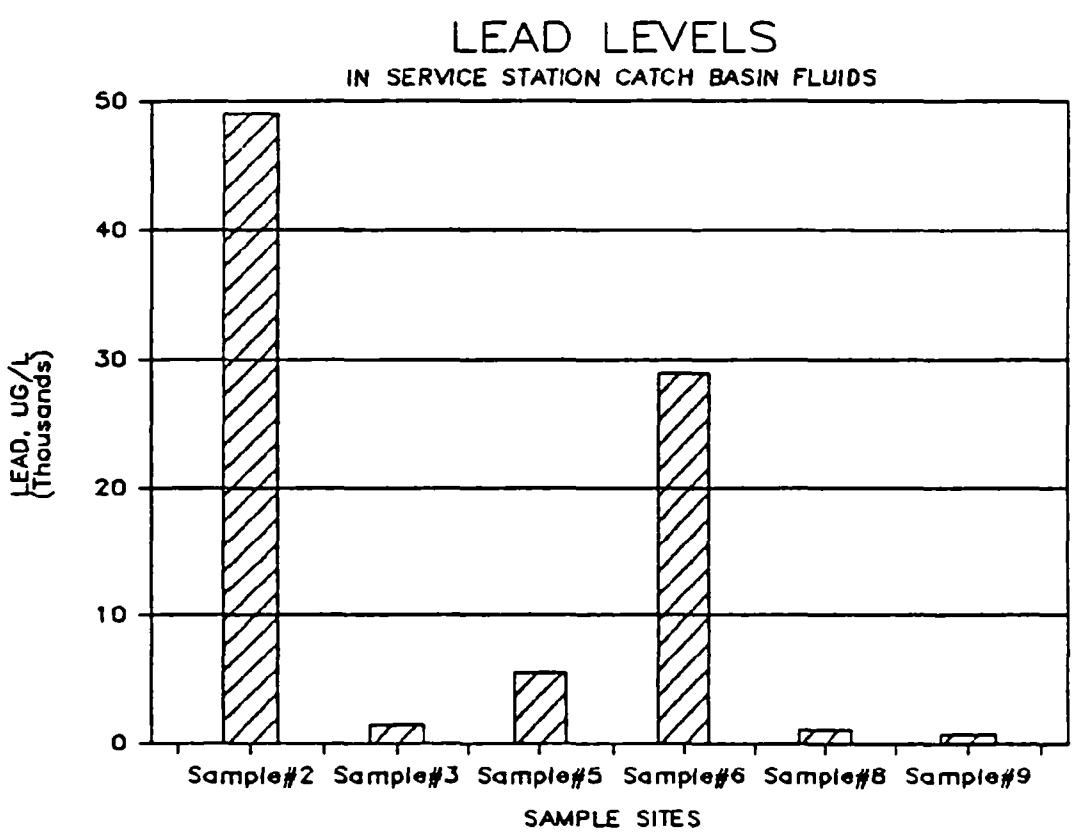


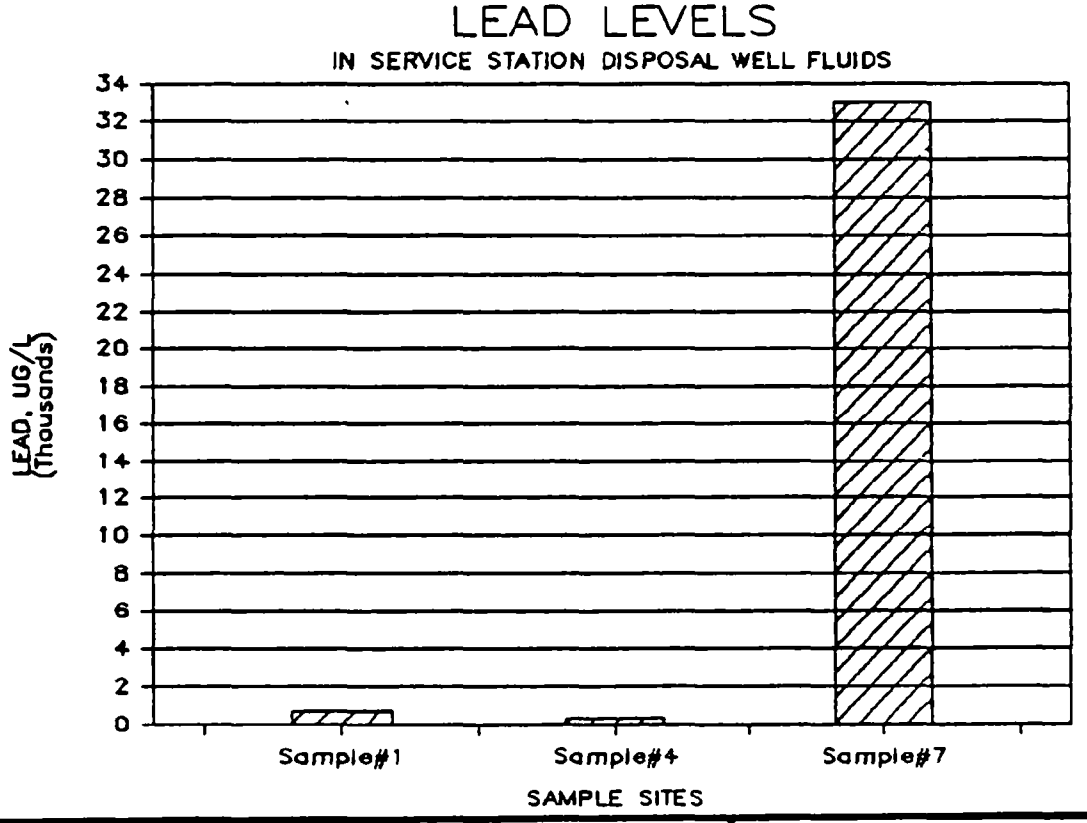


TOTAL HEAVY METAL LEVELS DETECTED BY CONTRACT LABORATORY PROGRAM (C.L.P.) ANALYTICAL TECHNIQUES FOR SAMPLES COLLECTED AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK.

EEI ENGINEERING ENTERPRISES, INC.

Figure 5

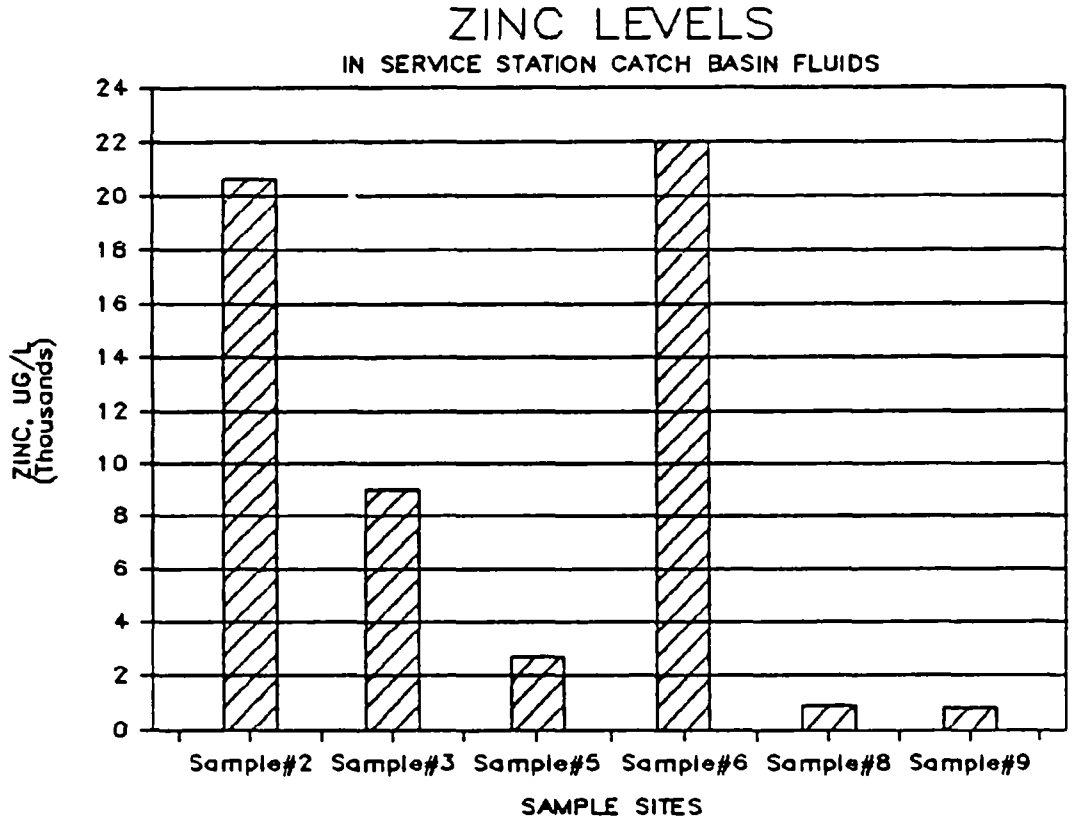


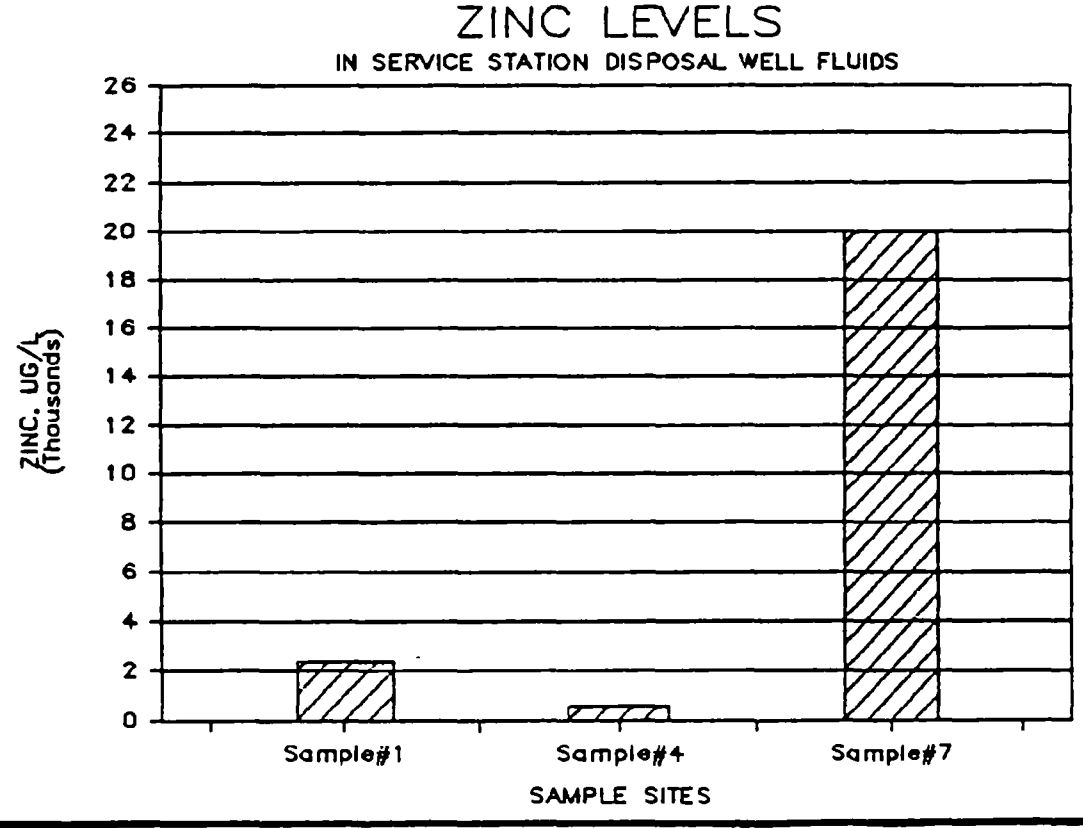


TOTAL LEAD LEVELS DETECTED BY CONTRACT. LABORATORY PROGRAM (C.L.P.) ANALYTICAL TECHNIQUES FOR SAMPLES COLLECTED AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK..

EEI ENGINEERING ENTERPRISES, INC.

Figure 6

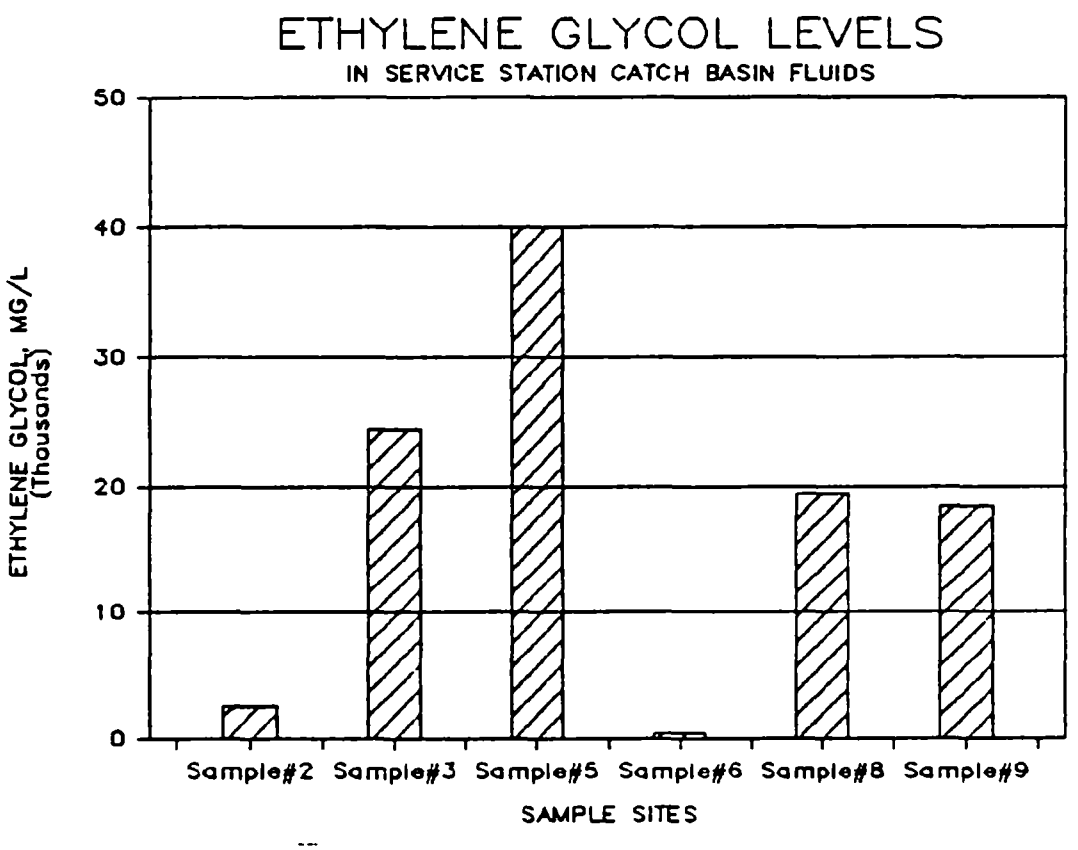


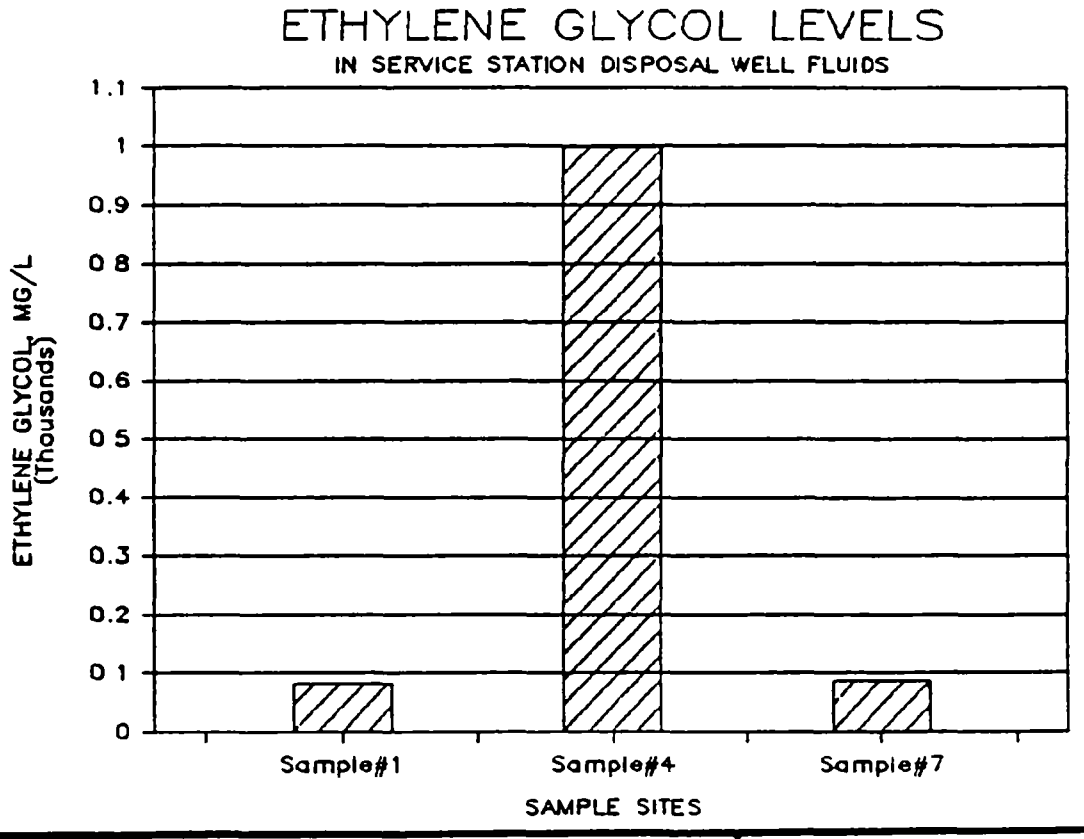


TOTAL ZINC LEVELS DETECTED BY CONTRACT LABORATORY PROGRAM (C.L.P.) ANALYTICAL TECHNIQUES FOR SAMPLES COLLECTED AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK.

EEI ENGINEERING ENTERPRISES, INC.

Figure 7

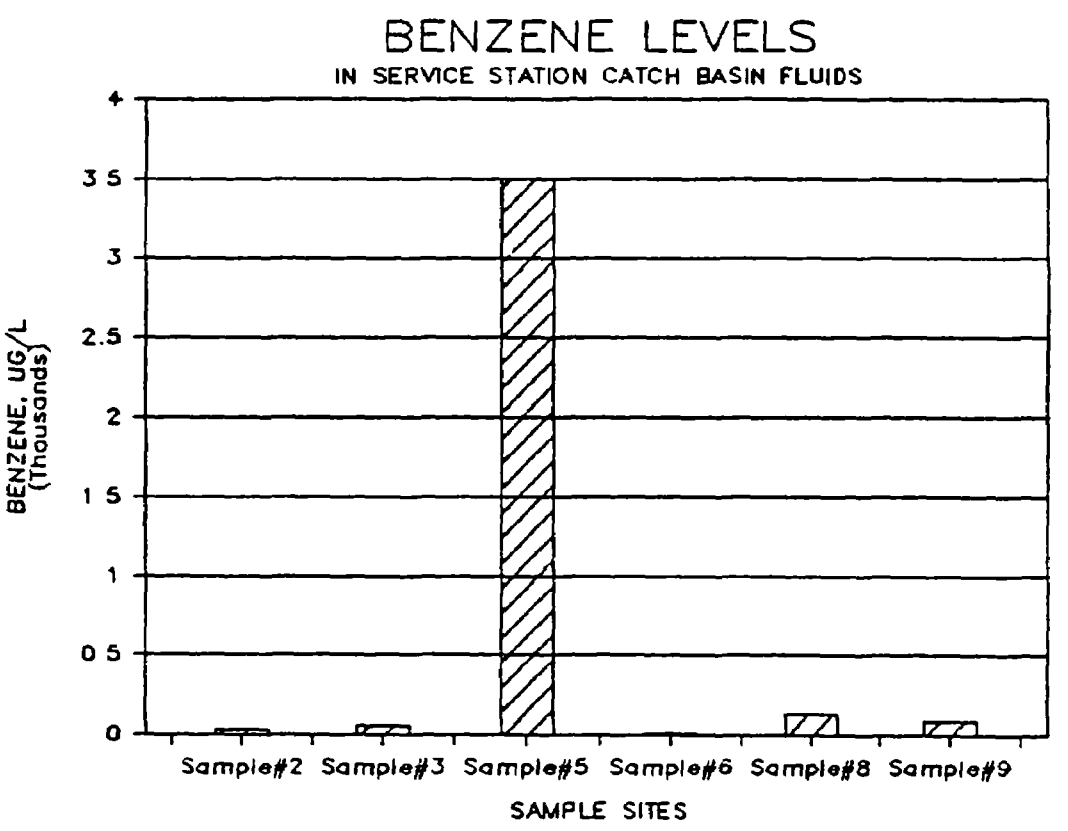


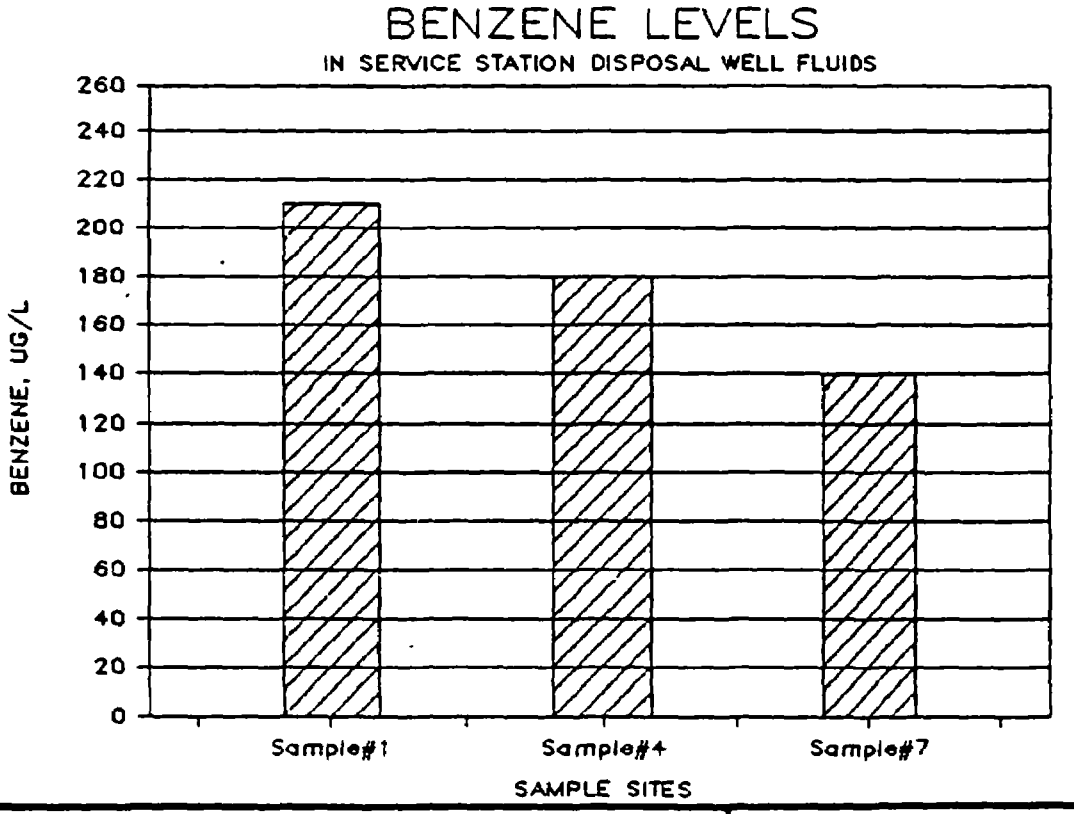


TOTAL ETHYLENE GLYCOL LEVELS DETECTED BY CONTRACT LABORATORY PROGRAM (C.L.P.) ANALYTICAL TECHNIQUES FOR SAMPLES COLLECTED AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK.

EEI ENGINEERING ENTERPRISES, INC.

Figure 8

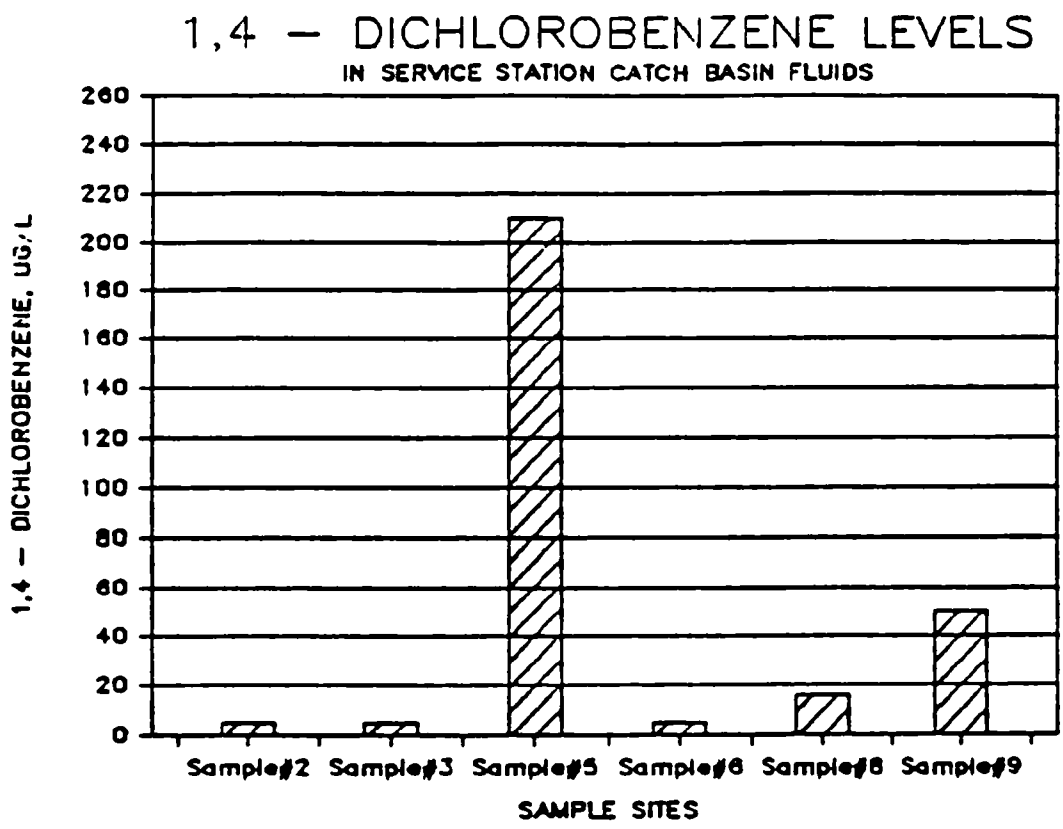


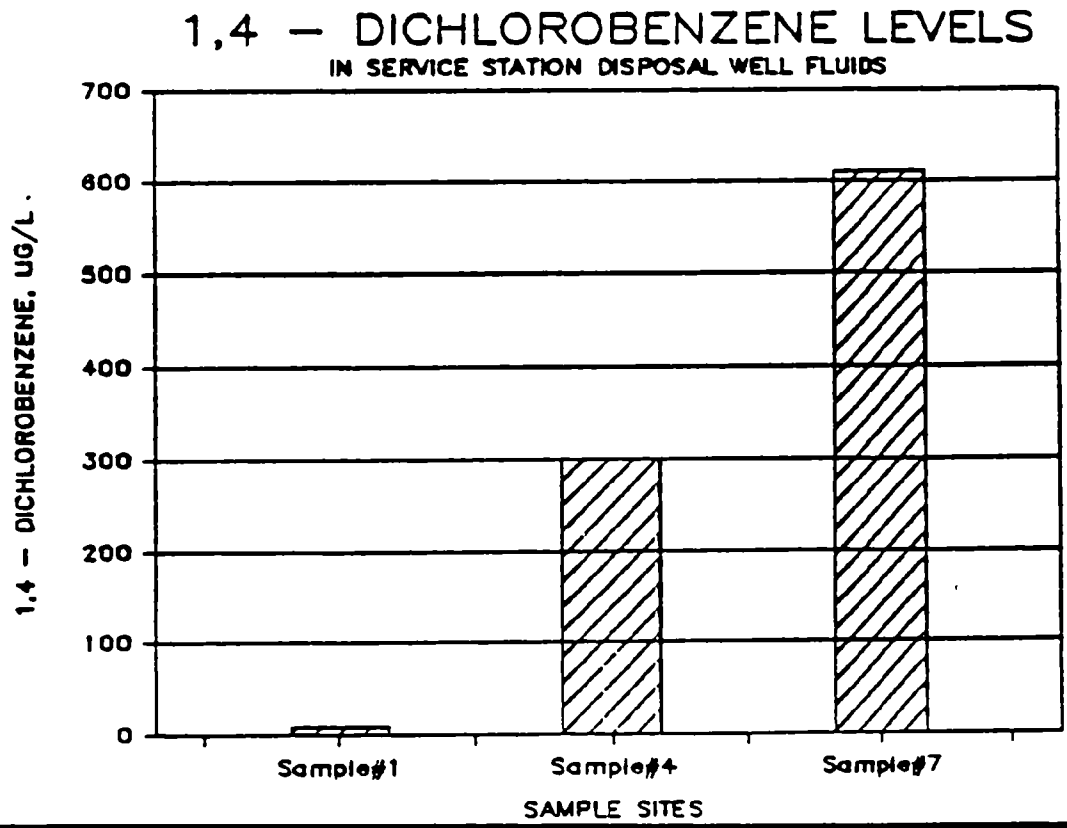


TOTAL BENZENE LEVELS DETECTED BY CONTRACT LABORATORY PROGRAM (C.L.P.) ANALYTICAL TECHNIQUES FOR SAMPLES COLLECTED AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK.

EEI ENGINEERING ENTERPRISES, INC.

Figure 9

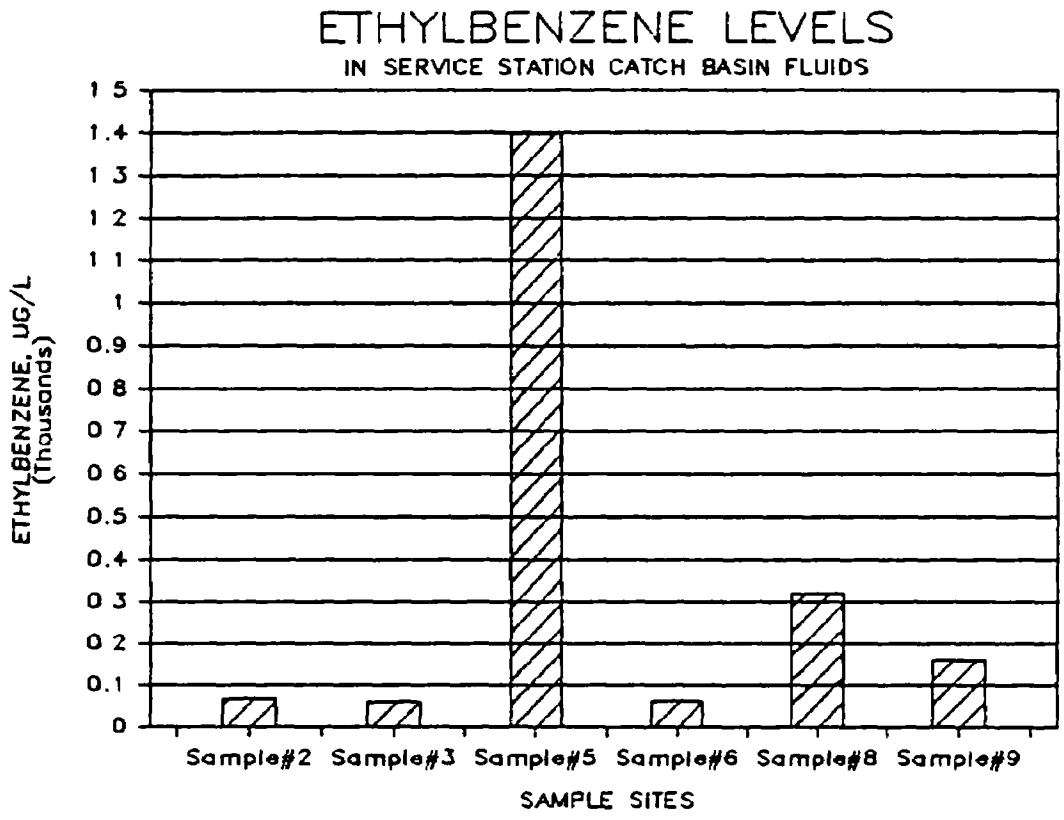


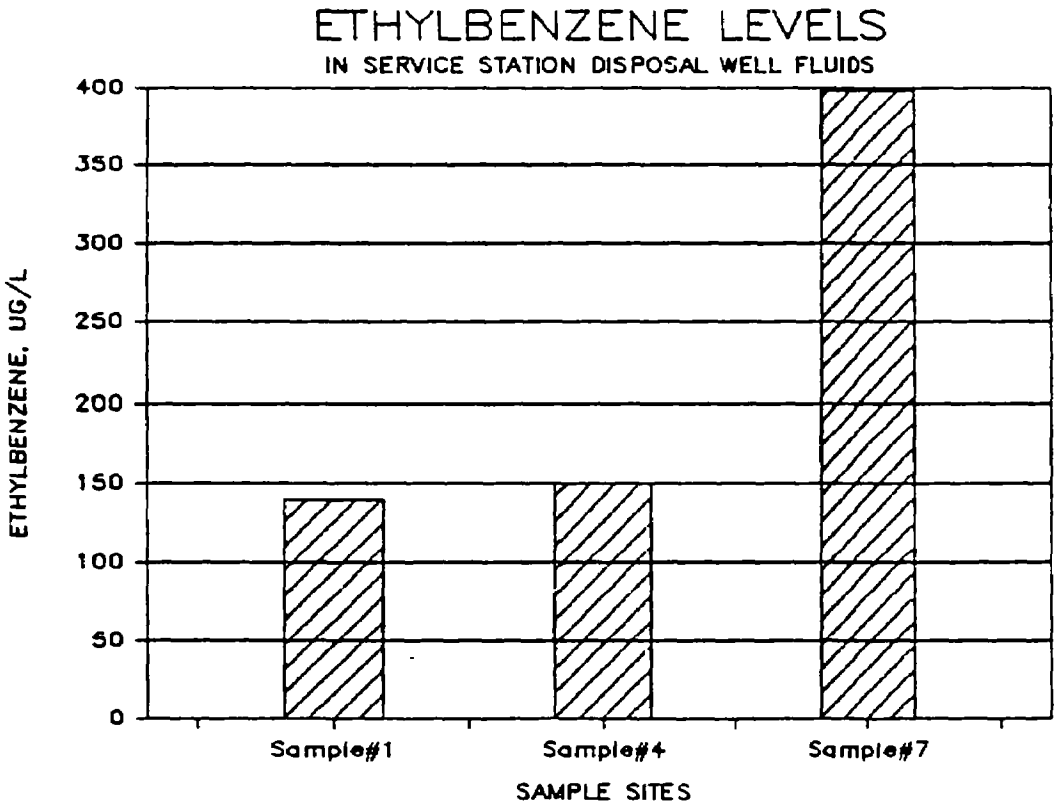


TOTAL 1,4-DICHLOROBENZENE LEVELS DETECTED BY CONTRACT LABORATORY PROGRAM (C.L.P.) ANALYTICAL TECHNIQUES FOR SAMPLES COLLECTED AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK.

EEI ENGINEERING ENTERPRISES, INC.

Figure 10

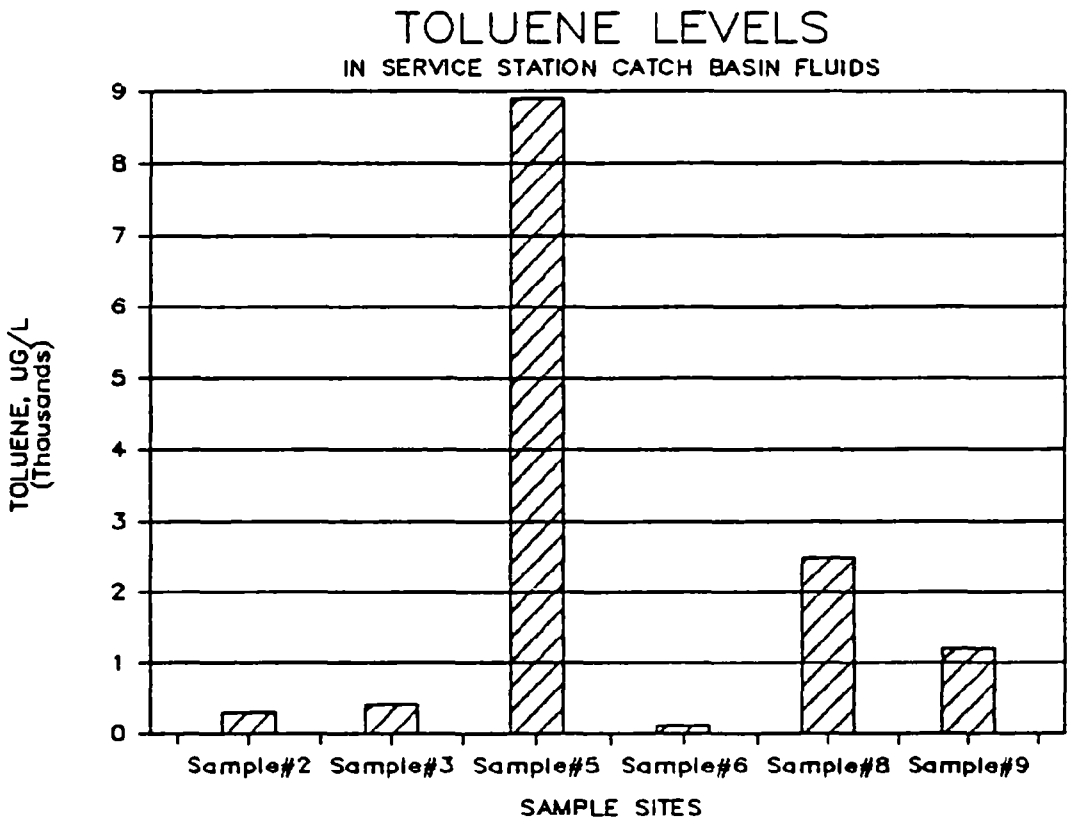


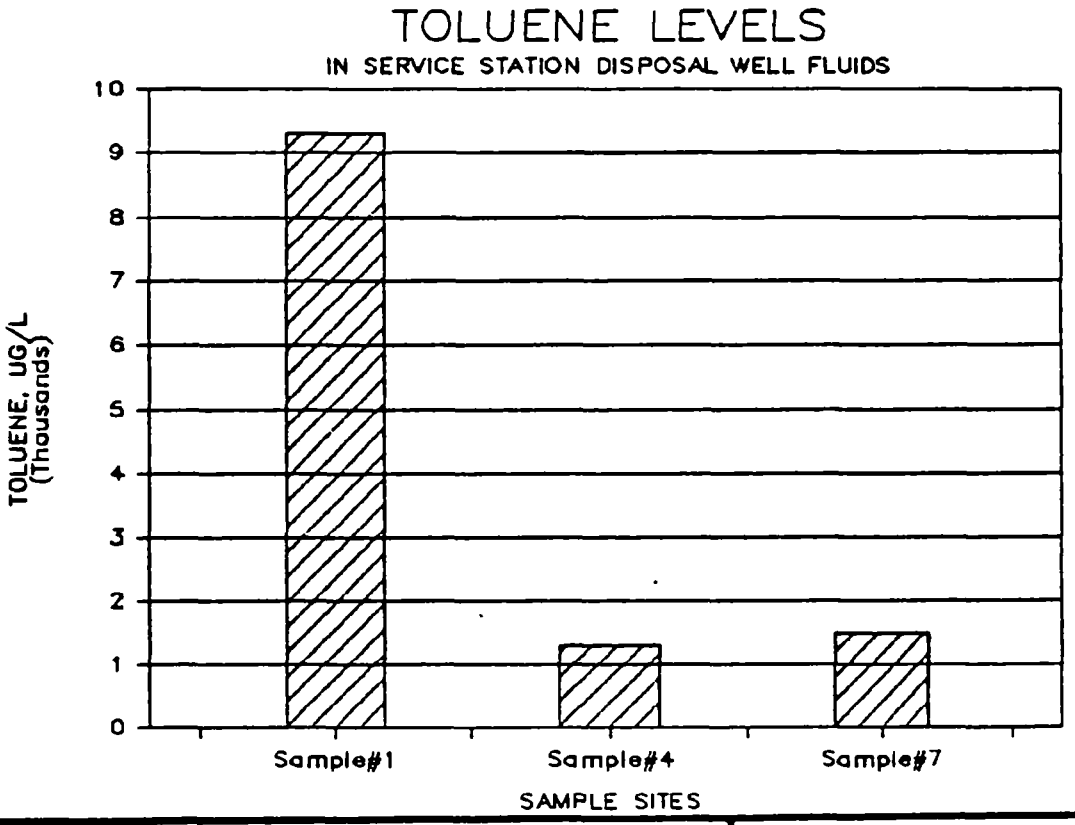


TOTAL ETHYL BENZENE LEVELS DETECTED BY CONTRACT LABORATORY PROGRAM (C.L.P.) ANALYTICAL TECHNIQUES FOR SAMPLES COLLECTED AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK.

EEI ENGINEERING ENTERPRISES, INC.

Figure 11





TOTAL TOLUENE LEVELS DETECTED BY CONTRACT LABORATORY PROGRAM (C.L.P.) ANALYTICAL TECHNIQUES FOR SAMPLES COLLECTED AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK.

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Figure 12

HYPOTHETICAL VIEW OF VARIOUS SOURCES OF CONTAMINATION AND TRANSPORT OF TOXICS IN THE SUBSURFACE

EEI ENGINEERING ENTERPRISES, INC.

602.006.01

Figure 13

NUMBER OF AUTOMOBILE SERVICE STATION WELLS
(5X28)
X
VIII
V
I
II
III
VII
IX
IV
VI
X
LEGEND
NUMBER OF WELLS BY STATE
0 to 1
1 to 10
10 to 100

Figure 14

TABLE 1: ANALYTICAL RESULTS OF INORGANIC COMPOUNDS AND ETHYLENE GLYCOL LEVELS FOUND IN SAMPLES COLLECTED FROM CATCH BASINS AND DISPOSAL WELLS AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK(September, 1986)

SAMPLE PARAMETERS	N.Y State Drinking Water, stds.	Instrument Detection Limits	Sample#1 N.Babylon, N.Y.	Sample#2 Plainview, NY	Sample#3 Seaford, N.Y	Sample#4 Westbury, N.Y.	Sample#5 Carle Place, N.Y.	Sample#6 Plainview, N.Y	Sample#7 Cold Spr Harbor, N.Y	Sample#8 Deer Park, N.Y.	Sample#9 (Dup. of Sample#8)
			Disposal Well(L,S)	Catch Basin(L)	Catch Basin(L)	Disposal Well(L)	Catch Basin(L)	Catch Basin(L)	Disposal Well(L)	Catch Basin(L)	Catch Basin(L)
INDICATOR PARAMETERS											
pH, units	6.5-8.5 §	0.01	4.8 +	5.56 +	4.6 +	10.77 +	5.8 +	5.25 +	6.2 +	6.03 +	6.03
Conductivity, u mhos/cm	N.S.A	0.1	2410 +	1280 +	2580 +	4000 +	4360 +	7250 +	2940 +	912 +	912
Temperature, deg.cent.	N.S.A	0.1	23.4 +	19.8 +	22.1 +	22.8 +	24.5 +	22.3 +	19.1 +	21.3 +	21.3
HEAVY METALS, ug/l(ppb)											
Arsenic	50	2	100 (85.6 s	220 +	49.5 .	40 .	100 (	165 +	305 +	22 .	16
Barium	1000	5	420 . 260 s	680 .	200 (	200 (	300 .	920 .	2500 +	200 (	200
Cadmium	10	2	62 + 24 s	660 +	89 +	18 +	61 +	700 +	370 +	30 +	19
Chromium	50	3	510 + 25 s	600 +	32 .	28 .	81 +	2100 +	690 +	16 .	26
Lead	50	2	665 + 1030 s	49000 +	1400 +	285 +	5600 +	29000 +	33000 +	1000 +	710
Mercury	2	0.2	2 + 0.35 s	0.2 (	0.2 (	0.2 (	0.4 (	2 +	2.6 +	0.4 .	0.4
Selenium	10	2	5 (5 s	50 (	5 (	50 (	50 (	50 (	50 (	5 (	5
Silver	50	10	10 (8.6 s	10 (	10 (	10 (	10 (	10 (	10 (	10 (	10
Zinc	5000	7	2400 . 340 s	20600 +	9000 +	570 .	2700 .	22000 +	20000 +	920 .	810
GENERAL ORGANICS, ug/l(ppm)											
Ethylene Glycol	0.05 §		80 + 50 s	2500 +	24500 +	1000 +	40000 +	375 +	85 +	19500 +	18500

(L)-Liquid Samples
(S)-Sediment Samples
NA-Not included for sample analysis
§ -Ground Water Quality Standards, New York State Department of Environmental Conservation
(s)-Contaminant levels in Sediment Samples, ug/kg
(-Sample has contaminant levels less than the reported value
+ -Contaminant levels exceed drinking water standards

TABLE 1: ANALYTICAL RESULTS OF INORGANIC COMPOUNDS AND ETHYLENE GLYCOL LEVELS FOUND IN SAMPLES COLLECTED FROM CATCH BASINS AND DISPOSAL WELLS AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK(September, 1986) - Continued

SAMPLE PARAMETERS	N.Y State Drinking Water, stds.	Instrument Detection Limits	Total % Exceeding Standards	% RELATIVE DIFFERENCE BB v/s 09	MIN CONC. REPORTED	MAX CONC. REPORTED
INDICATOR PARAMETERS						
pH, units	6.5-8.5 @	0.01 ♦	ERR	NA	4.6	10.77
Conductivity, u mhos/cm	N.S.A	0.1 ♦	NA	NA	912	7250
Temperature, deg.cent.	N.S.A	0.1 ♦	NA	NA	19.1	24.5
HEAVY METALS, ug/l(ppb)						
Arsenic	50	2 .	ERR	31.6%	16	305
Barium	1000	5 <	ERR	0.0%	200	2500
Cadmium	10	2 ♦	ERR	44.9%	18	700
Chromium	50	3 .	ERR	47.6%	16	2100
Lead	50	2 ♦	ERR	33.9%	285	49000
Mercury	2	0.2 .	ERR	0.0%	0.2	2.6
Selenium	10	2 <	ERR	0.0%	5	50
Silver	50	10 <	ERR	0.0%	10	10
Zinc	5000	7 .	ERR	12.7%	570	22000
GENERAL ORGANICS, ug/l(ppm)						
Ethylene Glycol	0.05 @	♦	ERR	5.3%	80	40000

(L)-Liquid Samples
(S)-Sediment Samples
NA-Not included for sample analysis
@ -Ground Water Quality Standards, New York State Department of Environmental Conservation
(s)-Contaminant levels in Sediment Samples, ug/kg
< -Sample has contaminant levels less than the reported value
♦ -Contaminant levels exceed drinking water standards

TABLE 2: ANALYTICAL RESULTS OF VOLATILE ORGANIC COMPOUND LEVELS FOUND IN SAMPLES COLLECTED FROM CATCH BASINS AND DISPOSAL WELLS AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK(September, 1986)

SAMPLE PARAMETERS	N.Y State Drinking Water, stds.	Instrument Detection Limits	N.Y State Drinking Water, stds.	Instrument Detection Limits	Sample#1 N.Babylon, N.Y.	VOC Field Blank 9/17/86	Sample#2 Plainview, NY	Sample#3 Seaford, N.Y	Sample#4 Westbury, N.Y.	Sample#5 Carle Place, N.Y.	VOC Field Blank 9/19/86	Sample#6 Plainview, N.Y
					Disposal Well(L,S)	Field Blank	Catch Basin(L)	Catch Basin(L)	Disposal Well(L)	Catch Basin(L)	Field Blank	Catch Basin(L)
VOLATILE ORGANICS, ug/l(ppb)												
Acrolein	50	10	50	10	50 U (s)2500 U	50 U	50 U	50 U	1700	4400	500 U	50 U
Acrylonitrile	50	10	50	10	50 U (s)2500 U	50 U	50 U	50 U	500 U	2500 U	500 U	50 U
Benzene	5	1	5	1	210 (s)280 J	5 U	27 B	57 B	180 B	3500	5 B	7
Bromomethane	50	5	50	5	10 U (s)1000 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U
Bromodichloromethane	50	1	50	1	5 U (s)1000 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
Bromoform	50	1	50	1	5 U (s)1000 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
Carbon Tetrachloride	50	1	50	1	5 U (s)1000 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
Chlorobenzene	50	1	50	1	4 J (s)9500	5	6	8	2 J	61	1 J	5 U
Chloroethane	50	5	50	5	10 U (s)1000 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U
2-Chloroethylvinyl ether	50	5	50	5	10 U (s)1000 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U
Chloroform	50	1	50	1	3 J (s)1000 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
Chloromethane	50	5	50	5	10 U (s)1000 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U
Dibromochloromethane	50	1	50	1	5 U (s)1000	5 U	5 U	5 U	5 U	50 U	5 U	5 U
1,1-Dichloroehtane	50	1	50	1	5 U (s)1000 U	5 U	5 U	5 U	15	50 U	2 U	5 U
1,2-Dichloroethane	50	1	50	1	8 (s)1000 U	5 U	6	5 U	5 U	50 U	5 U	5 U
1,1-Dichloroethylene	50	1	50	1	5 U (s)1500	5 U	3 J	5 U	12	50 U	5 J	5 U
trans-1,2-Dichloroethylene	50	1	50	1	5 U (s)1000 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
1,2-Dichloropropane	50	1	50	1	35 (s)1800	5 U	5 U	5 U	5 U	50 U	5 U	5 U
cis-1,3-Dichloropropene	2	1	2	1	5 (s)1000 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
trans-1,3-Dichloropropene	50	1	50	1	14 (s)1000 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
Ethylbenzene	50	1	50	1	140 (s)140000	5 U	66	60	150	1400	9	62
Methylene chloride	50	1	50	1	10 (s)3800	5 U	33	4 J	34	34 J	1 J	5
1,1,2,2-Tetrachloroethane	50	1	50	1	68	9	5 U	5 U	5 U	50 U	5 U	5 U

TABLE 2: ANALYTICAL RESULTS OF VOLATILE ORGANIC COMPOUND LEVELS FOUND IN SAMPLES COLLECTED FROM CATCH BASINS AND DISPOSAL WELLS AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK(September, 1986) - Continued

SAMPLE PARAMETERS	N.Y State Drinking Water, stds.	Instrument Detection Limits	N.Y State Drinking Water, stds.	Instrument Detection Limits	Sample#1 N.Babylon, N.Y.	VOC Field Blank 9/17/86	Sample#2 Plainview, NY	Sample#3 Seaford, N.Y	Sample#4 Westbury, N.Y.	Sample#5 Carle Place, N.Y.	VOC Field Blank 9/19/86	Sample#6 Plainview, N.Y
					Disposal Well(L,S)	Field Blank	Catch Basin(L)	Catch Basin(L)	Disposal Well(L)	Catch Basin(L)	Field Blank	Catch Basin(L)
VOLATILE ORGANICS, ug/l(ppb)												
Tetrachloroethylene	50	1	50	1	5 U (s)2100	5 U	1 J	5 U	52	50 U	5 U	1 J
1,1,1-Trichloroethane	50	1	50	1	54 (s)95000	5	26 B	10 B	120 B	640 B	21 B	5 B
1,1,2-Trichloroethane	50	1	50	1	5 U (s)580 J	5 U	5 U	5 U	5 U	50 U	5 U	5 U
Trichloroethylene	50	1	50	1	5 U (s)1000 U	5 U	1 J	5 U	5 U	50 U	5 U	5 U
Trichlorofluoromethane	50	11	50	11	5 U (s)1000 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
Toluene	50	1	50	1	9300 (s)150000	5 U	290 B	410 B	1300 B	8900	23 B	100
Vinyl chloride	5	5	5	5	10 U (s)1000 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U
1,2 Dichlorobenzene	50	1	50	1	9 (s)1000 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
1,3 Dichlorobenzene	50	1	50	1	7 (s)1000 U	1 J	5 U	5 U	5 U	50 U	5 U	5 U
1,4 Dichlorobenzene	50	1	50	1	8 (s)1000 U	5 U	5 U	5 U	300	210	5 U	5 U

(L)-Liquid Samples
(S)-Sediment Samples
-Ground Water Quality Standards, New York State Department of Environmental Conservation
(s)-Contaminant levels in Sediment Samples, ug/kg
U -sample concentration less than detection limit
J -Estimated value & less than detection limit
B - Analyte was found in method/instrument blank

TABLE 2: ANALYTICAL RESULTS OF VOLATILE ORGANIC COMPOUND LEVELS FOUND IN SAMPLES COLLECTED FROM CATCH BASINS AND DISPOSAL WELLS AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK(September, 1986) - Continued

SAMPLE PARAMETERS	N.Y State Drinking Water, stds.	Instrument Detection Limits	Sample#7 Cold Spr Harbor, N.Y	Sample#8 Deer Park, N.Y.	Sample#9 (Dup. of Sample#8)	VOC Field Blank 9/22/86	Percent Exceeding Standards	RELATIVE DIFFERENCE #8 v/s #9	MIN CONC. REPORTED	MAX CONC. REPORTED
			Disposal Well(L)	Catch Basin(L)	Catch Basin(L)	Field Blank				
VOLATILE ORGANICS, ug/l(ppb)										
Acrolein	50	10	1100	250 U	500 U	50 U	100%	66.7%	50	4400
Acrylonitrile	50	10	500 U	250 U	500 U	50 U	92%	66.7%	50	2500
Benzene	5	1	140	130	88	5	100%	38.5%	7	3500
Bromomethane	50	5	100 U	50 U	100 U	10 U	31%	66.7%	10	100
Bromodichloromethane	50	1	50 U	25 U	50 U	5 U	23%	66.7%	5	50
Bromoform	50	1	50 U	25 U	50 U	5 U	23%	66.7%	5	50
Carbon Tetrachloride	50	1	50 U	25 U	50 U	5 U	23%	66.7%	5	50
Chlorobenzene	50	1	50 U	25 U	50 U	5 U	23%	66.7%	2	61
Chloroethane	50	5	100 U	50 U	100 U	10 U	31%	66.7%	10	100
2-Chloroethylvinyl ether	50	5	100 U	50 U	100 U	10 U	31%	66.7%	10	100
Chloroform	50	1	50 U	25 U	50 U	5 U	23%	66.7%	3	50
Chloromethane	50	5	100 U	50 U	100 U	9 J	31%	66.7%	10	100
Dibromochloromethane	50	1	50 U	25 U	50 U	5 U	23%	66.7%	5	50
1,1-Dichloroethane	50	1	50 U	25 U	50 U	5 U	23%	66.7%	5	50
1,2-Dichloroethane	50	1	50 U	25 U	50 U	5 U	23%	66.7%	5	50
1,1-Dichloroethylene	50	1	50 U	25 U	50 U	5 U	23%	66.7%	3	50
trans-1,2-Dichloroethylene	50	1	86	6 J	18 J	5 U	15%	100.0%	5	86
1,2-Dichloropropane	50	1	50 U	25 U	50 U	5 U	23%	66.7%	5	50
cis-1,3-Dichloropropene	2	1	50 U	25 U	50 U	5 U	100%	66.7%	5	50
trans-1,3-Dichloropropene	50	1	50 U	25	50	5 U	23%	66.7%	5	50
Ethylbenzene	50	1	398	320	160	3 J	69%	66.7%	60	1400
Methylene chloride	50	1	11 J	25 U	50 U	6	8%	66.7%	4	50
1,1,2,2-Tetrachloroethane	50	1	50 U	25 U	50 U	5 U	31%	66.7%	5	68

TABLE 2: ANALYTICAL RESULTS OF VOLATILE ORGANIC COMPOUND LEVELS FOUND IN SAMPLES COLLECTED FROM CATCH BASINS AND DISPOSAL WELLS AT AUTOMOBILE SERVICE STATIONS IN LONG ISLAND, NEW YORK(September, 1986) - Continued

SAMPLE PARAMETERS	N.Y State Drinking Water, stds.	Instrument Detection Limits	Sample#7 Cold Spr Harbor, N.Y	Sample#8 Deer Park, N.Y.	Sample#9 (Dup. of Sample#8)	VOC Field Blank 9/22/86	Percent Exceeding Standards	RELATIVE DIFFERENCE #8 v/s #9	MIN CONC. REPORTED	MAX CONC. REPORTED
			Disposal Well(L)	Catch Basin(L)	Catch Basin(L)	Field Blank				
VOLATILE ORGANICS, ug/l(ppb)										
Tetrachloroethylene	50	1	50 U	18 J	30 J	5 U	23%	50.0%	1	52
1,1,1-Trichloroethane	50	1	300 B	70 B	190 B	32 B	46%	92.3%	5	640
1,1,2-Trichloroethane	50	1	50 U	25 U	50 U	5 U	23%	66.7%	5	50
Trichloroethylene	50	1	50 U	25 U	50 U	5 U	23%	66.7%	1	50
Trichlorofluoromethane	50	11	50 U	25 U	50 U	5 U	23%	66.7%	5	50
Toluene	50	1	1500	2500	1200	5	69%	70.5%	100	9300
Vinyl chloride	5	5	100 U	50 U	100 U	10 U	100%	66.7%	10	100
1,2 Dichlorobenzene	50	1	800	21 J	50 U	2 J	23%	81.7%	5	800
1,3 Dichlorobenzene	50	1	630	25 U	50 U	1 J	23%	66.7%	5	630
1,4 Dichlorobenzene	50	1	610	16 J	50 U	5 U	31%	103.0%	5	610

(L)-Liquid Samples
(S)-Sediment Samples
B -Ground Water Quality Standards, New York State Department of Environmental Conservation
(s)-Contaminant levels in Sediment Samples, ug/kg
U -sample concentration less than detection limit
J -Estimated value & less than detection limit
B - Analyte was found in method/instrument blank

TABLE 3

NATURAL PROCESSES THAT AFFECT SUBSURFACE CONTAMINANT TRANSPORT. (KELLEY, PIWONI, AND WILSON, 1986)

Physical processes
Advection (porous media velocity)
Hydrodynamic dispersion
Molecular diffusion
Density stratification
Immiscible phase flow
Fractured media flow
Chemical processes
Oxidation-reduction reactions
Radionuclide decay
Ion-exchange
Complexation
Co-solvation
Immiscible phase partitioning
Sorption
Biological processes
Microbial population dynamics
Substrate utilization
Biotransformation
Adaption
Co-metabolism

TABLE 4 : SYNOPSIS OF STATE REPORTS FOR AUTOMOBILE SERVICE STATION WASTE DISPOSAL WELLS(SIC 75)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	2 WELLS	N/A	YES	HIGH
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	2 WELLS	N/A	YES	LOW
Vermont	I	9 WELLS	N/A	YES	MODERATE/HIGH
New Jersey	II	18 WELLS	NJPDES PERMIT	YES	N/A
New York	II	3 WELLS	PERMIT	YES	HIGH
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	1 WELL	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	YES	PERMIT	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	5 WELLS	RULE	NO	N/A
Indiana	V	2 WELLS	N/A	NO	N/A
Michigan	V	27 WELLS	N/A	NO	N/A
Minnesota	V	NO	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	YES	N/A	NO	N/A
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	NO	N/A	NO	N/A
Iowa	VII	1 WELL	N/A	NO	HIGH
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	5 WELLS	N/A	NO	UNKNOWN
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	2 WELLS	BANNED	NO	6 (7=HIGHEST)
Wyoming	VIII	NO	N/A	NO	N/A
Arizona	IX	NO	N/A	NO	N/A
California	IX	NO	N/A	NO	N/A
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	YES	N/A	NO	HIGH
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	21 WELLS	RULE	NO	4TH HIGHEST/14 TYPES
Oregon	X	NO	N/A	NO	N/A
Washington	X	NO	N/A	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

[6-517]

BIOGRAPHICAL SKETCH

Mr. Basavaraj Mahadevaiah is currently serving as an underground pollution control engineer with Engineering Enterprises, Inc., Norman, Oklahoma. His responsibilities include investigating the impact of waste fluids on the subsurface due to injection practices at automobile service stations and industrial facilities. Mr. Mahadevaiah recently conducted generic assessments of automobile service station disposal wells and special drainage wells on a nationwide basis and evaluated the SPDES permit compliance system in New York for inclusion in the Report to Congress on Class V wells. He also provides technical support to other UIC and related projects, such as remediating sites contaminated by hydrocarbon and related petroleum products (from leaks and spills at automobile service stations, terminals and refineries). Mr. Mahadevaiah has conducted research in the biodegradation of petroleum hydrocarbons in shallow aquifers, at the Environmental and Groundwater Institute, University of Oklahoma, where he earned his M.S. degree in Civil Engineering. Mr. Mahadevaiah is a member of the Association of Groundwater Scientists and Engineers, American Society of Civil Engineers, and Chi Epsilon, the National Civil Engineering Honor Society.

Ms. Lorraine C. Council is currently Director of the Class V Injection Well program at Engineering Enterprises, Inc. in Norman, Oklahoma. Ms. Council earned a B.S. in Geology from the University of Oklahoma in 1982. Upon graduation, Ms. Council worked for the US Geological Survey in their Comprehensive Summer Field Training Program at sites in Wyoming, Montana, and Oregon. She has been with Engineering Enterprises, Inc. for the past five years, working on a variety of projects such as RCRA monitoring system design and implementation, municipal landfill siting and monitoring, oil recovery from large spills and leaks, and most recently, underground injection control.

SECTION 7

Recharge Wells

Section 7.1

Aquifer Recharge Wells Supporting Data

Section 7.1.1

TITLE OF STUDY: (or SOURCE OF INFORMATION)	"Class V Connector Wells," From Florida Underground Injection Control Class V Well Inventory and Assessment Report
AUTHOR: (or INVESTIGATOR)	Bureau of Groundwater Protection, Florida Department of Environmental Protection
DATE:	December, 1986
STUDY AREA NAME AND LOCATION:	Polk and Hillsboro Counties, Florida USEPA Region IV
NATURE OF BUSINESS:	Phosphate Mining
BRIEF SUMMARY/NOTES:	This excerpt from Florida's Class V report discusses the following topics concerning "Connector Wells": usage, well construction, and statistics; hydrostratigraphy and ground-water quality of the phosphate mining district; DER field investigations; data evaluation; and conclusions. Connector wells are used to convey groundwater from one aquifer to another, predominantly in the phosphate mining district in Florida. Parameters of concern include iron, and gross alpha radiation and the combined radium 226/228. According to this study, most of the connector wells do not receive water that grossly exceeds drinking water standards for most parameters, and far-field effects are not anticipated.

DRAFT

INTRODUCTION

Connector Well Usage and Construction

Usage

Class V connector wells are used to convey ground water from one aquifer to another. The predominant use of these interaquifer connector wells in Florida is in the phosphate mining district of Polk and Hillsborough counties (Figure C-1). The wells are usually located in open lands targeted for mining.

The Florida phosphate industry uses significant quantities of ground water in mining and processing activities. This ground-water usage has been identified as a major cause of a reduction in the potentiometric surface of the Floridan aquifer in the vicinity of the phosphate mining district in the early 1970's.

To offset this decline in the potentiometric surface of the Floridan aquifer, the phosphate industry began to construct inter-aquifer connector wells in areas to be mined. This practice has a two-fold benefit: it mitigates the decline in the Floridan aquifer potentiometric surface, and it also lowers the water table, resulting in improved mining conditions. The use of these connector wells, among other steps taken by the phosphate industry, has resulted in a significant mitigation in the decline of ground-water levels in the mining area. For example, Floridan aquifer potentiometric levels in the area south of Bartow, Florida in Polk County were about 10 to 25 feet higher in May 1980 compared to May 1975 (Kimrey and Fayard,1984).

Well Construction

The connector wells of the phosphate mining district are constructed to convey ground water from one aquifer to a lower aquifer. Most injection is from the surficial (water-table) aquifer to the lower Floridan aquifer (below the Tampa clay) (Kimrey and Fayard,1984).

Connector wells are typically 12 inches in diameter or greater (Upchurch,1984). The wells are usually cased with pvc pipe to the top of the Floridan aquifer carbonate rocks. The losing zone is commonly in the surficial sand aquifer, which is screened. The mining horizon is cased off, to avoid Floridan aquifer contamination by ground water in contact with phosphate ore. Figures C-2 and C-3 show the primary features of these Class V wells.

Statistics

The number of connector wells active in Florida is approximately 91, according to a Florida Department of Environmental Regulation 1986 computer database. Twenty four additional wells are located on the property of of the International Minerals & Chemicals Corporation (IMC); five other IMC wells are obstructed and receive no recharge (Cawley,1986). A number of the wells listed as active in the computer database may also be obstructed or have been destroyed by mining.

The total number of connector wells is down from a total of

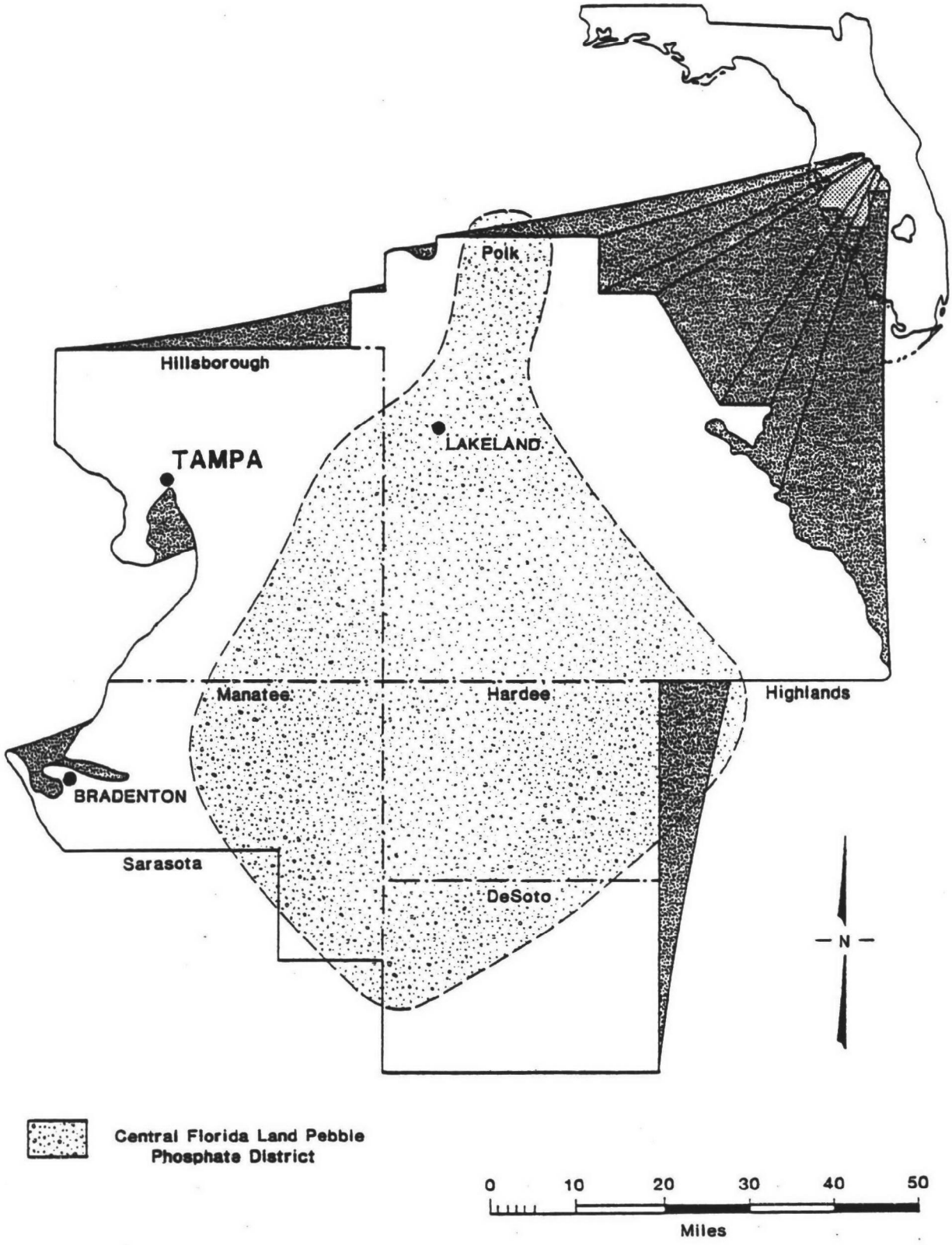

FIGURE C-1. GENERAL LOCATION OF THE CENTRAL FLORIDA PHOSPHATE DISTRICT

considerably over 100 wells in use during the late 1970s. The decline in the number of connector wells has occured due to a general decline in the phosphate industry as well as concerns over the quality of the water being conveyed down certain of these wells.

The injection rates for single connector wells range from less than 10 to over 600 gallons per minute (gpm), with most wells injecting from about 40 to 275 gpm (Kimrey and Fayard,1984). A summary for March 1980 indicated a total injection rate of about 26 million gallons per day for 142 wells in the central Florida phosphate district (Kimrey and Fayard,1984).

Hydrostratigraphy of the Phosphate Mining District

The hydrostratigraphy of the phosphate mining district can be separated into several aquifers and intervening aquitard strata. The shallowest aquifer is a predominantly sand aquifer known as the surficial aquifer. This aquifer is unconfined, and is a few tens of feet in thickness. The transmissivity of the aquifer, as reported from two pumping tests in the phosphate mining district, is about 15,000 gallons per day per foot (Hutchinson, 1978). The storage coefficient of the aquifer is about 0.29 (Hutchinson, 1978). The aquifer becomes increasingly clayey and phosphatic with depth, grading into the underlying Bone Valley strata. The potentiometric suface of this aquifer is, under natural conditions, at a depth of 10 feet or less over most of the phosphate mining district.

The Bone Valley Formation and a part of the underlying Hawthorn Formation more or less constitute an aquitard or leaky confining bed in the phosphate mining area. This interval is primarily a sandy clay. It constitutes the phosphate mining horizon and contains a variable amount of sand to pebble-size phosphate ore.

Underlying the phosphate mining horizon is an artesian aquifer which is identified as the upper Floridan aquifer by the U.S. Geological Survey. This aquifer is considered by the U.S. Geological Survey to be the permeable limestone and dolomite beds of the Hawthorn Formation and the Tampa Limestone, which are separated from the lower Floridan aquifer by the sand and clay unit of the Tampa limestone (Hutchinson,1978). The transmissivity of this aquifer is highly variable, ranging from about 75 to over 100,000 gallons per day per foot (Hutchinson,1978). The storage coefficient of the aquifer is representative of an artesian aquifer. The potentiometric surface of this aquifer is somewhat lower than that of the surficial aquifer.

Underlying the upper Floridan aquifer is a basal clay unit of the Tampa Formation.This clay acts as the lower confining bed for the upper Floridan aquifer and as the upper confining bed for the lower Floridan aquifer.

The lowermost hydrostratigraphic unit of concern in this report is the lower Floridan aquifer. This aquifer is the principal source of ground water in the phosphate mining district, and it is used to the virtual exclusion of other sources for public water supplies (Kimrey and Fayard,1984). As a result primarily of the well developed solution cavities within this carbonate-rock aquifer, transmissivities of over 1,000,000 gallons per day per foot are not uncommon in the lower

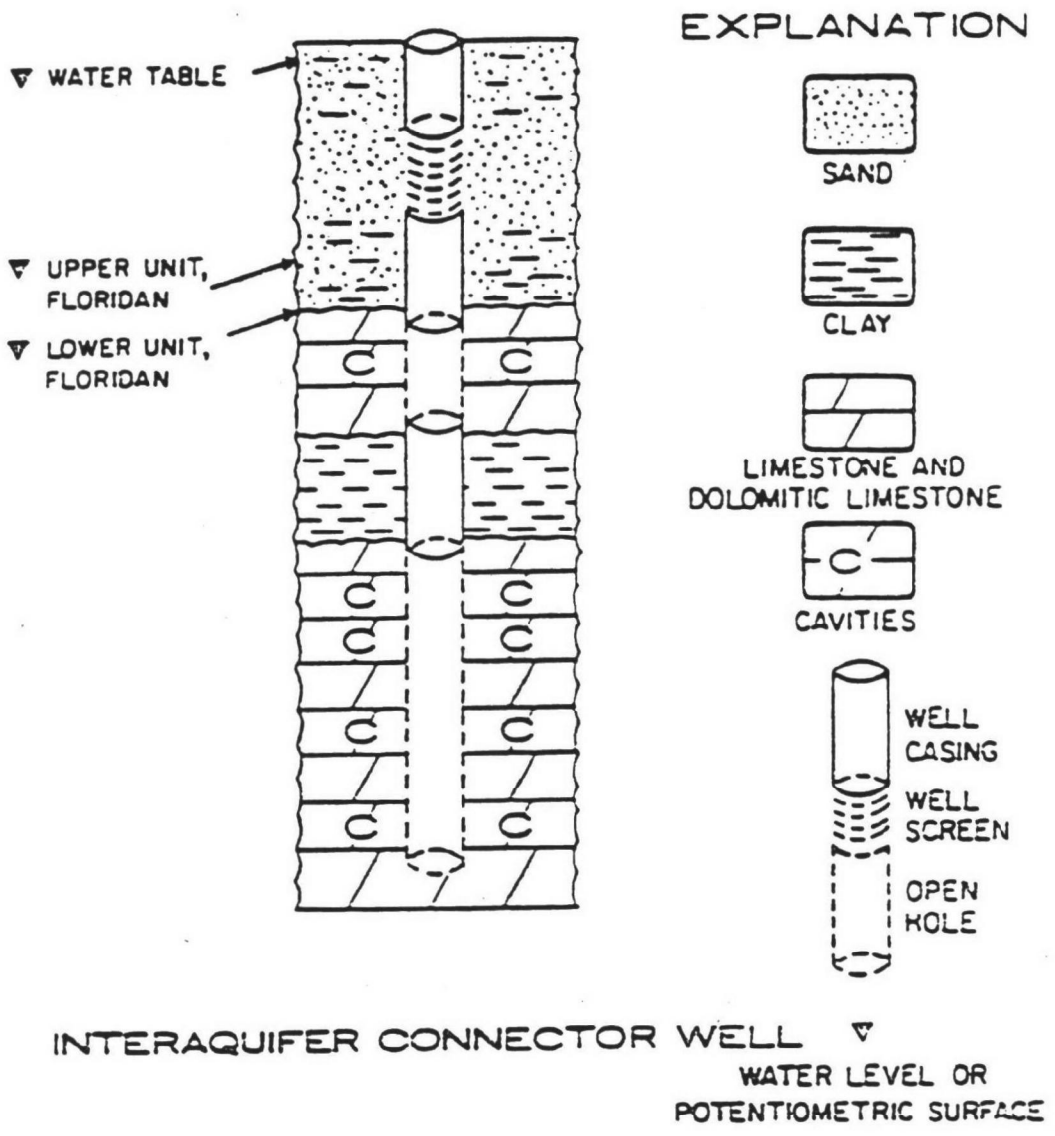

FIGURE C-2. CONSTRUCTION DETAILS OF CLASS V CONNECTOR WELLS IN THE CENTRAL FLORIDA PHOSPHATE DISTRICT (FROM KIMREY AND FAYARD, 1984)

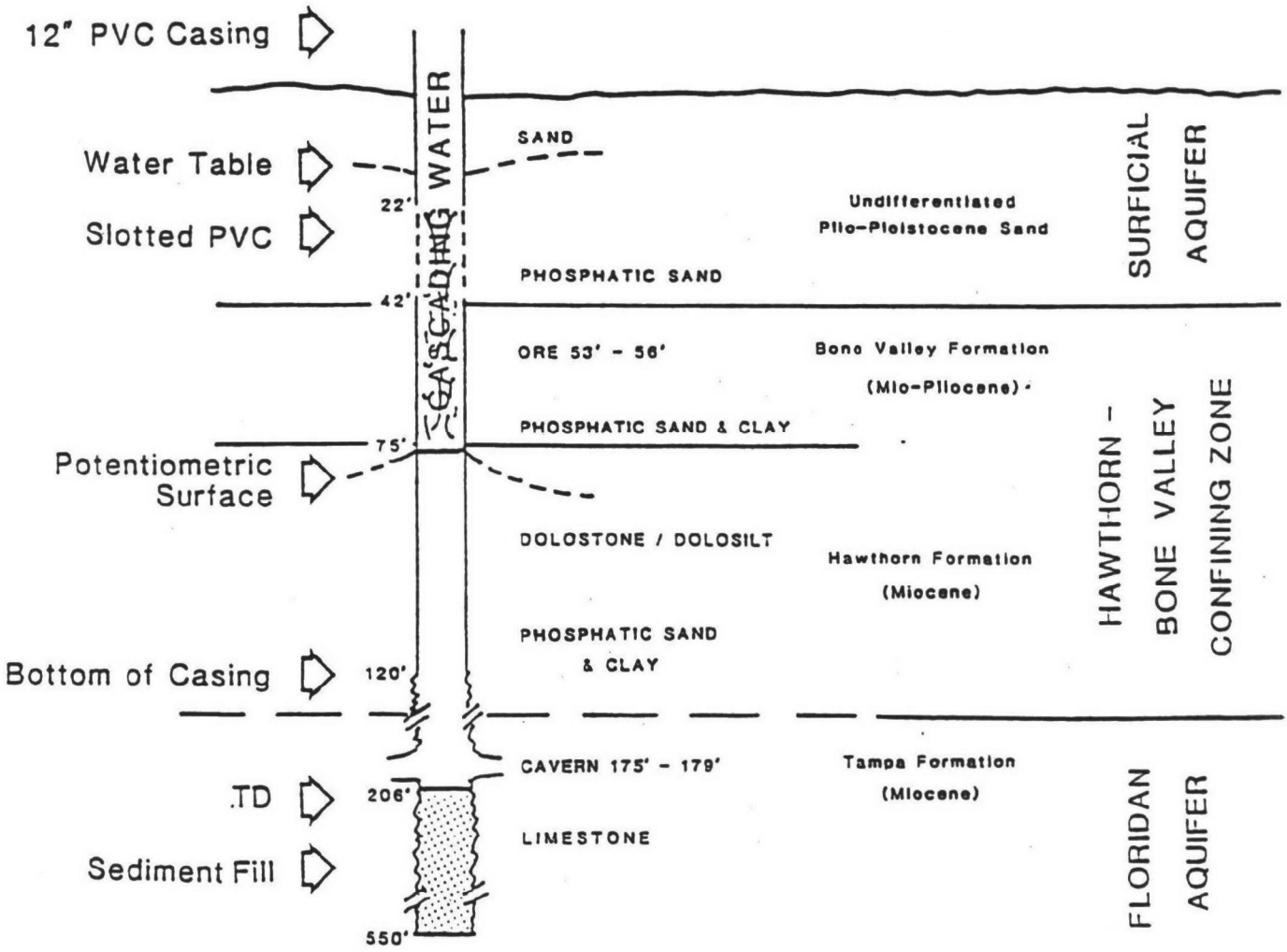

FIGURE C-3. CONSTRUCTION DETAILS OF A CLASS V CONNECTOR WELL IN THE CENTRAL FLORIDA PHOSPHATE DISTRICT (FROM OURAL, BROOKER, AND UPCHURCH, 1984)

Floridan aquifer. The aquifer potentiometric surface is generally lower than either the surficial or upper Floridan aquifer potentiometric surfaces.

In the lower Floridan aquifer, well-developed caverns commonly occur near the top of the aquifer (top of the Suwannee Limestone) and also near the Suwannee-Ocala Group contact (Upchurch,1984). These cavernous systems receive the connector-well recharge water which drains to the aquifer (Upchurch,1984).

Ground-Water Quality

Several investigators have evaluated the ground-water quality of the surficial and Floridan aquifers in the phosphate-mining district and the potential water-quality impacts from phosphate connector wells. Overall, both the Floridan and the surficial aquifers contain ground water of reasonably good quality. A comparison of the water quality of the surficial aquifer and the Floridan aquifer shows that Floridan aquifer ground water contains appreciably more sulfate and calcium than the surficial aquifer and has a higher pH (Oural et al,1984).The ground water in both aquifers is reducing and contains low concentrations of phosphate, sodium, fluoride, potassium and magnesium (Oural et al, 1984). The surficial aquifer contains a higher concentration of iron than does the Floridan aquifer.

The parameter of greatest concern in the operation of connector wells is the gross alpha radiation, which frequently exceeds drinking water standards in the surficial aquifer. Both the surficial and Floridan aquifers may contain concentrations of Radium-226 in excess of the primary drinking water standard for combined Radium 226/228 (Hutchinson,1978). However, the intervening Bone Valley and Hawthorn strata contain ground water with a considerably higher concentration of Radium-226 than either the Floridan or surficial aquifers (Oural et al,1984).

Much has been made of a so-called "gross-alpha anomaly" in the ground waters of the surficial aquifer within the phosphate district. A concern of one researcher was that the gross alpna activity of a surficial aquifer water sample would often greatly exceed that which would be predicted by the concentration of radium-226 alone. Following a review of the water-quality data generated by the Polk County Health Department Office of Radiation Control (1983), a consortium of phosphate mining interests sponsored a research program to determine why the gross alpha radiation in the Polk County samples was so high. The Florida Department of Environmental Regulation (DER) position was that the gross-alpha radiation was explainable by considering all of the 22 alpha-emitting radionuclides of the U238, U235 and Th232 decay series (Kell,1983).

The research sponsored by the phosphate industry consortium indicated that the "gross-alpha anomaly" was basically due to the activity of polonium-210 (Oural et al,1984). These researchers also reported that the polonium concentration decreases with increasing depth in the connector wells; thus, sample depth influences the measured gross-alpha radiation reported (Oural et al,1984).

The geochemical processes that occur once surficial aquifer ground water enters a connector well are important in determining the water

quality impacts to the Floridan aquifer. Ground water in the surficial aquifer is very reducing before entering a connector well. During well operation, the inside of the screen in the collection zone is commonly aerated, resulting in the growth of iron bacteria and the precipitation of iron oxyhydroxides on the screen (Oural et al,1984; Kimrey and Fayard,1984). As recharge waters cascade down the connector well to mix with the more alkaline ground water of the Floridan aquifer, continued precipitation of iron oxyhydroxides occurs (Oural et al,1984). Ferric hydroxide can sorb polonium-210 very strongly, but as the recharge water from a connector well enters the Floridan aquifer, the Eh begins to drop (Oural et al,1984). This drop in the Eh can result in the release of the polonium, as it tends to cause the ferric hydroxide to dissolve (Oural et al, 1984). However, polonium in the lower (+2) oxidation state is rapidly sorbed to clays and other particulates which are also introduced into the Floridan aquifer through the connector wells (Oural et al,1984). These researchers believe that the introduction of the polonium-210 through the connector wells generally has no significant effect on the gross alpha concentration in the Floridan aquifer away from the wells.

It is noteworthy that in more mineralized ground water than that normally associated with the surficial aquifer, other ions compete with radium-226 for ion exchange and adsorption sites on clays (Miller and Sutcliffe, 1984). This results in elevated concentrations of radium-226 in more mineralized ground water. In the surficial aquifer of nearby Sarasota County, water with a specific conductance of over 700 micromhos/cm, frequently contains over 5 picocuries per liter of radium-226 (Miller and Sutcliffe, 1984). This observation could have significant implications for the siting of connector wells near phosphate chemical plants, which are commonly associated with highly mineralized shallow ground water (Florida Department of Environmental Regulation, Bureau of Ground-Water Protection files).

Investigative Approach

Initially, the DER Bureau of Ground-Water Protection planned to rely upon a few selective case studies in our assessment of the Class V connector wells. Three connector wells, along with nearby surficial and Floridan aquifer monitoring wells, would be sampled and evaluated. Later it was clear, however, that this approach would not accurately represent either the entire population of connector wells now in use, or the potential for future connector wells to cause ground-water quality problems.

After a review of available literature, it became apparent that considerable data on the water quality of connector well water was available. This data was in essentially "raw" form; it had never been pieced together or compared source-to-source. Certainly, some water-quality parameters considered as possibly important in our evaluation were lacking in the existing data. However, available data was capable of yielding far more information about the overall water-quality impacts from connector wells than would the data generated by a thorough analysis of only three individual connector wells. Therefore, the existing data base was heavily relied upon for this assessment.

DER FIELD INVESTIGATIONS

Investigation Setting

The Department of Environmental Regulation's field investigation of Class V connector wells took place in March 1986 at the IMC Kingsford mine. This phosphate mining area is located in eastern Hillsborough and western Polk counties Florida, in the heart of the central Florida phosphate district.

Prior to the March 1986 well sampling, the Department of Environmental Regulation, in association with the University of South Florida, had constructed paired surficial/Floridan aquifer monitor wells near three operating connector wells. As these wells were the only monitor wells in such close proximity to connector wells and were available for sampling, the Depa·tment chose these three well sets (connector, surficial and Floridan monitor wells) for sampling. Well construction details and stratigraphic data from the monitor wells are included as Appendix C-1 of this report.

An initial sampling effort was made in February, 1986. This effort was abandoned due to equipment problems that occured in the field. A second sampling effort was initiated on March 13, 1986. The first set of wells selected for sampling was IMC well KR127 and the associated Floridan (KR127D) and surficial (KR127S) monitor wells. The discharge of surficial aquifer water down well 127 was not measured; however, previous flow measurements by IMC indicate a range in discharge for this well between 79 and 247 gallons per minute (gpm), with a median discharge of 110 gpm (IMC, 1985). This connector well has a metal surface casing 10 inches in diameter. The exact depth of the well was not measured; other connector wells at the Kingsford mine range from about 200 to 300 feet in total depth and were drilled into the upper Floridan aquifer (Geraghty & Miller, Inc., 1983).

Sampling Methods

All three wells were sampled using a clean bailer.The two monitor wells were purged before they were sampled. The field pH, specific conductance, and temperature were allowed to stabilize in the monitor wells before purging was considered complete. Because water was continually cascading down the connector well, well purging procedures were unnecessary to collect a sample of water at the top of the standing water level in this well.

Water samples were collected using appropriate bottles provided by the contract laboratory. Samples were preserved per laboratory instructions, and were kept following strict custody control. The samples were shipped to the contract laboratory the day after they were collected.

Parameters which were analyzed from the wells included several heavy metals, selected base/neutral organic compounds, several radionuclide parameters, anionic "indicator" parameters, total dissolved and suspended solids, plus field pH, specific conductance, and temperature. Analytical results are included in this report as Appendix C-2. Field filtration was done for soluble orthophosphate and radionuclide samples from all wells. The surficial aquifer well,

KR127S, produced copious amounts of silt and required the purging of over 20 bore volumes of water to yield even moderately turbid samples. Because this well continued to yield sediment, all samples from the well were field filtered.

A four-inch submersible pump was lowered into Well KR127D to purge the well. The well discharge was only about 1 gallon per minute, which is much less than the rated capacity of the pump. After pulling the pump out of the well, it was apparent that the wire cable used to support the pump in the well had constricted the discharge hose, thereby reducing the flow. As it turns out, this condition was fortuitous. Following several hours of well purging and 20 minutes of water-level recovery, the estimated water level in the well was at least 40 feet below the initial well water level. This residual drawdown indicates that the specific capacity of the well is much less than 1 gpm per foot of drawdown. If the discharge was not reduced by the constriction, the pump could have been damaged by unanticipated drawdown below the pump intake. Clearly, this well is not completed into a highly transmissive part of the Floridan aquifer. Therefore, it is unlikely that this well is monitoring the connector well injection zone.

Evaluation of Analytical Results

The analytical results presented in Appendix C-2 indicate about what was expected. The ground water in the surficial aquifer is somewhat acidic and has a hydrogen sulfide concentration that would make it objectionable for domestic purposes.The ground water in the upper Floridan aquifer sample also contains an objectionable amount of hydrogen sulfide. Otherwise, the groundwater from both the surficial and the upper Floridan aquifer is of fairly good quality. The sample from the connector well does show that the ground water in the surficial aquifer may contain gross alpha radiation in excess of the primary drinking water standard. The source material for the high gross alpna concentration in this sample is uncertain, as neither a polonium 210 or radium 226 concentration was detected in the sample. Radon gas is not included in the gross alpna analysis because the sample is evaporated before the gross alpha is determined (Standard Methods for the Examination of Water and Wastewater, 15th edition,1980). The radon gas concentration reported in the samples is within the range of concentrations normally found in ground water, based upon reported values in Davis and Dewiest (1966).

After sampling the first three wells, further equipment malfunction and inclement weather caused the field investigations to be terminated a second time. Before returning for a third time to sample wells at the IMC phosphate mine, it was decided that the limited sampling program that was prepared by our UIC staff could not reliably be used to predict the overall pollution potential of a much larger number of connector wells. Therefore, an evaluation of previously collected data was made, to develop a broader picture of the pollution potential of the Class V connector wells. This second approach is discussed in the following section of this report.

EVALUATION OF EXISTING DATA

Existing Data

From a review of the literature and files which were available in the DER-Bureau of Ground-Water Protection, three sets of ground-water quality data for wells in phosphate mining areas were found. These data were statistically evaluated to determine the average and range of concentrations of key parameters anticipated in connnector-well waters. Data included in each set were also compared to that in the other two sets, as a check on the validity of each data source.

The most extensive data set used for analysis is the "Recharge Well Database" (IMC Corporation, 1985). These data were provided to the Southwest District of the Department of Environmental Regulation by IMC Corporation, in support of their contention that phosphate connector wells pose little or no threat to the water quality of a receiving aquifer. The data include several hundred analyses from over 50 wells at the IMC Kingsford mine. Drinking-water parameters which were analyzed from wells on the IMC property over a seven-year time period are pH, coliform bacteria, iron, fluoride, sulfate, total dissolved solids, turbidity, nitrate, gross-alpha radiation, and radium-226.

Several problems are apparent with this data. First, many of the connector wells which were sampled by IMC are represented in the data base by only a few analyses. Thus, the analyses from those wells are not amenable to certain statistical tests. Secondly, the sample results reported in this data base were obtained from samples which were collected, handled, and analyzed without complete quality control procedures. It could also be argued whether such data provided by the phosphate company are unquestionably reliable. Regardless of these shortcomings, this database was evaluated in an attempt to determine what would be indicated by the presumably "best-case" data provided by a phosphate company.

The second data set evaluated is the analytical results reported by the Polk County Health Department, Office of Radiation Control, from their analyses of about 80 wells at several phosphate mines (Polk County Health Department, 1983). Data in this set includes analyses for radiation-related parameters only. Sampling and analytical methods are reported in the file document. Although the techniques used by Polk County were not entirely according to EPA-approved methods, they were accepted by the Department of Environmental Regulation's Groundwater Section as yielding essentially valid results (Kell, 1983).

The third data set evaluated in this report is data reported in the U.S. Geological Survey Water-Resources Investigations Report 84-4021 by Kimrey and Fayard. This report contains water-quality data from 13 connector well samples collected in 1980. Several drinking-water standard parameters are included in tne data set.

Evaluation of the IMC Data Set

Of the parameters reported in the IMC data set, pH, iron, fluoride, sulfate, total dissolved solids, gross-alpha radiation, and radium-226 are drinking-water parameters that are associated with phosphate mining and/or processing. A cursory review of the data

indicated that of these parameters, only total iron, gross-alpha radiation, and radium-226 may be parameters which frequently approach or exceed drinking-water standards in connector-well waters. The other parameters all exceed drinking-water standards on an occasional basis in some wells.

The three parameters total iron, gross-alpha radiation, and radium-226 were evaluated for wells in the IMC data set for which a sufficient number of observations were available to perform certain statistical tests. A relatively small number of radium-226 analyses were available for statistical testing because this parameter was usually only determined when the gross-alpha radiation of a sample equaled or exceeded the gross alpha drinking-water standard. Since the mean and range in concentration of parameters was so variable between individual wells and normality was not assured for any of the population distributions, statistical testing was performed on the mean values of iron, gross alpha radiation, and radium 226 for each well that was evaluated. This contrived sample population of mean values has a smaller variance than the underlying population from which it was drawn, and should be closer to a normally-distributed population, because it is similar to a sampling distribution of means (where each individual observation is sampled the same number of times). By evaluating data in the this manner, the results should be most representative of the population mean and variance. Appendix C-3 contains the data which were statistically evaluated to estimate the population mean and variance of each parameter.

Data evaluation was done using the Minitab Statistical Computing System, developed in the Department of Statistics at the Pennsylvania State University (Ryan et al, 1976). This statistical package allows for a number of relatively simple but computationally tedious statistical methods to be run easily by computer.

The printout of the data evaluation by Minitab is included in Appendix C-3 of this report. Parameter mean values for each of the 27 connector wells evaluated were summed and averaged by Minitab to yield the estimated population mean for that parameter. The standard deviation of each population of mean values from Appendix C-3 was also calculated by Minitab. The populations of mean values were also tested by Minitab for normality. Where a population was considered normal with a statistical significance of at least 0.1 alpha by Minitab analysis, a confidence interval about the mean value was calculated directly using Minitab. For the populations which were not considered normal, a logarithmic transformation of the data was made and this transformed population was tested for normality by Minitab. The populations of mean values for total iron and gross alpha radiation were log-normally distributed, while the population of mean values of radium 226 was normally distributed.

Table 1 shows summary statistics for the iron concentration of the sample population of connector wells at the IMC phosphate mine. Both the statistics for the log-transformed data and the raw data are shown.

Table 1. Summary Statistics for the Iron Concentration of the Population of Connector Wells at the IMC Mine

Mean Iron Concentration (raw data)	Standard Deviation (raw data)	Mean Iron Concentration (log-transform data)	Standard Deviation (log-transform data)
9.58 mg/l	12.65 mg/l	6.11 mg/l (95% confidence interval: 4.30-8.71 mg/l)	2.45 mg/l

In the population of logarithmically transformed average iron concentrations of the 27 connector wells (mean= 6.11 mg/l; standard deviation= 2.45 mg/l, log normally distributed), 16% of the population would be less than one standard deviation below the mean, (less than 3.66 mg/l). Only 2.5% of the population would be less than 2 standard deviations below the mean, (less than 1.21 mg/l). In any case, it is clear that the total iron concentration which is estimated for the population of connector wells at this phosphate mine is well above the 0.3 mg/l secondary drinking-water criterion.

Table 2 shows summary statistics for the gross alpha radiation of the sample population of connector wells at the IMC phosphate mine. Both the statistics for the log-transformed data and the raw data are shown.

Table 2. Summary Statistics for the Gross Alpha Alpha Radiation of the Population of Connector Wells at the IMC Phosphate Mine

Mean Gross Alpha (raw data)	Standard Deviation (raw data)	Mean Gross Alpha (log-transform data)	Standard Deviation (log-transform data)
9.81 pCi/l	7.45 pCi/l	8.00 pCi/l (95% confidence interval: 6.24-10.26 pCi/l)	1.87 pCi/l

For the log normal population of mean values of gross alpha radiation for the 27 connector wells at the IMC mine (population mean= 8.00 pCi/l; standard deviation= 1.87 pCi/l,log normally distributed), 16% of the population would be at least one standard deviation above the mean, or exceed 9.87 pCi/l. Only 2.5% of the population should exceed 2 standard deviations above the mean, or 11.74 pCi/l. However, it is apparent from the original population of mean values of gross alpha radiation that there is a higher probability that mean gross alpha radiation in a connector well will exceed the drinking water standard of 15 pCi/l. In fact, somewhat over 10% of the mean gross alpha values should exceed 15 pCi/l, based upon the sample distribution of mean values. The log-transformed data set is a normally- distributed population in which the higner values in the right skewed,

non-transformed population are not predicted by the population statistics.

As will be further discussed in a later section of this report, there are apparently localized spots at the IMC Kingsford mine which contribute water quality that is not well predicted by the statistical distribution. Thus,even though the gross alpha radiation in the ground water cascading down the connector wells at this locale is generally not cause for concern, certain "hot" wells are present. These wells may constitute a threat to the receiving aquifer water quality.

The radium 226 of the sample population of connector wells at the IMC mine is estimated to average 2.73 pCi/l, with a 95% confidence that the average is between 2.12 and 3.34 pCi/l. This parameter, unlike the gross alpha and total iron, was found to be normally distributed in the sample population when it was tested for normality by Minitab. Regrettably, many connector wells are represented by only one or two radium 226 analyses. However, the data show a small enough spread around the mean (coefficient of variation= 0.4) to assume that the underlying population is reasonably well represented by the data set. The standard deviation of 1.10 pCi/l indicates that for the assumed population, only about 2.5% of the radium 226 concentrations will exceed about 4.9 pCi/l, and 16% of the radium 226 concentrations exceed about 3.8 pCi/l. As the Florida drinking-water standard for radium of 5 pCi/l includes both radium 226 and radium 228 (Florida Department of Environmental Regulation, 1982), it is reasonable to assume that perhaps 5 to 10% of the connector wells in the population are draining ground water with excessively high radium concentrations into the Floridan aquifer. The Polk County data set which will be discussed in a later section of this report includes radium 228 data; this data suggests that radium 228 is a fairly uncommon constituent in the ground water draining through IMC connector wells.

Of more than passing interest is the existence of certain connector wells on the IMC property which exhibit water quality that is much worse than the average quality. The IMC "Recharge Well Database" contains several examples of such wells. For example, the reported September 1979 analysis from IMC well 7 indicates that the sample contained 4.7 mg/l of fluoride; 380 mg/l of sulfate; a total dissolved solids concentration of 780 mg/l; gross alpha radiation was 56 pCi/l; and radium 226 was 56 pCi/l. IMC well 3 had a sulfate concentration of over 2000 mg/l; a gross alpha concentration of 32 pCi/l; and a radium 226 concentration of 8.3 pCi/l when it was sampled in December 1980. Clearly these wells exhibit a gross violation of drinking-water quality standards. Such wells are prohibited under state regulations (Florida Department of Environmental Regulation, 1984). These wells may have been located within a ground-water contamination plume associated with the nearby IMC New Wales chemical plant. Their exact location is not known.

Overall, the IMC connector wells represented by the company water-quality data do not drain water that greatly exceeds water-quality standards when one considers most parameters which are associated with phosphate connector wells. However, high iron concentrations in the connector well water are common, and there have certainly been some IMC connector wells receiving water which is

characteristically in excess of the Florida primary drinking-water standards.

Evaluation of the Polk County Health Department Data Set

The data set from the Polk County Health Department represent the water quality with respect to radionuclides for a number of connector wells in the central Florida phosphate-mining district. These analyses tend to suggest that the quality of water draining down most of the connector wells on the IMC property is better with respect to radionuclides than the water draining into connector wells at some of the other phosphate mines. The reason for that trend is unclear; actual spatial variation in water quality, well construction practices, or sample collection and handling differences are all potential reasons.

Whatever the cause for the very poor water quality represented by samples from some of the wells in the Polk County data set, it is clear from this data set that the "hot well" concept suggested by the IMC data is even more strongly indicated by the Polk County data. A disparity in mean and median values for gross alpha radiation, soluble radium 226, and insoluble radium 226, as shown in Table 3 below, indicates that a small number of observations with relatively high parameter concentrations significantly influence the mean value. For example, the mean gross alpha value from the Polk County data (73 observations) is 95.4 pCi/l, while the median reported gross alpha value is only 18 pCi/l. Obviously, there are some wells with extremely high gross-alpha concentrations that influence the mean value of this parameter. In fact, over 20% of the wells sampled had gross alpha concentrations in excess of 100 pCi/l. Only about half the wells had gross-alpha concentrations below the drinking-water standard of 15 pCi/l.

Table 3. Comparison of Mean and Median Values of Gross Alpha Radiation, Soluble Radium 226, and Insoluble Radium 226, Polk County Data

Parameter	Mean Value	Median Value
Gross Alpha Radiation	95.4 pCi/l	18.0 pCi/l
Soluble Radium 226	4.1 pCi/l	1.0 pCi/l
Insoluble Radium 226	16.6 pCi/l	1.5 pCi/l

A similar disparity in mean and median values is indicated for the Polk County soluble radium 226 data. For 86 observations, the mean concentration for soluble radium 226 is 4.1 pCi/l, whereas the median value is only 1 pCi/l. Of the 86 values, only 9 observations (about 10% of the observations) exceed 5 pCi/l. For those 9 observations, the median soluble radium 226 concentration is 22.6 pCi/l. It is very apparent from a cursory review of these statistics that the sample population shows a skewed distribution to the right or even a bimodal-type distribution .

The mean value of insoluble radium 226 (84 observations) is much higher than the mean concentration of soluble radium 226 (16.6 pCi/l

versus 4.1 pCi/l), but a comparison of the median values indicates a relative parity (1.5 pCi/l versus 1 pCi/l). This comparison indicates that the sample population of insoluble radium 226 observations has a very pronounced distribution of a number of low values punctuated by a few very high observations. Of the 84 observations, 14 (about 17%) exceed 5 pCi/l. Of those 14 observations, the median value is 25.7 pCi/l, about the same as the median value of soluble radium 226 observations that exceed 5 pCi/l.

Considering both the soluble and insoluble radium 228 reported in the Polk County analyses, it is apparent that this parameter is in very low concentrations in virtually all wells. The mean and median concentrations of soluble radium 228 from 85 samples is less than 1 pCi/l; the mean concentration of insoluble radium 228 is below 1.2 pCi/l and the median value is under 0.6 pCi/l. Of the 85 observations, none had a soluble radium 228 concentration of over 5 pCi/l, and only one had a concentration of insoluble radium 228 in excess of 5 pCi/l. The much lower concentrations of radium 228 relative to radium 226 are explained by the fact that radium 228 is not a part of the uranium 238 decay series. Uranium 238 is the principal parent radionuclide found in the phosphate ore (Oural et al, 1984).

Combining all of the radium analyses to get the total percentage of samples with a radium concentration greater than 5 pCi/l, 33 out of 86 analyses or about 38% of the observations exceeded the drinking-water standard. This statistic can be evaluated furtner by making up a sample frequency distribution table for the observations where combined radium 226 and 228 exceeds 5 pCi/l (Table 4). This table shows that about half of the observations that exceed 5 pCi/l cluster at the low end of the scale (combined radium about 5 to 15 pCi/l) and few observations have over 30 pCi/l combined radium 226 and 228. However, 8% of the observations exceed 50 pCi/l, indicating that there is somewhat of a bimodal distribution of the combined radium concentration observations. Thus, even if there is no real significance to a combined radium concentration in connector-well water that slightly exceeds the drinking-water standard, there are many wells represented by this sample population with combined radium concentrations more than ten times the drinking-water standard.

Table 4. Frequency Distribution for Number of Observations that Exceed 5 pCi/l Combined Radium 226 and 228; Polk County Data

Percentage of Observations With At Least 5 pCi/l Radium	Percentage of Observations With at Least 15 pCi/l Radium	Percentage of Observations With at Least 30 pCi/l Radium	Percentage of Observations With at Least 50 pCi/l Radium
38%	19%	11.4%	8%

Evaluation of the USGS Data Set

The data set included in the U.S. Geological Survey Water-Resources Investigations Report 84-4021 consists of the analyses of 13 connector

wells which were sampled in 1980. These wells were located in the central Florida phosphate mining region. The wells were sampled by pumping from about 20 to 30 feet below the static water level in the well.

The wells that were sampled showed the following ranges and median concentrations of phosphate-related parameters:

Table 5. Concentrations of Phosphate-Related Parameters in the U.S.G.S. Data Set (Data Selected from a Larger Data Set)

Parameter	Range of Concentration		Median Concentration	
pH	4.3-7.1		6.3	
Sulfate	0.2-2600	mg/l	7.8	mg/l
Fluoride	0.2-1.6	mg/l	0.6	mg/l
Sodium	3.2-400	mg/l	6.9	mg/l
Arsenic	0.0-110	ug/l	2.0	ug/l
Barium	<50-100	ug/l	100	ug/l
Cadmium	0.0-9.0	ug/l	0.0	ug/l
Chromium	10 -20	ug/l	10	ug/l
Iron	110-25000	ug/l	1200	ug/l
Lead	1.0-36	ug/l	4	ug/l
Manganese	10 -710	ug/l	10	ug/l
Silver	0.0-0.0	ug/l	0	ug/l
Selenium	0.0-1.0	ug/l	0	ug/l
Mercury	<0.1-0.7	ug/l	0.1	ug/l
Radium 226	0.34-8.9	pCi/l	0.95	pCi/l
Gross Alpha Radiation	<3.3-850	ug/l	12	ug/l
Dissolved Uranium	0.06-11	ug/l	0.7	ug/l
Conductivity	185-4850	micromhos/cm	310	micromhos/cm

From this data, the authors report that the concentration of total iron exceeded applicable drinking-water standards in 11 of 12 wells. The gross alpha radiation exceeded standards in 6 of 12 connector wells. Other parameters in the data set were either below drinking-water standards or were exceeded by only one or two observations.

Similar to the other two sets of connector well data, the USGS data for gross alpha radiation concentration suggests that this parameter is not normally distributed. The mean value for this parameter is 88.8 ug/l, compared to a median value of only 12 ug/l. Although less pronounced than gross alpha radiation in the difference in mean and median values, the mean value of radium 226 is higher than the median value (2.01 pCi/l versus 0.95 pCi/l), and the dissolved uranium mean and median values also vary significantly (1.74 ug/l versus 0.7 ug/l). These observations suggest that for each of these radiation-related parameters, a small percentage of observations in the population of connector wells have parameter concentrations that are significantly higher than the median value for the parameter. Interestingly, there is no significant correlation ($r<0.1$) between any of these three

parameters when linear regression is performed on this data set. This condition indicates that the concentration of only one of the parameters does not indicate the approximate concentration of either of the other two parameters.

One connector well exhibits water quality that is indicative of ground-water contamination found in the surficial aquifer in the vicinity of phosphate chemical processing plants. Especially indicative of this contamination source is the sample's ammonia nitrogen concentration, as phosphate chemical plants may produce nitrogen-based fertilizers. These plants are found in the phosphate-mining district, near or sometimes even overlying a former phosphate mining area. As is obvious from the following table, ground-water contamination by these pollution sources often contains very high concentrations of major inorganic parameters and heavy metal ions.

Table 6. Concentrations of Select Parameters In a Connector Well that Apparently Receives Recharge from a Phosphate Chemical Plant Waste Disposal System Contaminant Plume

pH	4.3		Iron	25000	ug/l
Ammonia Nitrogen	160	mg/l	Lead	8	ug/l
Sodium	400	mg/l	Manganese	710	ug/l
Dissolved Residue	3580	mg/l	Mercury	0.2	ug/l
Sulfate	2600	mg/l	Arsenic	2	ug/l
Chloride	20	mg/l	Cadmium	8	ug/l
Fluoride	1.6	mg/l	Chromium	20	ug/l
Radium 226	8.9	pCi/l	Gross Alpha Radiation	99	ug/l

Certainly, any connector well that was located within a discharge plume from this type of pollution source could receive very poor quality water. For example, ground-water samples from surficial aquifer monitor wells within such a contamination plume have shown sulfate and fluoride concentrations in excess of 5000 mg/l, sodium concentrations of over 2000 mg/l, pH values below 2, and chromium concentrations that are 40 times the primary drinking-water standard (Florida Department of Environmental Regulation, Bureau of Ground Water Protection files). Numerous other contaminants have also been documented in very high concentrations in monitor well samples from wells near phosphate chemical plants.

CONCLUSIONS OF THE STUDY

As a group, Class V connector wells appear to constitute little threat to the receiving aquifer, other than in the immediate area around a well. Although ground water from the surficial (source) aquifer drained by these wells generally does not meet all primary and secondary drinking-water standards, most wells drain water that greatly exceeds only the drinking-water standard for iron, and water that meets or only slightly exceeds the drinking-water standard for other parameters.

Other than iron, the parameters of greatest concern in the connector well waters are gross alpha radiation and the combined radium 226/228. As a "best-case" estimate, using industry-supplied data, about 10% of the connector wells may be expected to receive ground water that commonly exceeds the 15 pCi/l standard for gross alpha radiation. The industry-supplied data indicates that such wells generally receive water that only slightly exceeds the standard for gross alpha radiation. Data from other sources indicate that some 10% to 20% of the connector wells receive ground water that greatly exceeds the standard for gross alpha radiation, and another 30% to 40% of the wells receive ground water that slightly exceeds that standard.

The concentration of combined radium 226/228 exceeds the primary drinking water standard in about 10% of the connector wells, considering both the industry-supplied data and data collected by the U.S. Geological Survey. A third data base indicates that almost 10% of the connector well waters greatly exceed the combined radium 226/228 standard in samples analyzed for both dissolved and suspended radium. Analytical results from that data base indicate that at least 75% of the connector wells drain water that is below or only slightly above the drinking water standard for radium.

Of considerable interest is the existence of two subsets of connector wells draining ground water with unusually high concentrations of some drinking water standards. One such type of well receives ground water with extremely high levels of one or more radionuclide parameters. Possibly 10% of the connector wells are in this category. The cause for the high levels of radionuclide parameters is unclear, but is almost certainly either a result of "hot spots" within the surficial sand aquifer and/or is the result of poor well construction that allows poor quality water from the phosphate ore horizon to enter the receiving aquifer.

To minimize the occurence of connector wells draining water with high levels of radionuclide parameters, ground water in the surficial aquifer should be thoroughly analyzed in advance of connector well construction, and all new connector wells should be properly constructed and routinely sampled. More attention to well construction and maintenance would also improve well performance and prevent suspended solids, which may include phosphatic sediment, from entering the connector wells.

The second group of connector wells that may drain water of extremely poor quality are wells that are constructed within a ground-water contamination plume from a phosphate chemical plant waste disposal area. Such wells may receive ground water tnat is extremely contaminated by a variety of parameters including heavy metals, major ions such as sulfate and sodium, and radionuclides. These areas of shallow ground-water contamination should be avoided in siting connector wells.

The ultimate impact of the Class V connector wells has not been determined in this study. Most of the connector wells are located thousands of feet from any Floridan aquifer production wells other than those owned by the phosphate mining companies. Samples from Floridan aquifer wells on phosphate company properties have not indicated that there is any ground-water contamination tnat can be attributed to connector wells. In any case, most of the connector wells do not

receive water that grossly exceeds drinking water standards for most parameters, and far-field effects are not anticipated for those wells. For wells that do receive water which grossly exceeds drinking water standards, more research would be needed to determine if those wells are a potential source of ground-water contamination that would threaten drinking water wells. Because such connector wells are perceived as a potential threat to the receiving aquifer, they would not be permitted by DER. There are only about 90 active connector wells and their geographic extent is limited to a small area within the state. Therefore, these Class V wells presently constitute a relatively minor threat to the ground-water resources of the state.

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Section 7.1.2

TITLE OF STUDY: (or **SOURCE OF INFORMATION**)	Assessment of Irrigation Dual Purpose Wells
AUTHOR: (or **INVESTIGATOR**)	Ben K. Knape, Texas Dept. of Water Resources
DATE:	December, 1984
STUDY AREA NAME AND LOCATION:	High Plains, Texas USEPA Region VI
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	This excerpt describes irrigation and recharge projects in the High Plains of Texas. Recharge wells are used to drain playa lakes and to recharge aquifers to meet municipal and agricultural needs. Two wells were sampled to analyze water being injected into the aquifer. Results indicate that injected water may be of better quality than that of the receiving aquifer. This suggests a very minimal impact on the aquifer locally from agricultural pesticides.

Excerpt from Texas Department of Water Resources, 1984, Underground Injection Operations in Texas: A Classification and Assessment of Underground Injection Activities.

Assessment of Irrigation Dual Purpose Wells

Dual purpose wells, the most common type of artificial recharge installation in the State, are found throughout the High Plains of Texas. This type of well is used to recharge groundwater aquifers when surface water is in surplus, but may also be used to pump water from an aquifer to meet municipal and agricultural needs. Since the 1950's, recharge wells have also aided farmers in draining standing water from playa lakes. When these lakes are drained, additional fertile land is made available for farming. The wells are drilled so that lake water that is normally lost to evaporation is allowed to pass through the impermeable clay layer at the bottom of the playa lake and recharge the aquifer.

During the early 1970's, there were approximately 200 artificial recharge wells in existence, however, only a few are presently operating. The few remaining dual purpose wells in operation generally inject water by gravity flow. When needed, pumps may be used to increase recharge rates and remove excess water from playa lakes. Ten existing wells were inventoried in the High Plains, two of the wells were sampled to analyze water being injected into the aquifer. Wells investigated by the Department staff are considered representative of recharge wells on the Texas High Plains.

The decline in use of recharge wells can be attributed to problems with sediment-laden water found in playa lakes. Due to these sediment problems, many privately owned and operated dual purpose wells failed within 5 to 10 years. Preventative measures in well construction are required to control the clogging effect caused by sediment. Casing is perforated or a screen is used, depending upon the subsurface geology or individual operator's preferences. The well is commonly equipped with a valve to control recharge flow through the intake line, down the casing and into the aquifer. In addition, water can be pumped back to the surface for irrigation use.

No data are available on the injection volumes of dual purpose wells. These injection volumes will depend upon rainfall runoff, the efficiency of the well design, and the permeability of the injection formation.

Chemical analyses of water samples taken from the High Plains aquifer are shown in Table 1. The High Plains aquifer was sampled near Lamesa in Dawson County and in Levelland in Hockley County. Comparison of aquifer water samples with corresponding recharge water samples (Table 2) suggests that injected water may often be of better quality than that of the receiving aquifer. Table 3 indicates very low levels of organic chlorides in the two High Plains recharge water samples. This suggests a very minimal impact on the aquifer locally from agricultural pesticides. Dual purpose irrigation and recharge wells on the High Plains are therefore assessed to have very low potential for contamination

of underground supplies of drinking water, provided that care is taken to keep agricultural and industrial pollutants and domestic and municipal wastes out of playas which collect recharge water.

Table 1. Chemical Analyses of Aquifer Waters (Constituent concentrations are in mg/l.)

	Dawson Co. Well (near Lamesa)	Hockley Co. Well (in Levelland)
Injection zone	Ogallala	Ogallala
State well number	28-17-103	24-30-401
Date sample collected	7/17/75	7/7/80
Well depth (feet)	156	211
Nitrate (NO_3)	43	8.4
Silica (Si)	70	50
Calcium (Ca)	61	60
Magnesium (Mg)	53	88
Sodium (Na)	65	61
Potassium (K)	8	--
Bicarbonate (HCO_3)	375	337
Sulfate ($SO4$)	81	218
Chloride (Cl)	68	86
Fluoride (F)	4.5	4.4
pH	7.8	8.4
Dissolved Solids (sum)	637.8	741.5
Specific Conductance (micromhos at 25°C)	935	1,002

Table 2. Chemical Analyses of Recharge Waters (Constituent concentrations are in mg/l.)

	Dawson Co. Well (near Lamesa)	Hockley Co. Well (in Levelland)
Injection zone	Ogallala	Ogallala
Water level (feet)	70	130
Date sample collected	4/27/82	4/27/82
Well depth (feet)	250	225
Nitrate (NO_3)	0.04	0.04
Silica (Si)	2	2
Calcium (Ca)	39	27
Magnesium (Mg)	3	7
Sodium (Na)	25	15
Potassium (K)	6	6
Carbonate (CO_3)	0	6
Bicarbonate ($HCO3^)$	113	87
Sulfate (SO_4)	32	24
Chloride (Cl)	33	20
Fluoride (F)	0.3	0.5
pH	8.3	9
Dissolved Solids (sum)	206	154
Specific Conductance (micromhos at 25°C)	331	251

Table 3. Organic Chloride Concentrations in Recharge Waters (Concentrations are in micrograms per liter)

	Dawson Co. Well (near Lamesa)	Hockley Co. Well (in Levelland)
Aldrin	0.02	0.02
Chlordane	1	1
DDD	.25	.25
DDE	.2	.2
DDT	.27	.27
Diazinon	.3	.3
Dieldrin	.1	.1
Endrin	.2	.2
Heptachlor	.02	.02
Heptachlor epoxide	.06	.06
Lindane	.03	.03
Methoxychlor	.5	.5
Methal parathion	.25	.25
Parathion	.25	.25
Toxaphene	5	5
PCB	1	1
Malathion	.4	.4
Diethylhexyl phthalate	50	50
Dibutyl phthalate	5	5
Guthion	10	10
Ethyl parathion	.25	.25
Trifluralin	.06	.06

Analyzed by the Texas Department of Health.

Section 7.1.3

TITLE OF STUDY: (or **SOURCE OF INFORMATION**)	National Artificial Recharge Activity-Past and Present Projects, Demonstrations, Pilot Projects, Experiments, and Studies
AUTHOR: (or **INVESTIGATOR**)	O'Hare, et al.
DATE:	1986
FACILITY NAME AND LOCATION:	Not Applicable
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	The following information was taken from Artifical Recharge of Ground Water and describes numerous recharge projects throughout the United States.

The following information was taken from Artificial Recharge of Ground Water, by O'Hare, et al., 1986.

National Artificial Recharge Activity - Past and Present Projects, Demonstrations, Pilot Projects, Experiments, and Studies. (See Figure 4-68)

ALASKA

1. Anchorage - Experiments with spreading basins allowing infiltration of diverted creek water (Anderson, 1977; Guymon, 1972).

ARIZONA

2. Lower Oak Creek Basin - Study of recharge potential of stock tanks capturing storm water runoff.*

3. Flushing Meadows, Phoenix - Pilot project to study feasibility of renovating secondary effluent with spreading basins (Pettyjohn, 1981).

4. Phoenix - Urban study, by the U.S. Army Corps of Engineers, to explore potential recharge.*

5. Salt River - Study of potential for recharge.*

6. Gila Bend - Debris pool of Painted Rock Reservoir released for artificial recharge through basins.*

7. Superior - Study of management considerations for artificial recharge along Queen Creek.*

8. Tucson - Experimental study with pit recharge.*

9. Tucson - Urban study, by the U.S. Army Corps of Engineers, to explore potential for recharge.*

ARKANSAS

10. Arkansas County - Experimental recharge injection wells to rejuvenate aquifer, discontinued 1969 (International Association of Scientific Hydrology, 1970).

* Hydrologic Engineering Center, 1984.

11. Newport - Disposal of groundwater, pumped for cooling system, through injection wells (International Association of Scientific Hydrology, 1970).
12. Fayetteville - Study of potential methods of artificial recharge in the Grand Prairie (Griffis, 1976).

CALIFORNIA

13. Butte Valley*
14. Santa Clara Valley*
15. Livermore*
16. Gilroy - Hollister Valley*
17. Salinas Valley*
18. Santa Maria Valley*
19. San Joaquin Valley*
20. Santa Clara River Valley*
21. San Fernando Valley*
22. Los Angeles Coastal Plain*
23. San Gabriel Valley*
24. Orange County Coastal Plain*
25. Upper Santa Ana Valley (Koehler, 1983)
26. San Jacinto Basin*
27. San Gorgonio Pass Area - Underground storage of imported water (Bloyd, 1969)
28. Santa Cruz and Monterey Counties, Pajaro Valley - Artificial recharge and sea water intrusion prevention (Muir, 1974).
29. Upper Coachella Valley - Artificial recharge effects (Swain, 1978).

COLORADO

30. Brush - Recharge of irrigation water, during non-irrigation seasons, through pits.*

* Hydrologic Engineering Center, 1984.

31. Denver - Study of potential recharge methods for the South Platte River Basin.*

32. Fort Morgan - Recharge of irrigation water, during non-irrigation seasons, through pits.*

33. Fort Garland - Recharge of irrigation water, during non-irrigation seasons, through pits.*

34. Morgan County - Proposed artificial recharge project diverting water from the South Platte River (Burns, 1980).

35. Prewitt - Recharge of irrigation water, during non-irrigation seasons, through pits.*

36. Arikaree River Near Cope (Brookman and Sunada, 1968).

37. San Luis Valley - Artificial groundwater recharge (Sunada et al., 1983).

38. Sterling - Recharge of wastewater effluent during winter months.*

39. El Paso County - Tests with recharge pits in Upper Squirrel Creek Basin (Emmons, 1977).

40. Kit Carson County - Evaluation of water availability (Jenkins and Hofstra, 1970).

DELAWARE

41. New Castle County - Possibility of a large-scale artificial groundwater recharge project to insure adequate water supply (University City Science Institute, 1971).

FLORIDA

42. Okaloosa County and adjacent area - Consideration of artificial recharge (Trapp el al., 1977).

43. Hillsborough County - Feasibility of artificial recharge (Sinclair, 1974).

44. East Orange County - Experiments and studies of connector well to allow water from shallow aquifer to recharge lower Floridan aquifer (Bush, 1979).

45. Orlando - Recharge through drainage wells (Kimrey, 1978).

* Hydrologic Engineering Center, 1984.

46. St. Petersburg - Feasibility tests with subsurface injection of storm water runoff through wells (Hickey and Barr, 1979).

47. Gainesville - Study of potential of combining flood control with artificial recharge in Peninsular Florida.*

48. Cocoa - Feasibility tests with recharge through injection wells to prevent saltwater intrusion (Tibbals and Frazee, 1976).*

49. Tampa Bay - Experiments to determine optimum method of recharge (Sinclair, 1977).

50. Lake Manatee - Recharge recovery (CH2M-Hill, 1984)

51. St. Lucie County - Artificial recharge of fresh water into brackish water aquifer (Wedderburn and Knapp, 1983).

HAWAII

52. Kahului (Maui) - Recharge of wastewaters through injection wells (Hargis and Peterson, 1974).

53. Hanapepe (Kauai) - Recharge of streamwater through wells (Hargis and Peterson, 1970).

54. Island of Hawaii - Recharge of streamwater through wells (Hargis and Peterson, 1970).

55. Pearl Harbor - Recharge of streamwater (Hirashima, 1971).

IDAHO

56. Snake River - Proposed project to divert waters from the Snake River for artificial recharge (Norvitch et al., 1969).*

57. Big Lost River - Disposal of low-level aqueous radioactive wastes through injection wells (International Association of Scientific Hydrology, 1970).

ILLINOIS

58. Peoria - Recharge with pits to prevent decline of groundwater levels (Pettyjohn, 1981; Harmeson et al., 1968).

59. Chicago Suburbs - Cost effective water supply alternative for the Chicago suburban area - Artificial recharge (Nielson and Aller, 1983).

* Hydrologic Engineering Center, 1984.

KANSAS

60. Groundwater Management District No. 1 - Pilot recharge site using impoundments.*

61. Groundwater Management District No. 2 - Pilot recharge site using pit infiltration basin with sedimentation trap.*

62. Groundwater Management District No. 3 - Several pilot recharge sites using various methods.*

63. Groundwater Management District No. 4 - Numerous pilot recharge sites using various methods.*

64. Groundwater Management District No. 5 - Pilot recharge site using channel modification.*

LOUISIANA

65. Baton Rouge - Recommendation to institute a program to construct reservoirs for direct water supply and artificial recharge.*

66. Jefferson Parish - Underground storage of treated water, a field study (Smith and Hanor, 1975).

MASSACHUSETTS

67. Statewide - Feasibility of increasing water supplies and preventing environmental damage by artificial recharge in Massachusetts (Motts et al., 1983).

MICHIGAN

68. Kalamazoo - Recharge by induced infiltration to prevent decline of water table (Pettyjohn, 1981).

69. East Lansing-Meridian Township - Surface water-esker recharge study (Sutherland and Bruce, 1977).

70. Clinton, Eaton, and Ingham Counties - Consideration of artificial recharge in water management (Vanlier, Wood, and Burnett, 1973).

MINNESOTA

71. St. Paul - Tests to determine feasibility of recharge with injection wells.*

* Hydrologic Engineering Center, 1984.

MONTANA

72. Old West Regional Commission - Artificial recharge project (Smith, 1977).

NEBRASKA

73. Aurora - Investigation of potential for recharge through injection wells (Lichtler, Stannard, and Kouma, 1979).

74. Little Blue Natural Resources District - Project with recharge of floodwaters under construction.*

75. Lincoln - Economic evaluation of the feasibility of artificial groundwater recharge in Nebraska (Supalla, 1981). Artificial recharge through injection wells (Marlette, 1968).

76. Tryon - Recharge with stock tanks.*

77. Upper Big Blue Natural Resources District - Proposed project to divert Platte River water for recharge.*

NEVADA

78. Cold Spring Valley - Study to determine feasibility of recharge by injection methods.*

NEW JERSEY

79. Malbaro - Storage of municipal water in a recharge well.*

80. Wildwood - Injection of freshwater during off-season to meet peak demands during the summer months.*

81. Princeton - Artificial recharge through augmented bank storage (Dewiest, 1967).

NEW MEXICO

82. Santa Clara Indian Reservation - Artificial aquifer used to retain waters infiltrating from surface (Pettyjohn, 1981).

83. Southern High Plains of New Mexico - Study of potential artificial recharge systems using playa lake water (Brown et al., 1978).

* Hydrologic Engineering Center, 1984.

NEW YORK

84. Bay Park - Recharge by injecting reclaimed waters through wells (Ku et al., 1975; Ragone, 1977).

85. Long Island, Nassau County - Stormwater basins used for recharge (Aronson, 1978).

NORTH CAROLINA

86. Coastal Plain - Artificial recharge in aquifer management (Sherwani, 1980).

NORTH DAKOTA

87. Glenburn - Subsurface dam retains groundwater in sand and gravel aquifer (Pettyjohn, 1981).

88. Minot - Injection of river water through shafts (Pettyjohn, 1981).

89. Valley City - Water diverted from river to recharge pit (Pettyjohn, 1981).

90. Old West Regional Commission - Artificial recharge project (Smith, 1977).

OHIO

91. Canton - Recharge with collector well connecting upper and lower aquifers (Pettyjohn, 1981).

92. Dayton - Lagoons and ditches flooded to allow infiltration of diverted river water (Pettyjohn, 1981).

93. Mill Creek Valley - Potential of injection well recharge studied (Fidler, 1970).

OKLAHOMA

94. Oklahoma Panhandle - Examination of potential for recharging the Ogallala Aquifer.*

95. Southwest Oklahoma - Recharge to dilute fluoride groundwater proposed (Pettyjohn et al., 1982).*

* Hydrologic Engineering Center, 1984.

OREGON

96. Dalles - Minor recharge project, closed down recently.*

97. Salem - Tests to determine feasibility of injection well recharge (Foxworthy, 1970).

SOUTH DAKOTA

98. Sioux Falls - Modification of channel diverting waters from a flood control dam (International Survey of Scientific Hydrology, 1970).

99. Old West Regional Commission - Artificial recharge project (Smith, 1977).

TEXAS

100. Dell Valley - Project under construction to inject impounded floodwaters through wells.*

101. El Paso - Potential for injection well recharge with treated sewage effluent appraised (Garza et al., 1980).

102. High Plains of Texas - Numerous sites where recharge with playa lake water has been attempted and appears to be economically infeasible (International Association of Scientific Hydrology, 1970).*

103. Houston - Studies of the feasibility of preventing land subsidence with artificial recharge (Garza, 1977).

104. San Antonio - Proposed project to recharge Edwards Aquifer (Green, 1967).*

105. Llano Estacado - Recharge to the Ogallala aquifer from playa lake basins (Wood and Osterkamp, 1984).

UTAH

106. Salt Lake Valley - Recommendation to purchase land and begin studies of potential for artificial recharge.*

107. Utah Valley - Potential for artificial recharge to protect and purify water for municipal and industrial uses exists.*

108. Wasatch Aquifer - Potential for artificial recharge along western front of Wasatch Mountains.*

* Hydrologic Engineering Center, 1984.

VIRGINIA

109. Norfolk - Tests with injection of fresh water into a brackish-water aquifer (Brown and Silvey, 1977).

110. Roanoke - Disposal of stormwater runoff through drainage wells.*

WASHINGTON

111. Walla-Walla - Recharge project no longer in operation.*

112. Columbia Basin Project - Economic analysis of artificial recharge in a conjunctive irrigation plan (Karlinger and Hansen, 1983).

113. Eastern Washington - Feasibility of artificially recharging basalt aquifers (Garret and Londquist, 1972).

WISCONSIN

114. Washura County - Demonstration project using an infiltration pond.*

WYOMING

115. Old West Regional Commission Project (Smith, 1977).

* Hydrologic Engineering Center, 1984.

Section 7.2

Saline Water Intrusion Barrier Wells Supporting Data

Section 7.2.1

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	"Injection/Extraction Well System-A Unique Seawater Intrusion Barrier" from Ground Water, Vol. 15, No. 1
AUTHOR: **(or INVESTIGATOR)**	N. Thomas Sheahan
DATE:	January-February, 1977
FACILITY NAME AND LOCATION:	Palo Alto, California USEPA Region IX
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	A multiple-aquifer system in the bayfront area of Palo Alto, California is being intruded with seawater from San Franciso Bay. In order to combat this potential degradation of the ground-water supplies in the area, a sea-water intrusion barrier is being constructed consisting of a series of injection wells used to inject reclaimed wastewater into a shallow aquifer. The injected water is subsequently removed by a similar system of extraction wells to avoid any possible degradation of the water-supply aquifers from this source and to allow reuse of the reclaimed wastewater.

Injection/Extraction Well System—A Unique Seawater Intrusion Barrier[a]

by N. Thomas Sheahan[b]

ABSTRACT

A multiple-aquifer system in the bay front area of Palo Alto, California is being intruded with seawater from San Francisco Bay. In order to combat this potential degradation of the ground-water supplies in the area, a sea-water intrusion barrier is being constructed consisting of a series of injection wells used to inject 2.0 million gallons per day (7.6 × 10^6 l/d) of reclaimed wastewater into a shallow aquifer. The injected water is subsequently removed by a similar system of extraction wells to avoid any possible degradation of the water supply aquifers from this source and to allow reuse of the reclaimed wastewater. The investigation phase included test drilling, aquifer testing and injection testing to determine the feasibility of the injection/extraction (I/E) concept. The number, spacing and location of I/E doublets were optimized using a digital computer model. The double-cased, double-screened wells were constructed using corrosion-resistant materials and were designed for ease of routine maintenance. In operation, injection and extraction will be computer controlled by sensing piezometric levels in a series of monitor wells. Water pumped from the extraction wells will be sold for industrial and agricultural purposes. The I/E well system has been approved for 87½ percent Federal and State grant funding.

INTRODUCTION

Among the objectives of the Santa Clara Valley Water District is the prevention of degradation of ground-water quality in the aquifers supplying various municipalities and industries in their district. The quality of ground water for these purposes is generally good. In a few locations, however, aquifers once used to produce good water have become intruded with salt water. One such area is the shallow aquifer above 150 feet (45.7 m) depth, around South San Francisco Bay. The aquifers deeper than 150 feet (45.7 m) still produce good water and are apparently protected by thick, clay aquicludes which have prevented salt water from the bay or from shallower aquifers from migrating to these deeper producing zones. Heavy pumping in the deep aquifers has produced a hydraulic gradient in the area away from the bay toward the producing well zones. Continued heavy pumping from the deeper aquifers may, in time, produce a degradation of these aquifers due to salt water migration from the shallower zone or from the bay. Recognizing the need for control measures to reduce the salt-water intrusion into the shallow aquifers, a system has been designed which will incorporate injection of water into the shallow aquifers by wells in order to control the seawater intrusion.

The proposed salinity intrusion barrier contemplates the use of a series of injection wells and extraction wells located in pairs, termed doublets. These doublets form two lines of injection and extraction wells located essentially parallel to the bay front. This arrangement will allow injection of reclaimed water into the injection wells and the complete removal of this water through the extraction wells.

An investigation of ground-water conditions in the area was prefaced by a review of the physical environmental characteristics of the area in order to provide a basis for evaluation of changes in the ground-water regime.

[a]Presented at The Third National Ground Water Quality Symposium, September 15-17, 1976, Las Vegas, Nevada.

[b]Chief Geologist, Brown and Caldwell, Consulting Engineers, 150 South Arroyo Parkway, Bin 83, Arroyo Annex, Pasadena, California 91109.

Discussion open until June 1, 1977

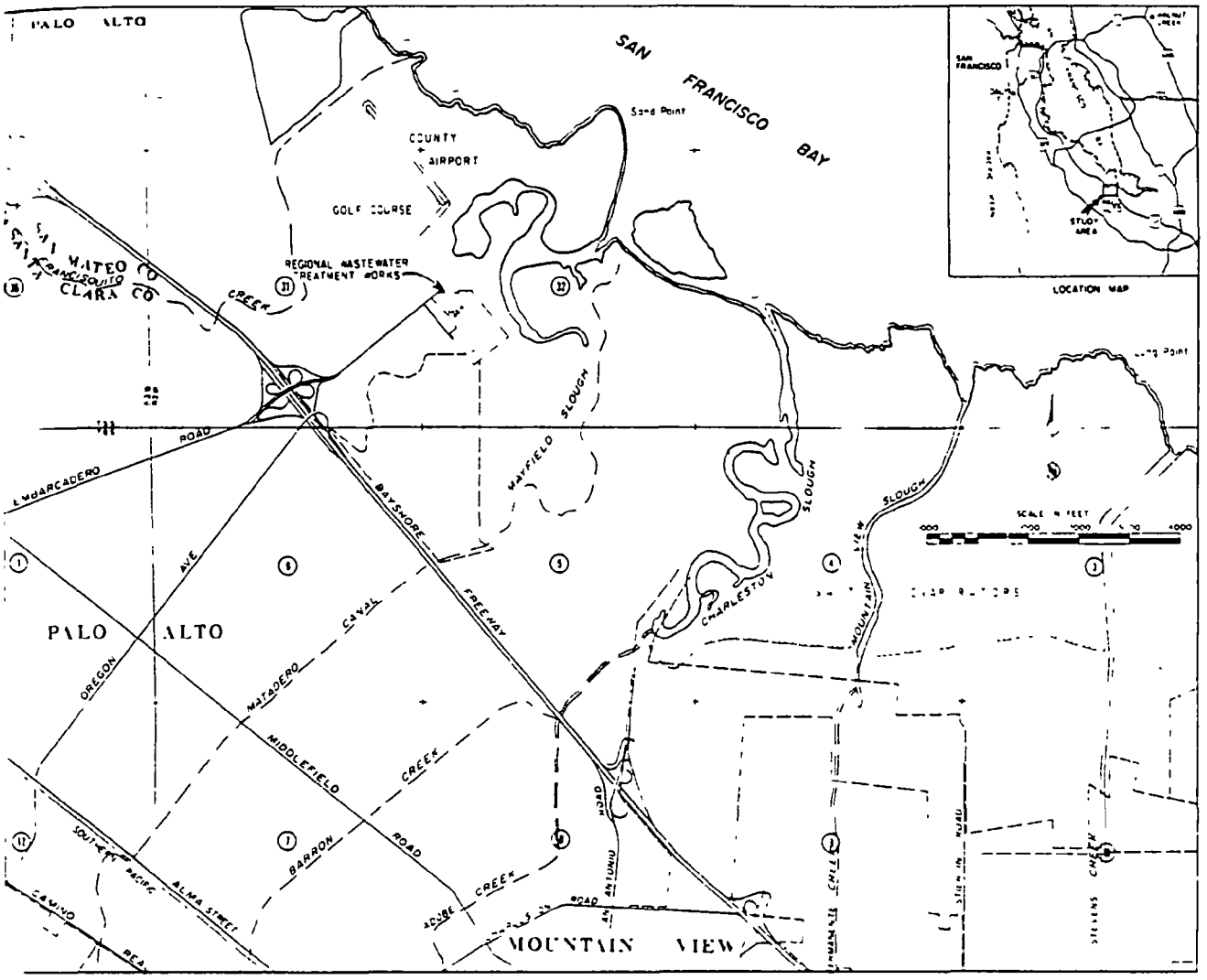

Fig. 1. Study area.

Study Area

The study area is located in the northwesterly corner of Santa Clara County, in the City of Palo Alto, along the south shore of San Francisco Bay. As shown in Figure 1, the area is bounded approximately by San Francisco Bay on the east, El Camino Real on the west, the City of Mountain View on the south and the City of Menlo Park on the north.

Topography

The study area is composed principally of flat lowlands and marshy baylands adjacent to San Francisco Bay. Generally the topography slopes northeasterly towards San Francisco Bay, and elevations in the area range from mean sea level at the bay front to a maximum of approximately 25 feet (7.6 m) above mean sea level in the western portion of the study area. The portion of the study area between Bayshore Freeway and the San Francisco Bay coast has been largely set aside by the City of Palo Alto for Baylands Park Preserve. There are, however, several areas of commercial and professional development near Embarcadero Road and along the Freeway.

Climate

The area exhibits normal ocean-moderated conditions. Temperatures in the area range from a mean of 47° F (8.30° C) in January to 66° F (18.90° C) in July with a mean annual temperature of 57° F (13.90° C). Average annual precipitation in the study area is approximately 15 inches (38.1 cm) although in the higher ground to the west of the study area, the average annual precipitation amounts to as much as 40 inches (101.6 cm). The higher rainfall to the west of the study area accounts for the extensive drainage patterns present and is the source of recharge water for the ground-water aquifers in the area.

[7-44]

Geology

The geology of the area has been studied and described extensively in reports of the Department of Water Resources (1967) and the reader is referred to these publications for more detailed information on the subject For the purposes of this paper, the discussion of geology is limited to the immediate local geology in the study area and particularly in the vicinity of the test well site, as it applies to this investigation.

The principal geological deposits of interest to this study are the alluvial sediments in the area. The alluvium consists of a series of coarse and fine sand and gravel aquifers separated by swamp clay, aquicludes and aquitards. The alluvium is underlain by the Santa Clara Formation which consists of loosely consolidated to compact, poorly-sorted sands, gravels, silts and clays The total thickness of alluvium and Santa Clara Formation in the study area is in excess of 1,000 feet (305 m) as shown by logs of wells in the vicinity

The alluvium is overlain in portions of the study area by soft, low-density clay deposits commonly referred to as bay mud The thickness of the bay mud deposits is quite variable and ranges from 0 to 70 feet (0.1 m)

Ground-Water Occurrence

The principal waterbearing deposits, and the ones of most significance to this investigation, are the unconsolidated sands and gravels occurring in the alluvium Based on the grouping of aquifers within the alluvium, the south bay area has been divided into various subareas which group areas of similar waterbearing formations (DWR, 1967). The study area includes portions of the Niles subarea and the San Francisquito subareas. Although the alluvium extends to approximately 1,000 feet (305 m) depth in the area, the aquifers of particular importance to this study occur in the upper 200 feet (61 m) of these deposits Salt-water intrusion has occurred in the shallow deposits but the deeper deposits in the study area appear to contain fresh water For this reason, only the aquifers occurring between ground surface and approximately 200 feet (61 m) depth are considered in detail here.

FIELD INVESTIGATION

In order to produce detailed information concerning the ground-water conditions and geology in the area of proposed injection of water for the seawater barrier, a program of test drilling and aquifer test analysis was developed. The site for initial test drilling was selected in order to provide the most representative information for the area. In addition, one of the goals of the drilling program was to result in the installation of a permanent injection well which could be utilized for initial testing, and later for continued testing and monitoring when incorporated as one of the operational wells.

Selection of Drilling Site

The site selected for the initial test drilling program is a portion of the City of Palo Alto property north of and adjacent to Embarcadero Road and east of Bayshore Freeway The site was convenient to a water-supply source from the City of Palo Alto and for water disposal along Embarcadero Road In addition, the site provided sufficient area in the vicinity for the installation of the second injection/extraction well required to complete the doublet, and the site is reasonably close to the proposed water reclamation plant Examination of drillers' logs and geophysical logs in the area indicated that this site would show geological conditions reasonably similar to those expected generally throughout the study area

Test Drilling

The test drilling consisted of drilling mud-rotary holes, 8-inch (20 3-cm) minimum diameter, to a depth of approximately 200 feet (61 m) and taking undisturbed samples of the soil at various locations during drilling In test hole-observation well number 1 (TH/OW-1), undisturbed samples were taken approximately every 5 feet (1.5 m) in order to obtain the maximum amount of information concerning the subsurface Samples of the materials encountered during drilling were examined on site both visually and with a mechanical sieve apparatus to determine grain-size distributions, material types, consistency and other soil characteristics After each hole was drilled, geophysical logging was performed in the well to verify the written descriptive log and to obtain additional information concerning material types and water qualities Locations of test holes are shown on Figure 2.

Observation Well Construction

After each TH/OW had been drilled and geophysically logged, and an analysis made of the information obtained, various sand and gravel formations were selected for installation of piezometers for measuring water-level changes and obtaining water-quality samples Piezometers were constructed of 1¼-inch (3 175-cm) polyvinyl-

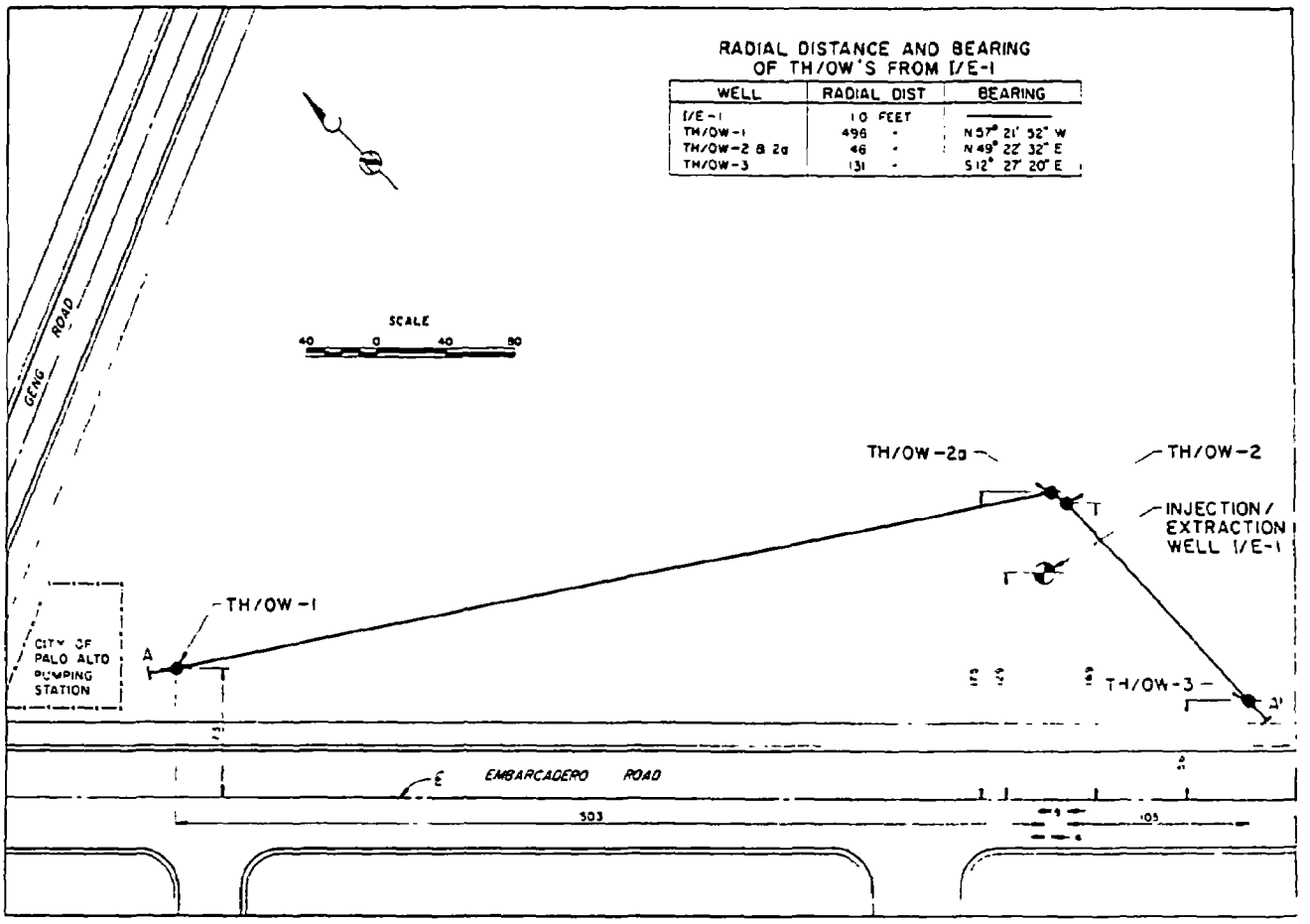

Fig. 2. Test well site.

chloride (PVC) pipe with 1¼-inch (3 175-cm) PVC slotted well screens The well screens were set and gravel-packed opposite to the particular aquifer formations to be monitored and these zones were sealed from other aquifer zones by cement seals.

A review of the geological information obtained during the test drilling and geophysical logging program indicated the presence of two shallow aquifers, herein referred to as the "20-foot" (6 2-m) aquifer and the "45-foot" (13 7-m) aquifer both of which are invaded by sea water, as evidenced by analyses of water samples. Below the 45-foot aquifer there is a thick clay aquiclude to a depth of approximately 200 feet (54 9 m) Below the aquiclude, there occurs another producing aquifer, herein called the "185-foot" (56 4-m) aquifer. This aquifer contains fresh water and analyses of water samples showed no evidence of seawater contamination The locations of the various aquifers found in the test drilling and their lateral relationships are shown in the geologic section in Figure 3 Slight variations in the formations were observed between adjacent borings, for example at TH/OW-1, there appeared to be a merger of the 20-foot and 45-foot aquifers It was not determined whether this merger was due to previous construction in the area or was a natural occurrence Comparison of additional subsurface information available near the north edge of the site indicated that the 20-foot aquifer is underlain in all cases by a clay aquitard as shown on Figure 3 However, south and east of the site area, additional test borings previously performed for another project did not disclose the presence of the 20-foot zone. It was, therefore, inferred that the 20-foot zone is an interrupted lense, although the fact that it is intruded by seawater indicates that it is areally extensive in other directions

Some variation in the 45-foot aquifer was demonstrated by the test drilling on site, however, the variation is essentially in aquifer thickness and not in material type The aquifer is essentially a sand and gravel zone in all three test holes The 45-foot zone, or lenses similar to this formation, occurs over a fairly widespread area.

The 20-foot aquifer and the 45-foot aquifer are separated, in all three test holes, by a zone composed of varying amounts of silt, clay and fine sand This zone, which is termed "aquitard" on Figure 3, has a measurable permeability but the

permeability is apparently much less than that of the formations above and below it. Examination of the areal geology confirmed that this relationship of two aquifers separated by an aquitard occurs extensively throughout the area.

A variation was found in the water-table elevations among the three aquifers examined. The 185-foot aquifer exhibited flowing conditions in the vicinity of TH/OW-1 and water levels at or near ground surface at the other test holes. The water levels in the shallower aquifers were 3 or 4 feet (0.9-1.2 m) below ground surface, generally, and showed a difference between themselves of approximately one-half foot (0.15 m).

Well Construction

After completion of the test holes, the design data necessary for construction of the initial I/E well was prepared. Among the items considered in the design phase were size of the well casing to allow ample room for anticipated pumping equipment, selection of materials of construction which would adequately resist normal corrosion as well as chemicals used in future development techniques, location, size and length of well screens and slot size openings to insure negligible head losses during injection and extraction, facility of future maintenance, and adequate sealing of aquifers.

Figure 4 shows the construction details of the initial injection/extraction well, I/E-1. The location and thickness of the cement seals used to separate the adjacent aquifers and to seal the zone near ground level are also shown on Figure 4, as well as the screen lengths, screen locations and gravel-pack dimensions.

There are various methods of well drilling available for shallow wells of this nature. For this particular installation, the reverse circulation method was selected. This method of drilling requires no drilling fluid additives, such as bentonite, which may adversely seal the water-producing formations. Excellent samples of the materials encountered during drilling are also available with this method which allow verification of material types, and depths and thicknesses of formations during well construction.

AQUIFER TESTING AND ANALYSES

In order to provide data necessary for the ultimate design of an I/E system, a series of aquifer tests were performed on each of the water-producing aquifers at the test site. The tests were designed to yield information concerning the aquifer characteristics and the relationship between aquifers in response to pumping and injection. The following presents the methods of testing, the analyses of the test data and a summary of the geohydrology of the site as determined by analyses of the aquifer-test data.

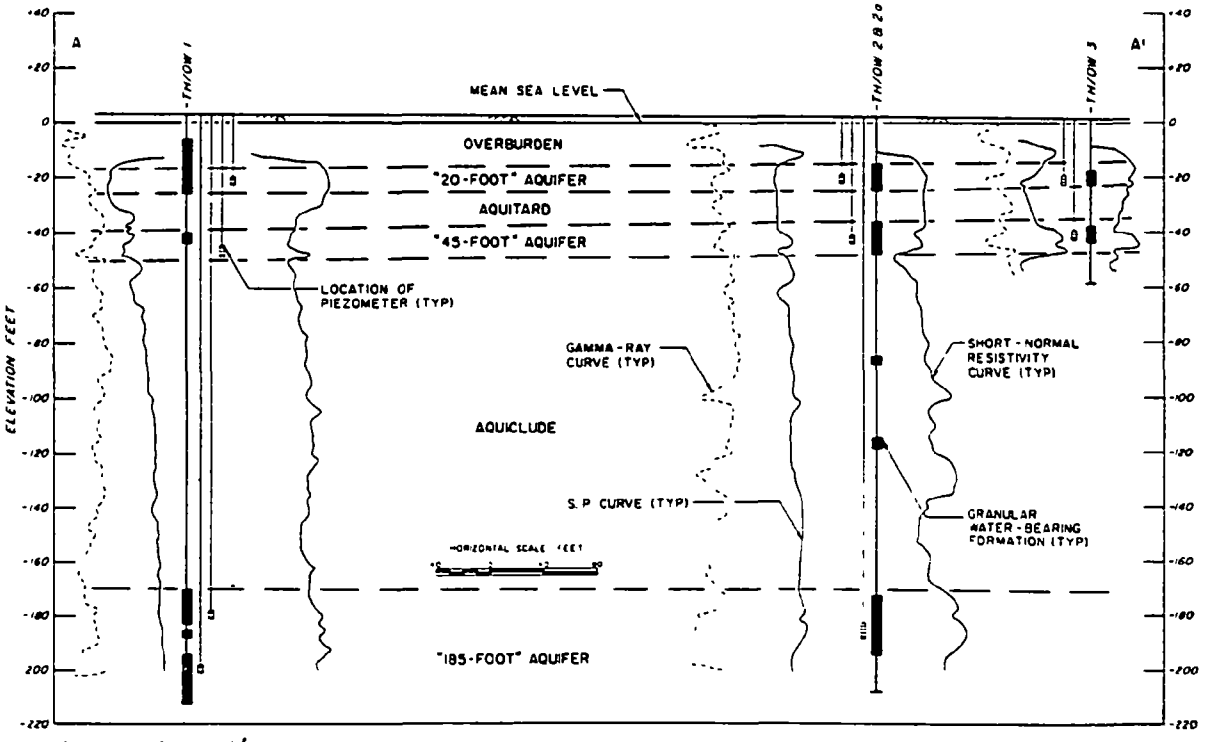

Fig. 3. Geologic section A-A'.

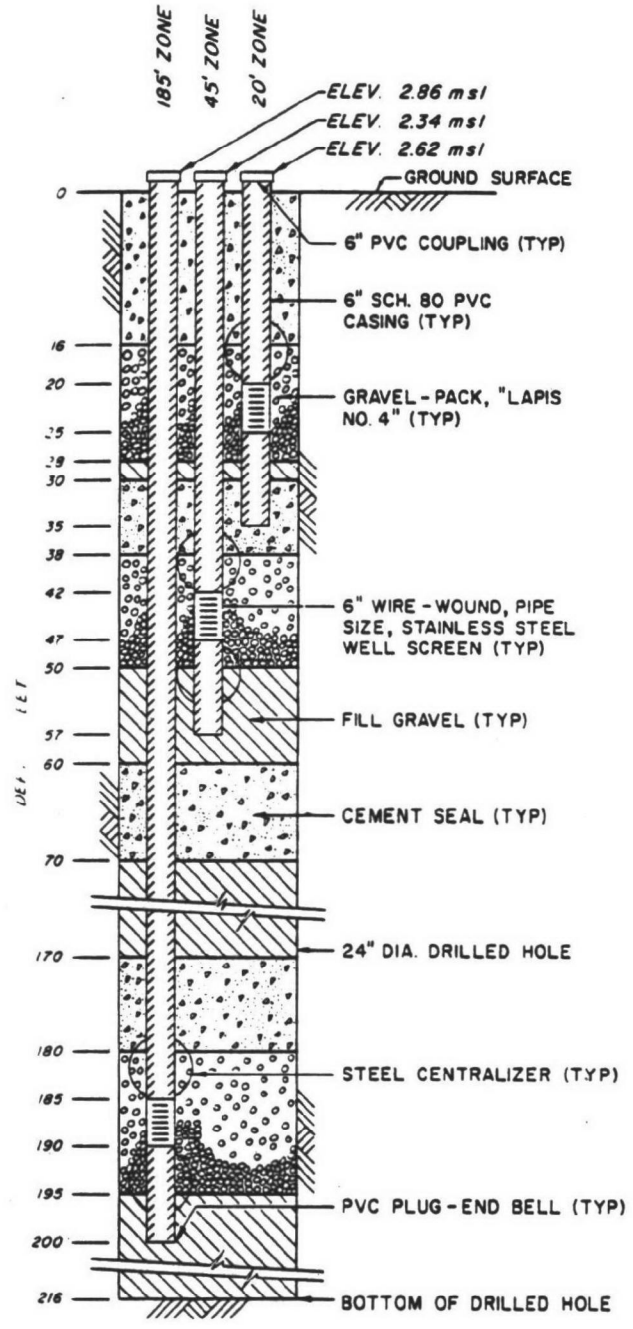

Fig. 4. Construction details, I/E-1.

Aquifer-Test Procedure

The aquifer testing of each screened aquifer was performed by pumping at a constant rate from I/E-1 for the period of approximately 24 hours, during which time changes in water level responding to the pumping were monitored in the pumping well, TH/OW's screened in that formation and in formations above and below the formation being tested. A series of water-level measurements were made in all the wells prior to starting the pumping portion of the test in order to establish a trend of water levels, and after pumping stopped, water-level monitoring was continued in all the wells to obtain data on the recovery of water levels after pumping.

In addition to the test wells and the pumping well at the test well site, water levels were measured in seven additional existing wells at various distances and directions from the test site in order to determine whether or not wells in these vicinities would respond to pumping at the test site.

Aquifer Test, 185-foot Zone

During the aquifer test of the 185-foot zone, the pumping rate in I/E-1 was held to a constant flow of approximately 165 gallons per minute (gpm) (10.4 l/s). Water-level changes were monitored in the pumping well, and TH/OW-2. In addition, water levels were monitored in the shallow aquifers in all three test holes and the I/E wells in the shallow aquifers. The water-level data were reduced to values of drawdown, corrected drawdown and recovery plotted against time since pumping began or time since pumping ceased. The drawdown values were corrected to account for projected trends of water levels prior to the beginning of the aquifer test. Pumping was continued for 24 hours, after which recovery was monitored for 24 hours. No response was noted in the shallow aquifers to pumping in the 185-foot zone. The data in these wells therefore were not considered in the following analysis.

The initial examination of the test data from the 185-foot zone indicated that the aquifer is an artesian, anisotropic aquifer, bounded on at least one side by a nearly impermeable boundary. The lack of response in the shallow aquifers during testing of this aquifer confirms the fact that it is a confined, artesian aquifer with no hydraulic communication to overlying zones.

Due to the confined nature of the aquifer in the 185-foot zone, the Theis nonequilibrium method of analysis was applied to the data (1935). The nonequilibrium formula is shown in Equations (1), (2) and (3).

$$s = 11{+}.6\, Q\, W(u)/T \qquad (1)$$

$$W(u) = \int_{u}^{\infty} (e^{-u}/u)\, du \qquad (2)$$

$$u = 2693\, r^2 S/Tt \qquad (3)$$

s = drawdown, in feet;

Q = discharge of well, in gpm;

T = transmissivity, in gpd/ft;

r = radial distance from pumping well, in feet;

S = storativity, a decimal fraction,

t = time since pumping started, in minutes.

In applying this method of analysis to the time-drawdown data for each observation well and the pumping well, it was found that the calculated coefficient of storativity increased with time These variations have been shown to be characteristic of an aquifer which is bounded by one or more impermeable boundaries (Sheahan, 1967) In order to determine the distance to and direction of the apparent impermeable boundary, the theory of images (Ferris, *et al*, 1962) was applied to the test data This method, which is essentially a graphical superposition method, and a nongraphical method (Sheahan, 1967) of analysis for boundary conditions were utilized in determining the boundary characteristics of the aquifer

The results of this portion of the analysis indicated that the 185-foot aquifer has an average transmissivity of 6 300 gallons per day per foot (gpd/ft) (78 12 m^2/d) and that there is apparently only one impermeable boundary reflected in the test data The boundary was determined to be to the east of the injection/extraction well, a distance of approximately 900 feet (274 m).

In making calculations for the coefficient of storativity from the time-drawdown data for each of the wells, based on that portion of the data which did not reflect the boundary effects, a large variation in the magnitude of storativity was observed. This variation in apparent storativity is normally indicative of anisotropic conditions in the aquifer (Papadopulos, 1965) In order to calculate the directions of the major and minor axes of transmissivity and the values of the major and minor transmissivities in an anisotropic aquifer, a minimum of three observation points are required in addition to the pumping well. In this particular case, only two observation wells were available and therefore a complete analysis for anisotropy cannot be made. However, by assuming that TH/OW-1 was on a principal axis, a calculation of an approximate range of minimum-to-maximum transmissivity and a value for storativity can be made. Analysis under these assumptions indicated that the transmissivity may range from as low as 3,000 gpd/ft (37 2 m^2/d) to as high as 12,500 gpd/ft (155 m^2/d) and that the storativity is approximately 0 002 under these conditions Based on the nature of the materials comprising this aquifer as shown on the drilling logs, together with the apparent thickness of the zone penetrated, the range of values of transmissivity, the average transmissivity and the apparent storativity values appear reasonable. It is noted that, if a value of storativity S, is assumed, calculation can be made of the other variables

Aquifer-Test Analysis, 45-foot Zone

The test procedure employed in performing the aquifer test of the 45-foot zone was similar to that of the deeper, 185-foot zone, in that it consisted of pumping the 45-foot aquifer of the I/E well at a constant rate of 80 gpm (5 l/s) for a period of 24 hours, preceded by a rest period. During the rest period, the 24-hour pumping period and the 24-hour recovery period following pumping, water levels in the observation wells and pumping wells were observed and recorded Water levels were monitored in both the 20-foot zone and the 45-foot zone during this test, however, the 185-foot zone was not continuously monitored since the aquifer test of that zone indicated it to be a confined aquifer and not hydraulically connected with the shallower aquifers The water-level data obtained during the aquifer testing was reduced to values of drawdown and recovery which were plotted against the time since pumping began and time since pumping ceased, respectively A graph of the aquifer-test data on a full logarithmic graph is shown in Figure 5 Due to the fact that the recovery readings were taken for a full 24 hours, corrections were necessary to these data to account for projected trends of drawdown due to the pumping portion of the test These corrected recovery readings are also shown on Figure 5

During the pumping and recovery portions of the test of the 45-foot aquifer, the water levels in the 20-foot aquifer were observed to respond to pumping in the 45-foot zone The response of the 20-foot aquifer indicated conclusively that the 45-foot zone was obtaining recharge during the test from the shallower, 20-foot zone, and thereby must be considered a leaky aquifer, or more explicitly, a semiconfined artesian aquifer Examination of the test data also indicated that the aquifer had not reached steady-state conditions and therefore must be considered in a nonequilibrium state for analysis

In order to take into consideration the leaky artesian, nonequilibrium characteristics of the test data from this aquifer, the modified Hantush method of analysis (1955) was employed The modified Hantush method utilizes a family of type-curves plotted according to Equations (4), (5) and (6).

$$s = 114\ 6\ Q\ H(u, \beta)/T \qquad (4)$$

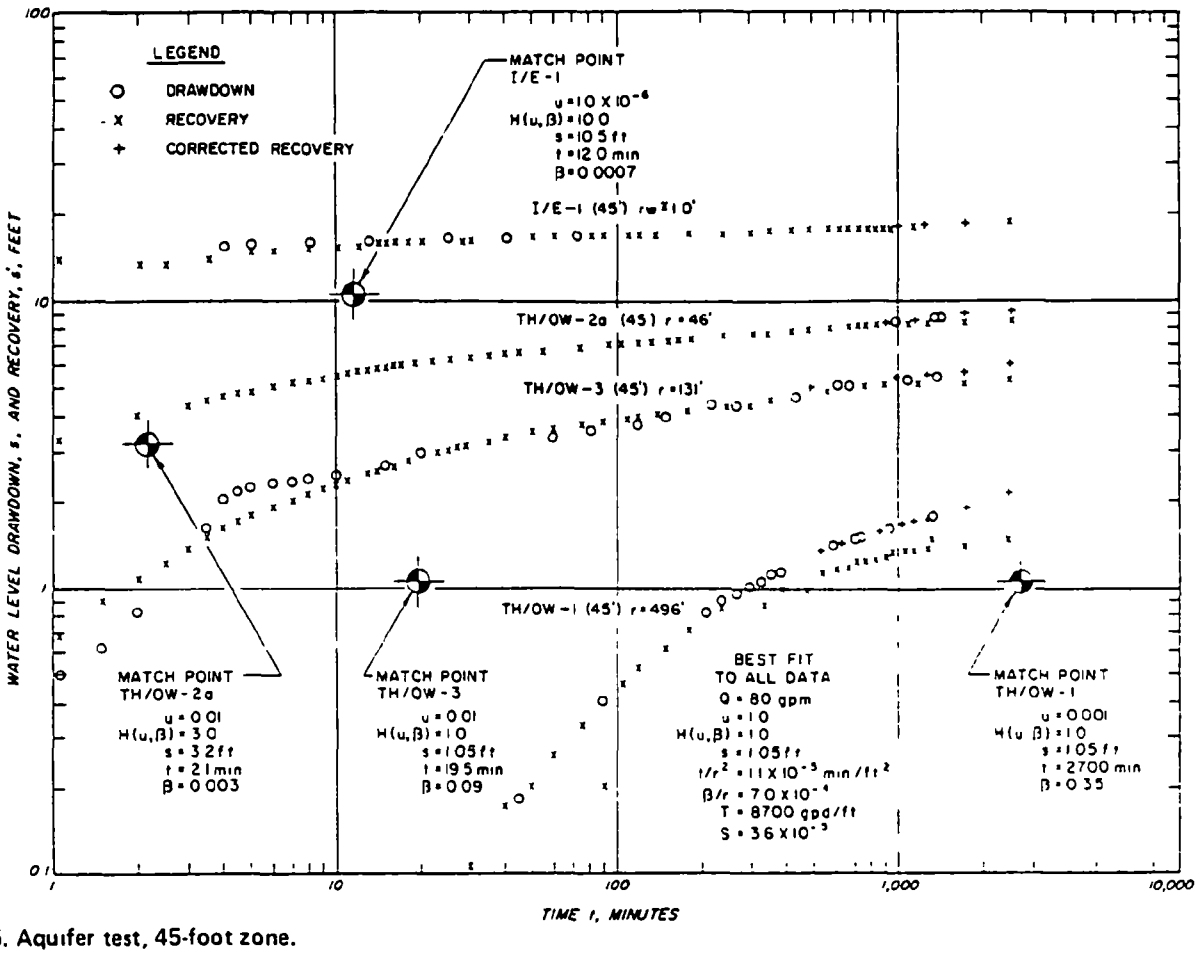

Fig. 5. Aquifer test, 45-foot zone.

$$H(u,\beta) = \int_{u}^{\infty} (e^{-y}/y)\ \mathrm{erfc}\ [\beta\sqrt{u}\,/\sqrt{y(y-u)}]\ dy \quad (5)$$

$$\beta = \frac{r}{4}\sqrt{\left(\frac{K'/b'}{T}\right)\left(\frac{S'}{S}\right)} + \frac{r}{4}\sqrt{\left(\frac{K''/b''}{T}\right)\left(\frac{S''}{S}\right)} \quad (6)$$

where

K', K'' = hydraulic conductivities of semipervious confining layers, in gpd/sq ft,

b', b'' = thickness of the semipervious confining beds, in feet,

S', S'' = storativities of the semipervious confining beds, as decimal fractions,

y = constant of integration,

and s, Q, T, r, S, and t are as previously defined

The analysis of data by this method consists of attempting to match one of the family of type-curves to the data as shown on Figure 5 using a superposition procedure. When a position of best-fit is obtained, values of the parameters are read from the superimposed graph at a convenient match-point and the storativity, transmissivity, and leakance characteristics of the aquifer are calculated. In the particular case under analysis, it is obvious that there is leakage occurring only from above the 45-foot aquifer This is substantiated by the fact that the 185-foot aquifer exhibited no hydraulic connection to the shallower aquifers, and the fact that there are no water-producing zones of any significant continuity occurring between the 45-foot aquifer and the 185-foot aquifer

Concerning other physical limitations in this aquifer such as impermeable boundaries or anisotropy, the fact that excellent match was possible with the type-curves to each of the data plots indicates that there are no boundary conditions of any significance affecting the test data. An examination of the relationship between drawdown and distance from the pumping well shows that the drawdown varies essentially linearly with the logarithm of distance indicating that the aquifer is isotropic.

Although the data from each TH/OW may be analyzed individually to determine a unique value for each of the aquifer coefficients, it is of greater

importance to evaluate all of the test data from all the observation points together, in order to obtain those values of the coefficients which are most representative of the entire aquifer In order to perform this type of analysis, the data shown on Figure 5 were replotted as a graph of drawdown, s, and recovery, s', versus a value of time divided by the square of the radius from the pumping well, t/r^2 The superposition method of curve-matching was applied to this graph using a family of type-curves based on Equations (4), (5) and (6), and a position of best-fit was determined. From this analysis, the match-points corresponding to each set of test data were determined and are shown on Figure 5

The composite aquifer-test data analysis yielded the value of 8,700 gpd/ft (108 m^2/d) for transmissivity, and a coefficient of storativity of 0 000036 These values appear to be reasonable based on the general geology and the relative geometry of the aquifer Using an average thickness of 13 feet (4 m) for the overlying semipervious confining layer, as determined from the logs of the test holes and a value of β/r equal to 0 0007, as determined from the analysis, the storativity and vertical hydraulic conductivity of the semipervious confining layer were calculated These calculations yielded a storativity of 0 001 and a value of vertical hydraulic conductivity of 0 032 gallons per day per square foot (gpd/sq ft) (0 013 m/d)

During the analysis of this set of test data, it was observed that the rate of change in water level in the 20-foot aquifer at I/E-1, TH/OW-1, and TH/OW-2a, with respect to the logarithm of time, were all essentially equal. The rate of change, or slope per log cycle time, of the data from TH/OW-3, however, was approximately twice the slope of the data plot from the other wells Examination of borings made immediately south and east of TH/OW-3 indicate that the shallow, 20-foot aquifer, appears to be discontinuous in that direction. Therefore the increase in slope observed from TH/OW-3 may be a response to an impermeable boundary in the 20-foot aquifer The leakance characteristics in this vicinity may also be different. This aspect of that aquifer is examined further in the analysis of test data from the 20-foot aquifer.

Aquifer-Test Analysis, 20-foot Zone

Due to the limited depth available for drawdown in the shallow aquifer, a very low constant pumping rate was used during this test The I/E well in the 20-foot zone was pumped at an average pumping rate of 8 6 gpm (0 54 l/s) for a period of 24 hours after which the pump was shut down and recovery readings were taken for 17 hours following pumping During the test, changes in water level were monitored in both the 20-foot aquifer and the 45-foot aquifer in all three TH/OW's and I/E-1. The small magnitude of drawdown in the wells produced a data graph which was considered less than satisfactory for proper analysis. However, the recovery data from the test was able to be monitored more exactly than the drawdown data and did produce usable data. Consequently, the water-level readings taken during the recovery period were reduced to a plot of recovery versus time

The 20-foot aquifer essentially reached equilibrium prior to the end of the test period The aquifer reached equilibrium due to the leakage occurring from the 45-foot aquifer below, and probably additional leakage from the overburden materials above the 20-foot zone The short time period required for this aquifer to reach steady state is due partly to the low value of pumping rate used during the test, and also due to the apparent additional leakage from the overlying beds Since the aquifer reached equilibrium during the test period, the leaky artesian formula of Hantush and Jacob (1955), which considers an aquifer approaching equilibrium was used in the data analysis The leaky artesian formula is shown in Equations (7), (8) and (9).

$$s = (114\ 6\ Q/T)\ W(u, r/B) \qquad (7)$$

$$W(u, r/B) = \int_u^\infty (1/u) \exp(-u - r^2/4\ B^2 u)\ du \qquad (8)$$

$$B = \sqrt{Tb'/K'} \qquad (9)$$

where all variables shown are as previously defined

For this analysis, the data were replotted as recovery, s', versus a value of time divided by the square of the distance from the pumping well, t/r^2, and a family of type-curves, based on Equations (7), (8) and (9), was superimposed to a position of best-fit to the data Utilizing the portion of the data prior to the point at which steady state was reached, values of transmissivity and storativity were determined. The transmissivity was found to be 3,500 gpd/ft (43 + m^2/d) and the storativity value determined was 0 002.

Since the leakage to the 20-foot aquifer apparently occurs from both above and below that aquifer, and since the analysis method used assumes leakage from only one bed, it is not possible to determine exact values of the vertical

hydraulic conductivity for the adjacent beds. However, the purpose of obtaining information concerning the aquifer characteristics is to allow prediction of future response to pumping or injection stresses on these aquifers, and a more usable parameter for this purpose is the range in values of B From type-curve analysis, the value of B was determined to be in the range of 33 to 131 and averaged about 105

Since, as indicated above, the latter part of the test data represents essentially steady-state conditions, it is possible to verify the value of transmissivity using a different method of analysis. The steady-state leaky artesian formula (Jacob, 1946) is shown in Equation (10)

$$s = (229\ Q/T)\ K_o\ (r/B) \qquad (10)$$

where

$K_o\ (r/B)$ = modified Bessel function of the second kind and zero order,

and s, Q, T, r and B are as previously defined.

The values of r/B obtained from the nonsteady-state analysis were plotted versus the steady-state, equilibrium recovery for each of the observation wells To this data was matched a type-curve of the steady-state leaky artesian aquifer conditions Analysis by this method yielded a value transmissivity of 3,650 gpd/ft (45.3 m^2/d) which compares favorably with the value of 3,500 gpd/ft (43 3 m^2/d) obtained from the nonsteady-state method of analysis

Summary of Geohydrology of Test Site

The subsurface consists of essentially three separate aquifers within the depth of investigation The deepest aquifer, the 185-foot aquifer, is a fully confined, artesian aquifer with an average transmissivity of 6,300 gpd/ft (78.1 m^2/d) and a storativity of 0 002, but is anisotropic in character and may have directional transmissivities ranging as low as 3,000 gpd/ft (37 2 m^2/d) to as high as 12,500 gpd/ft (155 m^2/d) The aquifer appears to be bounded by an impermeable hydraulic boundary located at a distance of approximately 900 feet (274 m) east of the I/E well. There was no hydraulic continuity observed between the 185-foot aquifer and the two shallower aquifers

The shallow aquifers, consisting of a 20-foot aquifer and a 45-foot aquifer, exhibit a certain degree of hydraulic communication Pumping of the 45-foot aquifer created a water-level response in the 20-foot aquifer. The 45-foot aquifer showed characteristics of a leaky artesian aquifer upon analysis. Although the pumping rate used in the 20-foot aquifer test was too small to allow any observable correlative response in the 45-foot aquifer, the fact that there is hydraulic communication between the two was established during the test of the 45-foot aquifer and verifies the apparent correlative response to pumping of the 20-foot aquifer.

Considering the fact that the depth to water level in both shallow aquifers is about the same, roughly 4 feet (1.2 m) below ground surface, it was anticipated that injection into the 45-foot aquifer at pressures greater than about 5 feet (1 5 m) of head, might eventually cause waterlogging of the surface of the ground due to leakage from the 45-foot aquifer, through the 20-foot aquifer, and up into the overburden material above this zone The 20-foot aquifer, however, provides a means for controlling the waterlogging effect that might possibly occur While injecting into the 45-foot aquifer at a fairly high rate, the 20-foot aquifer can be pumped at a much smaller rate, but a rate sufficient to control waterlogging in the area

Injection Testing

After the completion of aquifer testing of the three aquifers encountered in the test well site, actual injection testing was performed on the 45-foot aquifer. The purposes for which the injection testing was performed were actually threefold. First, although the analysis of the aquifer-test data provided the information necessary to predict the results of injection, it is valuable to be able to confirm the accuracy of these predictive techniques. Second, injection testing produces additional usable information obtained during the aquifer testing which was of value in design and operation of the injection system. Third, and possibly most important, it is valuable to demonstrate that the proposed injection procedure will perform as expected under actual field conditions and with the proper control of the operation.

In designing the injection test, the first criteria of importance was a value of maximum injection pressure to be used during injection. In order to arrive at this maximum figure, the criterion was established that the injection pressure should be no greater than the net loading of soil at the point of injection. In order to calculate this, the static loading of soil down to the top of the aquifer was determined to be 35 3 pounds per square inch (psi) (2 48 kgs/cm^2) Due to the

artesian nature of the 45-foot aquifer, the hydrostatic pressure in the formation is 15 6 psi (1.10 kgs/cm^2) The net static loading, therefore, is the difference between these two values, or approximately 20 psi (1 4 kgs/cm^2), at the design point Based on the aquifer-test coefficients available, this value corresponds to an injection pumping rate of approximately 200 gpm (12.6 l/s).

In order to obtain additional data concerning the possibilities of waterlogging in the area, additional shallow borings were made in the vicinity of the test holes on site and were equipped with piezometers to a depth of approximately 3 to 5 feet (0 9 to 1 5 m). These piezometers were also monitored during the injection testing In addition, concrete monuments were set in the soil at various locations around the test well site, and accurate elevations were determined at these monuments The elevations of the monuments were monitored during the injection testing to determine whether or not heaving of the upper layer might be occurring due to the injection pressures

Due to limitations in the availability of injection pressures at the site, the injection test was actually performed at an injection pressure of approximately 12 feet (3 66 m) and at a pumping rate between 90 and 100 gpm (5 7 and 6 3 l/s) The test was conducted using a constant-head, variable-capacity method which varied slightly from the aquifer test in that the aquifer tests were performed with a constant pumping rate and a variable head. The water used was fresh water from the City of Palo Alto municipal water supply, and was injected into the 45-foot aquifer at I/E-1. The test was continued for 48 hours under these conditions, and changes in water levels were monitored in the I/E well and the TH/OW wells in both the 20-foot and 45-foot aquifers. At the end of the 48-hour period, both the injection and the pumping operations ceased and recovery readings were obtained

Examination of the test data at the end of 24 hours of injection showed that the water levels in the 20-foot aquifer at TH/OW-3 had risen to a point approximately 6 inches below ground surface. By contrast, the water level in the 20-foot zone at TH/OW-2a, 85 feet (26 m) closer to the injection well, was still nearly 2 feet (0.6 m) below ground surface. This rapid rise at TH/OW-3, southeast of the injection well, correlated with what was expected in that area based on the aquifer-test analysis of the 45-foot aquifer which indicated the possibility of an impermeable barrier in the 20-foot aquifer to the southeast of the site At that point in the test, the shallow, 3 to 5-foot (0 9 to 1.5-m) piezometers still did not show any waterlogging of the overburden materials

After 24 hours of injection alone, and at the point at which the water level in the 20-foot aquifer in the vicinity of TH/OW-3 was 6 inches (15 2 cm) below ground surface, pumping was started in the I/E well at the 20-foot depth at a rate of approximately 8 gpm (0 5 l/s). This pumping continued for the next 24 hours, during which time no additional rise in the water level in the shallow aquifer at TH/OW-3 was observed In fact, the water level actually receded approximately 0 15 feet (0 05 m) during that time The shallow piezometers showed no response to injection during the entire 48 hours of injection and there was no change in elevations of the concrete monuments observed during testing

The injection test therefore demonstrated that fresh water can be injected into the 45-foot aquifer with no detrimental effects and that possibilities of waterlogging can be adequately controlled by pumping the shallow aquifer, thereby providing complete operational control of the injection system.

Prediction of Injection Response

As a result of the injection testing, the actual response of the 20-foot and 45-foot aquifers to injection of fresh water under the test conditions was known. The next step was to verify that this response could be accurately predicted based on the knowledge of the aquifer characteristics determined by the aquifer testing

In order to calculate the expected response of injecting at a constant head, a constant pumping rate was selected based on the range of injection rates used during the injection test and a variable-head, constant-rate method, similar to that used in analyzing the aquifer-test data for the 45-foot aquifer, was employed, since under the test conditions at I/E-1, very little change in pumping rate was observed The predicted response and the actual response of injection for two of the test holes in the 45-foot aquifer are shown on Figure 6 Similar data for the 20-foot aquifer for the same two test holes are shown plotted on Figure 7 As can be seen from the Figures, there is an excellen correlation of predicted response with actual response for the 45-foot aquifer, and for the nearest test hole in the 20-foot aquifer The low magnitude of water-level rise in the 20-foot aquifer at TH/OW-1, located 496 feet (151 m) from the I/E well, may account for the slight deviation of

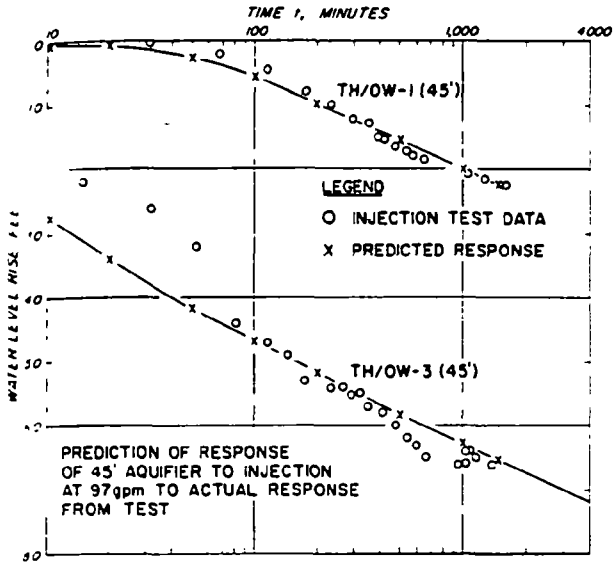

Fig 6 Response of 45-foot zone to injection into 45-foot zone

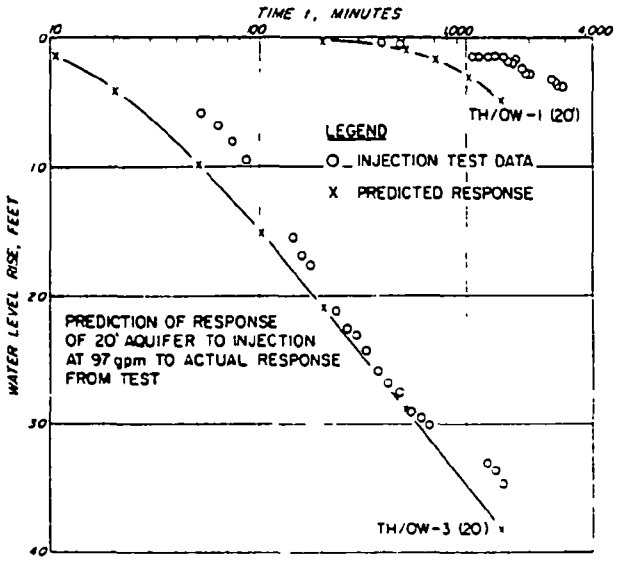

Fig. 7. Response of 20-foot zone to injection into 45-foot zone.

ictual response to predicted response observed for : well It is noted, however, that the predicted ponse is conservative in that it shows a greater rise of water level than actually occurred

In summary, therefore, it can be said that the aquifer characteristics as determined by aquifer testing are suitable for accurate prediction of injection response both in the injecting aquifer and in the aquifer into which leakage is occurring Even the effects of boundaries in the aquifer being charged can be taken into account in making these predictions

Water Quality

Throughout the course of the field investigation, water samples were obtained from the various monitoring wells for determination of chlorides and specific conductance A summary of the water-quality data is shown graphically on Figure 8 As shown by the Figure, there is a general correlation between specific conductance of the water samples obtained and the amount of chlorides present in the samples. There is also an apparent grouping of samples which correlates with the location of the wells and the depth of the aquifers from which the samples were taken The lowest chloride contents were found in the 185-foot aquifer at the test site. Chlorides in these samples averaged 28 milligrams per liter (mg/l) By contrast, the amount of chlorides in the shallow domestic wells, located approximately one-half to one mile farther away from the Bay than the test well site, showed an average chloride content of approximately 110 mg/l.

COMPUTER SIMULATION

The proposed operation of the injection system consists of injecting reclaimed water into a series of wells in order to hold back seawater intrusion, and to extract this water from a series of extraction wells in order to keep the reclaimed water from migrating out of the area of the injection wells and into the vicinity of producing water-supply wells Given an injection/extraction doublet located in an aquifer whose characteristics are known, under a regional hydraulic gradient greater than zero, there is a limiting streamline, the path of which can be determined, which will

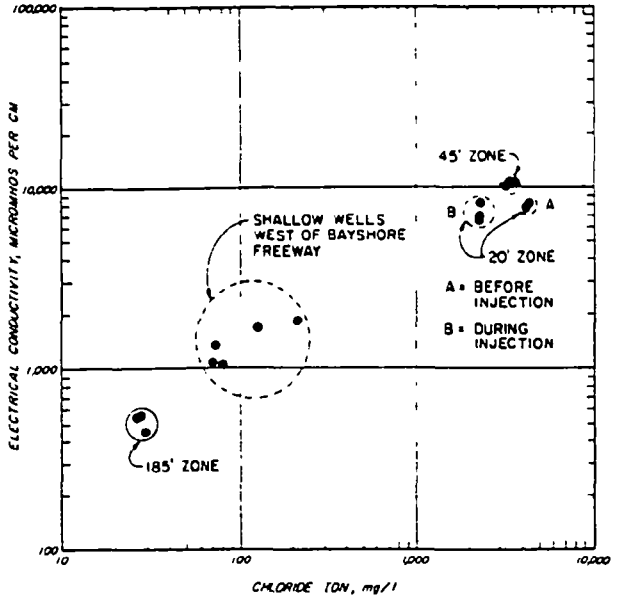

Fig 8. Relationship of chloride to specific conductance.

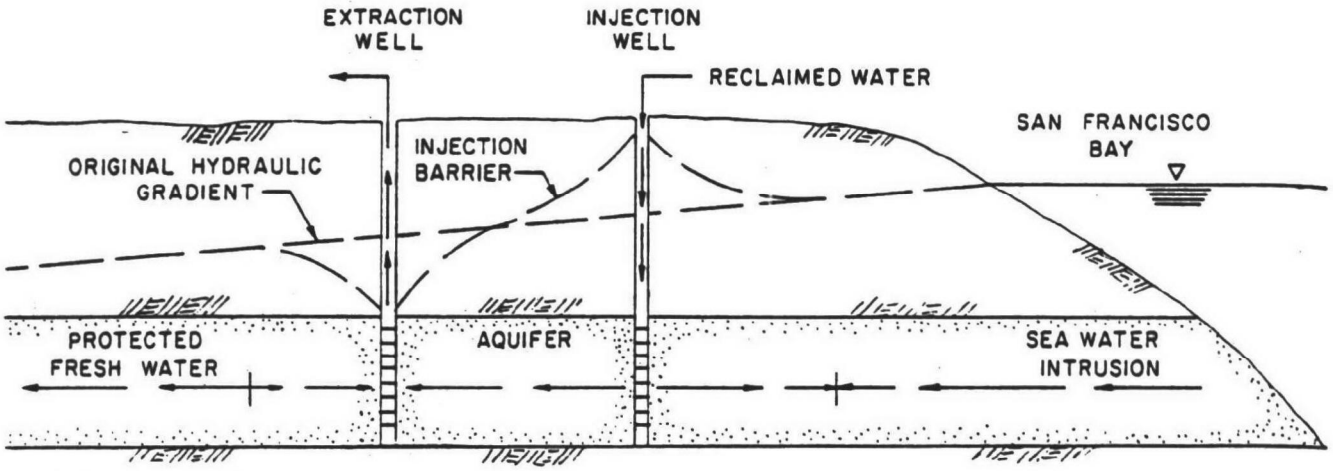

Fig. 9. Diagrammatic illustration of operation of injection/extraction doublet.

flow from the injection well to the extraction well, encompassing an area surrounding the doublet. Under the given circumstances, no particle of water can move outside of the perimeter of the area enscribed by the path of the limiting streamline. In addition, all other particles of water from the injection well will follow streamlines within that perimeter between the injection well and the extraction wells (D'Acosta and Bennett, 1960). A diagrammatic section illustrating this condition is shown in Figure 9.

Under simple, straightforward conditions, the path of the limiting streamline can be determined analytically. However, with conditions of multiple I/E doublets, complex aquifer conditions, and interaction between aquifers, the calculation of the path of the limiting streamline becomes a task more suitable to the use of a digital computer. For this reason, a computer simulation approach (Ramey, *et al.*, 1973) was used to determine the path of the limiting streamline under the conditions particularly applicable to the study area.

Aquifer Characteristics

The computer model was designed to include the aquifer characteristics from the 45-foot zone. These aquifer characteristics include the following values:

T = 8,700 gpd/ft (108 m^2/d);

S = 0.000036;

β/r = 0.0007;

Q = varies;

t = very large, to approach equilibrium;

r = varies.

The digital computer model essentially is a mathematical model applying Equations (4), (5) and (6), incorporating the above aquifer characteristics as determined from the aquifer testing.

In order to determine a value for the hydraulic gradient through the area which would be representative of the actual field conditions, the hydraulic gradients in various portions of the study area were calculated. These calculations were based on water-level elevations in various wells and the gradients varied from nearly zero to as much as 0.002 ft/ft (feet per foot).

Preliminary computer simulations indicated that the area encompassed by the limiting streamline was quite sensitive to variations in hydraulic gradients. It was determined that as the hydraulic gradient became greater, the area encompassed by the limiting streamline became smaller. Therefore, in order to present a conservative approach, the largest gradient measured was utilized in preparing the simulation model.

Injection/Extraction Doublet

The digital computer simulation model was first applied to the problem of determining the effects of spacing between the injection well and the extraction well, and variations in pumping rates at the wells. Since it was anticipated that the injection rate and extraction rate will be equal in actual operation, this relationship was also used in the simulation. Figure 10 shows the path of a particle of water along the limiting streamline in a single doublet oriented as shown with respect to the normal hydraulic gradient. In this instance, the limiting streamline traces the approximate shape of an ellipse. By applying the simulation model to various well spacings and pumping rates, the relative relationships among doublet spacing, pumping rate and area encompassed by the limiting

streamline were determined It was found that at a constant spacing, the area is proportional to the rate of pumping, such that if the pumping rate is doubled, the area encompassed by the limiting streamline is also essentially doubled It was further determined that the area is roughly proportional to the product of the rate times the spacing For example, the area encompassed by the limiting streamline for the case of injection and extraction wells spaced 1,000 feet (304 8 m) apart, pumping at 50 gpm (3 15 l/s), is the same as the area resulting from wells spaced 500 feet (152.4 m) apart pumping at 100 gpm (6 31 l/s) It was also shown, as mentioned previously, that the area is inversely proportional to the regional ground-water hydraulic gradient through the area

The path of the limiting streamline becomes somewhat more complicated when multiple injection/extraction (I/E) doublets are considered Obviously, if three doublets are spaced side-by-side, they will have the same effect on the limiting streamline as would a single doublet pumping at three times the pumping rate On the other hand, if the doublets are spaced great distances apart, each doublet will operate as if the other doublets do not exist However, in the intermediate zone between these two extremes, there is a particular spacing of doublets at which the path of the limiting streamline from the center doublet changes from a path completely encompassing all three doublets to a path that encompasses only the central doublet This effect of doublet spacing on the path of the limiting streamline is illustrated in Figure 11 In Example A on this Figure, the doublets are relatively close and the path of the limiting streamline encompassing all three doublets follows essentially the same path as if the system consisted of only a single doublet pumping at three times the rate of each of the doublets shown. Example B shows three doublets spaced somewhat farther apart The difference in shape of the area encompassed by the path of the limiting streamline in this example, as compared with Example A, shows the effects of the increased spacing The effect of the spreading out of the doublets, or

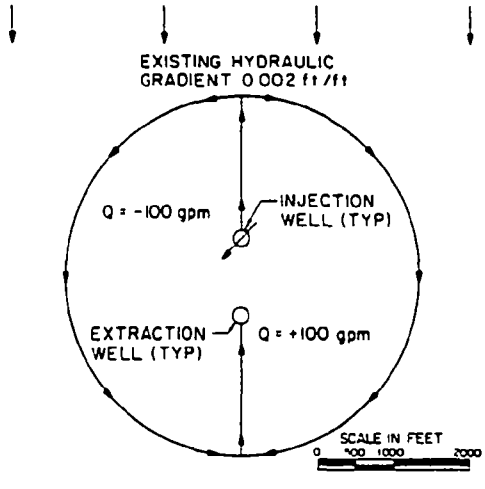

Fig. 10. Limiting streamline, one doublet.

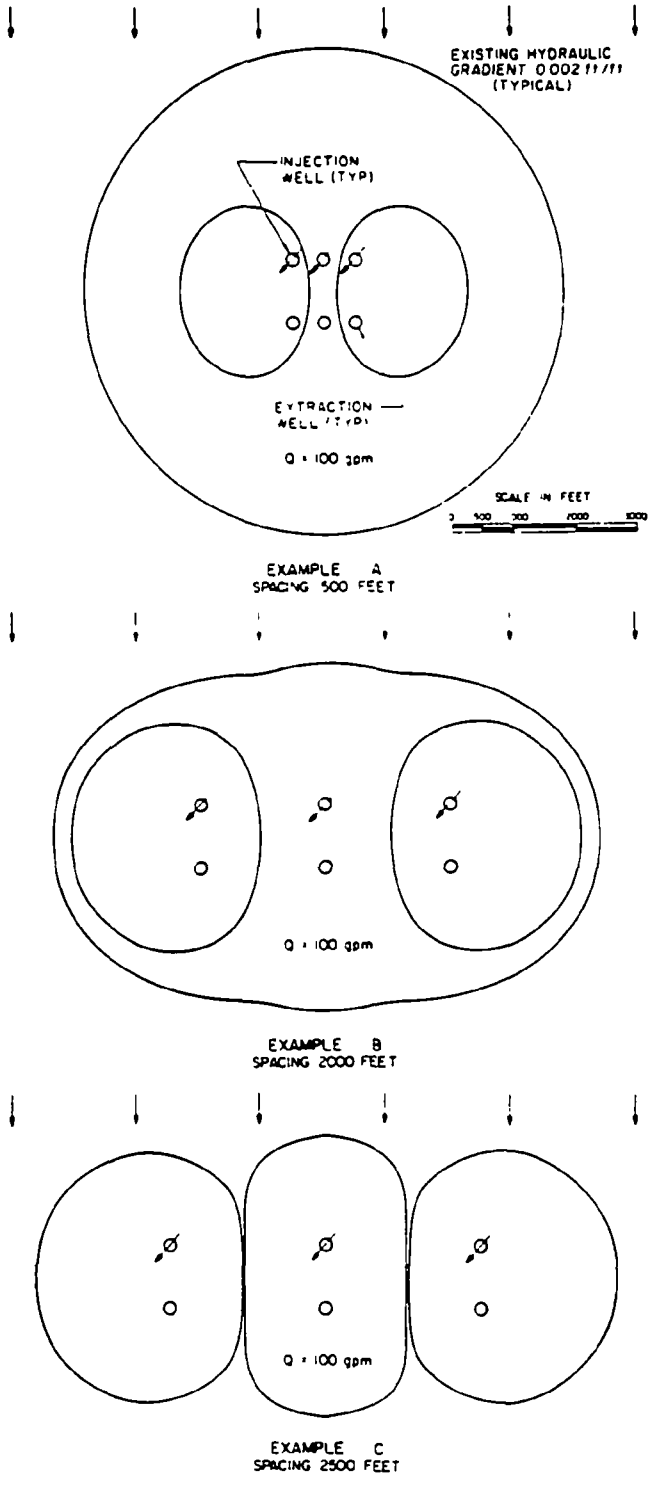

Fig. 11. Effect of doublet spacing on limiting streamline.

increase in side-to-side spacing, causes the limiting streamline path to approach the point at which it will change direction and pass between adjacent doublets Example C shows the doublets located at a spacing just greater than the critical spacing at which the streamlines have, in fact, broken through or changed direction, and each streamline path is encompassing an area around only its own doublet

It is noted that in the case of Example C in Figure 11, there is, in addition to the limiting streamline shown, another streamline resulting from the pre-existing hydraulic gradient which is also passing between the doublets If this existing hydraulic gradient is bringing salt water from a source such as the Bay toward the line of I/E doublets, the doublets spaced as shown in Example C are not effectively holding back seawater intrusion There is, obviously, for a given pumping rate and well spacing, a critical doublet spacing, somewhere between that shown in Example B and Example C, such that if the doublets are spaced less than that critical spacing, the line of I/E doublets will do an effective job as a barrier to seawater intrusion It was therefore necessary to determine the critical spacing requirements for the location of I/E doublets, and the relationship of the critical spacing to either the I/E pumping rates, the number of I/E doublets, or both.

As stated above, the area encompassed by the path of the limiting streamline is directly proportional to the pumping rate and to the spacing between wells Therefore, it is certain that the critical spacing between the doublets, depending as it does on the path of the streamline, is also dependent upon the spacing between the injection and the extraction well in each doublet. From an evaluation of the physical constraints of the study area and the geohydrologic parameters, the range of separation between the injection well and the extraction well in a given doublet was determined to be between 500 and 1,500 feet (152.4 and 457 2 m) For the purposes of this analysis, this dimension was assumed to be 1,000 feet (304 8 m) In addition, the aquifer characteristics and maximum injection pressure indicated that the pumping rates for both injection and extraction wells are in the range of 100 gpm (6.31 l/s) to 200 gpm (12 6 l/s) The pumping rate value of 150 gpm (9 5 l/s) was assumed as a reasonable value for this analysis.

To determine the relationship of the critical spacing between I/E doublets to both the pumping rate and the number of doublets, the computer simulation technique was first applied to a three-doublet system to calculate the critical doublet spacing for various pumping rates and various well spacings within each doublet The results of this analysis indicated that, for a particular well spacing in a three-doublet system, as the pumping rate in both the injection and the extraction well increased, the critical spacing between doublets approached a linear relationship with the pumping rate for any given spacing between wells in the doublet. With this information in hand, it was therefore possible to predict the critical doublet spacing and therefore the maximum design spacing for a three-doublet system

Since the physical constraints of aquifer characteristics and site parameters limited the assumed distance between the injection well and the extraction well in a doublet to approximately 1,000 feet (304 8 m) and to pumping rates of approximately 150 gpm (9 5 l/s), a three-doublet system was not sufficiently broad to prevent seawater intrusion through the study area Therefore, it was necessary to go to a greater number of doublets The additional I/E doublets raised the question of whether or not the critical doublet spacing will change with the addition of doublets The computer simulation model was utilized to determine the relationship between critical doublet spacing and number of doublets at any particular pumping rate The analysis indicated that there is a reduction in critical doublet spacing with the increased number of doublets

Evaluation of the computer simulation data showed that the critical spacing between doublets is inversely proportional to an exponential of the number of doublets. For the particular case assumed, that of wells separated a distance of 1,000 feet (304 8 m) in each doublet, pumping at 150 gpm (9 5 l/s), it was determined that, for nine doublets, the critical spacing between doublets is approximately 1,800 feet (585 m) and for seven doublets, the critical spacing is approximately 2,000 feet (610 m) Since the actual design spacing between doublets must be less than the critical spacing, and in order that the system be conservatively designed to accommodate any variation which may exist in aquifer characteristics or in the existing hydraulic gradient, a design spacing between doublets was established at 1,000 feet (305 ~~m~~)

Recommended Location of Injection/Extraction Doublets

Taking into account the physical and cultural characteristics of the study area, together with the

design criteria established above for location of the doublet system, the recommended locations of I/E doublets were determined. The system requires a total of nine I/E doublets, the total capacity of which would be approximately 2 0 million gallons per day (mgd) (7 6 × 10^6 l/d) Because of the conservative approach taken in design of the system, a certain amount of latitude was available for use in final location and construction of the doublets

DESIGN AND CONSTRUCTION

Following the analysis of the computer simulation, the seawater intrusion barrier system was designed. The system includes a total of nine doublets (18 wells), as shown on Figure 12, and 37 monitor wells. Eight existing monitor wells were incorporated into the system together with the initial injection/extraction well (test well)

Monitor Wells

Three types of monitor wells were designed for the injection/extraction well system, shallow wells ("S" series), mid-depth wells ("M" series) and deep wells ("D" series) Monitor wells were designed and located to serve as monitoring points for ultimate operation of the system and as test holes to obtain pertinent information on formation thicknesses and material types for design of the injection/extraction wells.

The "D" series wells were planned to monitor water levels and water quality in the 185-foot aquifer and to provide a supply of fresh water for future possible injection purposes. Each well is designed with 8-inch (20 32 cm) schedule 80 polyvinyl chloride (PVC) casing, type 304 stainless steel wire-wound type well screen, gravel-packed in an 18-inch (45 77 cm) drilled hole. The annulus from ground surface to a point 5 feet (1 5 m) above the top of the screen is sealed with neat cement grout to protect the lower aquifer from possible contamination by water from the shallow zone.

The "S" series wells were designed to penetrate the 20-foot and 45-foot aquifers The "M" series wells were designed similarly to the "S" wells with the exception that the initial drilled hole was planned for an approximate depth of 100 feet (30.5 m) for the "M" wells, while the "S" wells were scheduled to be only about 60 feet (18 3 m) total depth.

Each well in the "S" and "M" series is double-cased and double-screened with a neat cement grout seal separating the 20-foot and 45-foot aquifers Well design includes 3-inch (7 62 cm) PVC casing and PVC wire-wound-type well screen, gravel-packed in a 12-inch (30.5-cm) drilled hole

Both cuttings samples and split-spoon samples were specified to be obtained during drilling and each hole was to be geophysically logged and calipered to provide additional information for correlation with the geology of the area and for design of the injection/extraction wells.

Injection/Extraction Wells

In order to provide the facility for future use of each of the injection/extraction (I/E) wells for either injection or extraction, each of these wells were designed identically These wells also are double-cased, double-screened with neat cement grout separating the 20-foot and 45-foot aquifers. The casing and screen for the 45-foot zone were designed to be 8-inch (20 32 cm) nominal size to allow installation of pumping or injection equipment Since the 20-foot zone will be pumped only to control waterlogging, the casing and screen for this zone is 6-inch (15 24 cm)

All casing is Schedule 80 PVC and the screens are type 304 stainless steel, wire-wound, keystone-type screens Each screen is gravel-packed in a 24-inch (61 cm) drilled hole

Funding

Since the injection/extraction well system is part of the final treatment and disposal process of the regional wastewater treatment plant supplying the reclaimed wastewater for injection, application was made to the Environmental Protection Agency (EPA) and the California State Water Resources Control Board (SWRCB) for grant funding under P.L. 92-500 After review of the predesign report prepared by the Santa Clara Valley Water District and the report of Geohydrologic Investigation, both EPA and SWRCB approved the project for grant funding Under this program, EPA provides 75% funding of grant eligible costs while SWRCB provides an additional 12½%

The bid price of the injection/extraction well system was $400,000 Contracts were signed in late 1975 and construction began in January 1976

Construction

The project was scheduled for completion by the end of August 1976 However, a three-month delay due to right-of-entry restrictions occurred in late spring and early summer Consequently, at the time of preparation of this paper, only the monitor wells have been constructed.

Fig. 12. Injection/extraction well locations for seawater intrusion barrier.

It is anticipated that after completion of construction, a supplemental paper will be prepared describing the construction and operation characteristics of the system

ACKNOWLEDGMENTS

Assistance during the course of this study was provided by Mr William M Roman, Water Resources Engineer, Santa Clara Valley Water District, Mr. Thomas I Iwamura, Geologist, Santa Clara Valley Water District, Mr Ray Remmel, Chief Engineer, Utilities, Water Gas and Sewer, City of Palo Alto, Mr Perry Wood, Hydrologist, U S Geological Survey, Menlo Park, California, Dr Mohinder S Gulati, Union Oil Company Santa Ana, California, and Dr Henry J Ramey, Jr, Professor and Acting Chairman, Department of Petroleum Engineering, Stanford University Mr Mohamed Soliman and Mr Syed Tariq, both students in the Graduate Program, Department of Petroleum Engineering, Stanford University, assisted in the test drilling and aquifer-test portions of the field investigation

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DISCUSSION

The following questions were answered by N. Thomas Sheahan after delivering his talk entitled "Injection/Extraction Well System—A Unique Seawater Intrusion Barrier"

Q. by Peter Perez *Would you mention the R & D program to be conducted by Stanford University for transmission of viruses and organics between the injection and extraction wells?*

A As a long-term goal, the proposed injection/extraction facility will be used for research to determine the feasibility of such a system for reclaiming water for potable uses A research program has been established by Stanford University, supported by U S Environmental Protection Agency research grant EPA-R-804431, in order to answer some of the significant questions as necessary to realize this long-term goal The major objectives of this research study are as follows

1 To determine the effects the injected wastewater will have on the chemical, physical and biological quality of the basin and injected waters

2 To determine the effect injected wastewater will have on the hydrologic characteristics of the aquifer

3 To seek the optimum quality for injected water which will result in a high-quality basin water and minimum damage to the hydrologic characteristics of the aquifer

4 To develop generalized mathematical models for describing the movement of water the changes in hydrologic characteristics, and resulting changes in water quality from wastewater injection in order to make the results of most value for application in other similar projects

Along these lines technical report No 206 dated April 1976 entitled "Preproject Water Quality Evaluation for the Palo Alto Water Reclamation Facility" and the first quarterly progress report dated August 5 1976 entitled "Groundwater Injection of Reclaimed Water in Palo Alto" have been prepared by the Department of Civil Engineering, Stanford University

Q by Jon O. Nowlin *Was consideration given to the effect on the hydrologic characteristics of the aquitard of using lower-quality effluent as the recharge fluid?*

A. The aquitard allows leakage from the 45-foot zone, into which injection is to take place, to the shallower 20-foot zone The use of reclaimed wastewater or treatment plant effluent as the recharge fluid may have one of two effects on the aquitard it may either decrease its permeability or increase its permeability A third alternative would be no effect at all Since the project is designed to allow leakage through the aquitard and to control such leakage by pumpage from the 20-foot aquifer, an increase in

permeability of the aquitard would have negligible effect on the operation of the project If, on the other hand, use of reclaimed wastewater caused a decrease in permeability in the aquitard,-a reduction in leakage would occur requiring less pumpage from the 20-foot aquifer

Q. by Stanley N. Davis. *I question the postulated mechanism of seawater intrusion Are you aware of the large number of abandoned wells including the old Spring Valley Water Company test wells? These are near the salt marsh edge of the bay They were never adequately filled and subsequently rusted out thus feeding salt water vertically into the underlying aquifers*

A. Not only the Spring Valley Water Company test wells, but many similar [illegible] In addition, further westward there is a greater degree of vertical hydraulic communication between the shallow aquifers and the deeper, water-producing zones, which occurs naturally due to the modes of deposition of the sediments The site for construction of the injection/extraction system was selected so as to preclude any problems such as abandoned wells in its vicinity There are no abandoned wells located between the injection/extraction barrier and the Bayfront area, the source of saline intrusion into the shallow aquifers in the project area

Q. by Stanley N. Davis. *Upper zones have a total dissolved solids of about 5 000 ppm Is this "highly saline"? (See City records of Palo Alto Gold Course test well of about 1964)*

A. The upper zones, in fact, have total dissolved solids well above 5,000 ppm For example the test hole drilled by the Santa Clara Valley Water District in 1972, located immediately east of the injection/extraction system, shows a total dissolved solids of 17,400 mg/l in 1972 and a chloride content of greater than 10,000 mg/l The Palo Alto Golf Course test well penetrates both the shallow zones and the deeper, fresh-water zones Perhaps the water-quality analyses from this well reflect a mixture of both salinated ground water and fresh ground water

Q. by Russel E. Darr. *Do I understand correctly that the injection is in the 40-foot aquifer and the withdrawal is in the 20-foot aquifer?*

A. That is *not* a correct understanding [illegible] Injection is planned for the line of wells on the bayward side and extraction is to occur through the line of wells on the landward side The [illegible] only to [illegible] Injection into the 45-foot aquifer may produce leakage through the aquitard separating the two shallow aquifers and by pumping the 20-foot aquifer, such leakage can be controlled to eliminate any possibilities of waterlogging of the ground surface

Q. by Dennis Goldman *Were longer aquifer tests run? Do you feel that a 24-hour test should be extrapolated to imply zero leakage?*

A. This question concerns the zone between the base of the 45-foot aquifer and the lower 185-foot aquifer, herein termed an aquiclude The total time of pumping for testing of zones on either side of this aquiclude, including both the pumping tests and the injection tests, amounted to over 96 hours of pumping Concerning extrapolation of aquifer-test data to imply zero leakage, it is important to consider the scope and purposes of testing as well as the physical geology and other limitations of the test site Examination of the regional geology of the area shows that the aquiclude changes in character and lithology to the west of the test site In this area westerly, the aquiclude provides vertical intercommunication between the shallow and deep aquifer due to a pinching out of the clay zones, an increase in permeability due to changes in lithology, or a combination of the two In addition, the potential for abandoned wells located westerly of the test site which provide vertical intercommunication from the shallow to the deep aquifer through the aquiclude is also present With continued pumping in a confined aquifer, the area of influence or zone of depression due to such pumping eventually reaches far beyond the area of immediate interest at the test site Such continued pumpage in the project area would eventually show evidence of leakage from the shallow to the deeper zones The purpose of the aquifer test however, was to determine the characteristics of the aquiclude in the vicinity of the test site Therefore, for purposes of this investigation, the pumping tests performed were adequate to determine the characteristics of the aquiclude in view of both the project requirements and the physical geology of the site

Q. *You stated that injection of wastewater would increase head and prevent intrusion What was the head in the upper aquifer before injection? How much can the original head be increased?*

A The head in the 45-foot aquifer at the injection/extraction well prior to injection was at an elevation of −3 23 mean sea level It was determined that the original head can be increased by a maximum of 20 psi, or approximately 46 feet, without creating any potential for heaving or leakage around seals in the well

Q. *Recharge and subsequent extraction has no benefit over salt-water intrusion if the water cannot be used Do you agree?*

A. I do not agree Salt-water intrusion has the potential of degradation for the entire ground-water aquifer under heavy pumping conditions in the Palo Alto area, and is therefore detrimental Recharge and subsequent extraction have the benefit of controlling seawater intrusion as well as providing utilization of the recharged and extracted water for industrial and agricultural purposes downstream of the project area

Q. *Would you save pumping costs if you stopped seawater from coming into the bay if the Corps of Engineers were to build a locks and dam under Golden Gate Bridge?*

A. This may be a tongue-in-cheek question Even if the Corps of Engineers controlled the water quality within the bay and maintained fresh water in San Francisco Bay, the existence of salt evaporation ponds in the vicinity of the project site present the potential for further salination of shallow aquifers through leaching from these salt ponds Therefore such a project would still be required to prevent salination of the shallow aquifers and to provide protection of the deeper water supplies

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Section 7.3

Subsidence Control Wells Supporting Data

Section 7.3.1

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	"Case History No. 9.11, Alabama, U.S.A.". From Guidebook to Studies of Land Subsidence Due to Ground-Water Withdrawal
AUTHOR: **(or INVESTIGATOR)**	J.G. Newton U.S. Geological Survey Tuscaloosa, Alabama
DATE:	1984
FACILITY NAME AND LOCATION:	Alabama USEPA Region IV
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	Information presented here consists of excerpts taken from five reports by the author. They resulted from investigation by the U.S. Geological Survey made in cooperation with the Geological Survey of Alabama and/or the Alabama Highway Department. The reports are concerned with induced sinkholes resulting from a decline in the water table due to ground-water withdrawals. This case study addresses geologic and hydrologic setting, cause, magnitude and areal extent, economic impact, and corrective measures.

Case History No. 9.11. Alabama, U.S.A., by J. G. Newton, U.S. Geological Survey, Tuscaloosa, Alabama

9.11.1 INTRODUCTION

Sinkholes in Alabama are divided into two categories defined as "induced" and "natural." Induced sinkholes are those related to man's activities whereas natural sinkholes are not. Induced sinkholes are further divided into two types: those resulting from a decline in the water table due to ground-water withdrawals and those resulting from construction. Those resulting from a decline in the water table, the subject of this case history, far outnumber those resulting from all other causes. Information presented here consists of excerpts taken from five reports by the author. These reports, approved for publication by the Director, U.S. Geological Survey, are listed with the references cited in this case history. They resulted from investigations by the U.S. Geological Survey made in cooperation with the Geological Survey of Alabama and/or the Alabama Highway Department.

9.11.2 *GEOLOGIC AND HYDROLOGIC SETTING*

The terrane used to illustrate sinkhole development is a youthful basin underlain by carbonate rocks such as limestone and dolomite (Figure 9.11.1). The basin contains a perennial or near-perennial stream. This particular terrane is used because it is very similar to that of 10 active areas of sinkhole development in Alabama that have been examined by the author. Factors related to the development of sinkholes that have been observed in these areas are generally applicable to other carbonate terranes. The terrane illustrated differs from those examined only in the inclination of beds, which is shown as horizontal for ease of illustration.

The development of sinkholes is primarily dependent on past and present relationships between carbonate rocks and water, climatic conditions, vegetation, and topography, and on the presence or absence of residual or other unconsolidated deposits overlying bedrock. The source of water associated with the development of sinkholes is precipitation which, in Alabama, generally exceeds 1,270 mm annually. Part of the water runs off directly into streams, part replenishes soil moisture but is returned to the atmosphere by evaporation and transpiration, and the remainder percolates downward below the soil zone to ground-water reservoirs.

Water is stored in and moves through interconnected openings in carbonate rocks. Most of the openings were created, or existing openings along bedding planes, joints, fractures, and faults were enlarged by the solvent action of slighly acidic water coming in contact with the rocks. Water in the interconnected openings moves in response to gravity from higher to lower altitudes, generally toward a stream channel where it discharges and becomes a part of the streamflow.

Water in openings in carbonate rocks occurs under both water-table and artesian conditions; however, this study is concerned primarily with that occurring under water-table conditions. The water table is the unconfined upper surface of a zone in which all openings are filled with water. The configuration of the water table conforms somewhat to that of the overlying topography but is influenced by geologic structure, withdrawal of water, and variations in rainfall. The lowest altitude of the water level in a drainage basin containing a perennial stream occurs where the water level intersects the stream channel (Figure 9.11.1). Openings in bedrock underlying lower parts of the basin are water filled. This condition is maintained by recharge from precipitation in the basin. The water table underlying adjacent highland areas within the basin occurs at higher altitudes than the water table near the perennial stream. Openings in bedrock between the land surface and the underlying water table in highland areas are air filled (Figure 9.11.1).

The general movement of water through openings in bedrock underlying the basin, even though the route may be circuitous, is toward the stream channel and downstream under a gentle gradient approximating that of the stream. Some water moving from higher to lower altitudes is discharged through springs along flanks of the basin because of the intersection of the land surface and the water table. The velocity of movement of water in openings underlying most of

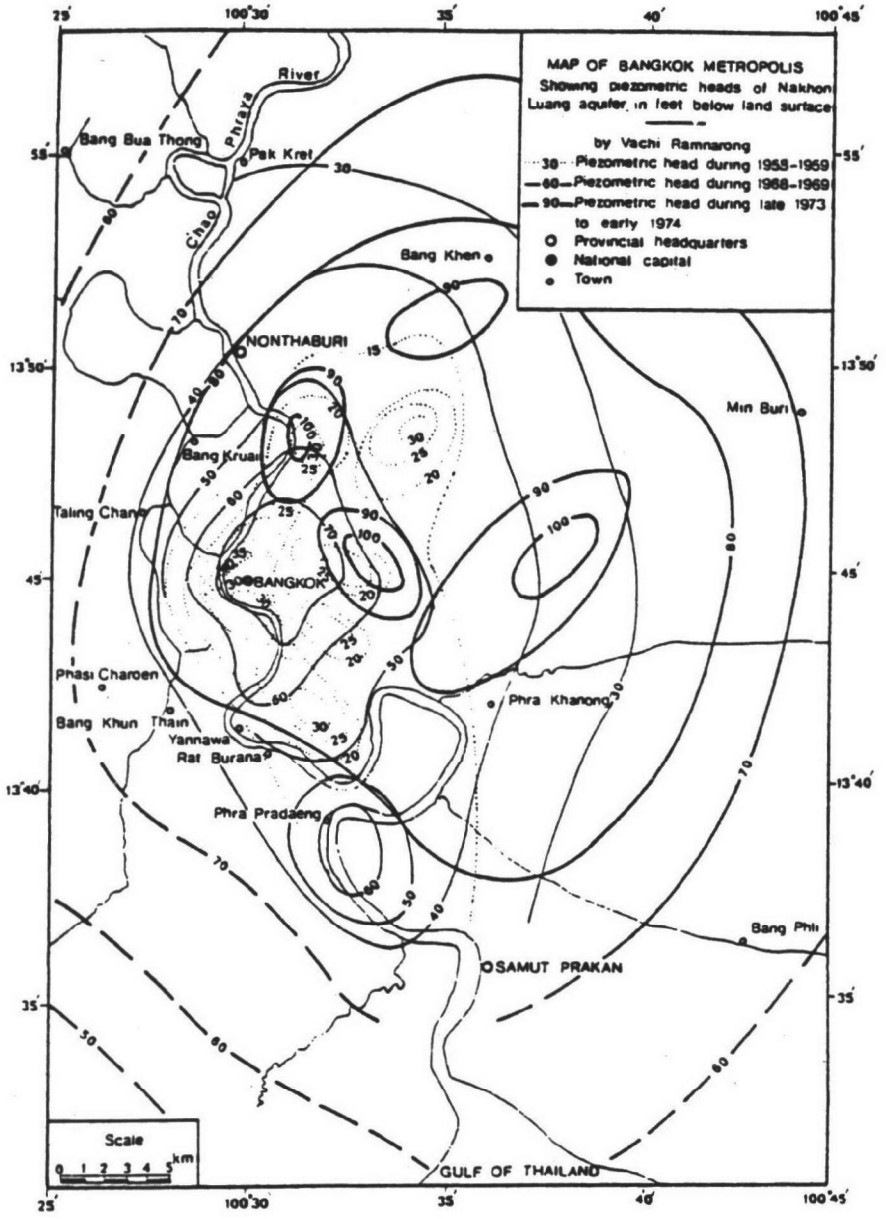

Figure 9.10.3 Water level map of the Nakhon Luang Aquifer (after Piancharoen, 1977, Figure 3).

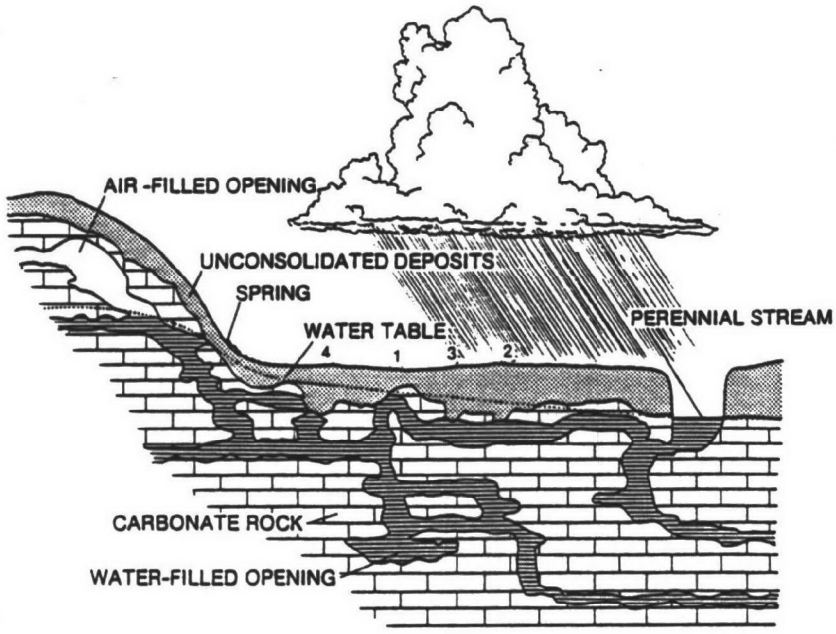

Figure 9.11.1 Schematic cross-sectional diagram of basin showing geologic and hydrologic conditions. (Numbers apply to sites described in report.)

the lowland area is probably sluggish when compared to that in openings at higher altitudes.

A mantle of unconsolidated deposits consisting chiefly of residual clay (residuum), that has resulted from the solution of the underlying carbonate rocks, generally covers most of the bedrock in the typical basin described. Alluvial or other unconsolidated deposits often overlie the residual clay. The residuum commonly contains varying amounts of chert debris that are insoluble remnants of the underlying bedrock. Some unconsolidated deposits are carried by water into openings in bedrock. These deposits commonly fill joints, fractures, or other openings enlarged by solution that underlie the lowland areas. The buried contact between the residuum and the underlying bedrock, because of differential solution, can be highly irregular (Figure 9.11.1).

9.11.3 CAUSE

A relationship between the formation of sinkholes and high pumpage of water from new wells was recognized in Alabama as early as 1933 (Johnston, 1933). Subsequent studies in Alabama (Robinson and others, 1953; Powell and LaMoreaux, 1969; Newton and Hyde, 1971; Newton and others, 1973; and Newton, 1976) have verified this relationship. Dewatering or the continuous withdrawal of large quantities of water from carbonate rocks by wells, quarries, and mines in numerous areas in Alabama is associated with extremely active sinkhole development. Numerous collapses in these areas contrast sharply with their lack of occurrence elsewhere.

Two areas in Alabama in which intensive sinkhole development has occurred and is occurring have been studied in detail. Both areas were made prone to the development of sinkholes by major declines of the water table due to the withdrawal of ground water. The formation of sinkholes in both areas resulted from the creation and collapse of cavities in unconsolidated deposits caused by the declines (Newton and Hyde, 1971; Newton and others, 1973). The growth of one such cavity in Birmingham has been photographed through a small adjoining opening (Newton, 1976).

Previous reports have described only indirectly or in part the hydrologic forces resulting from a decline in the water table that create or accelerate the growth of activities that collapse and form sinkholes. These forces, based on studies in Alabama (Newton and Hyde, 1971; Newton and others, 1973), are (a) a loss of support to roofs of cavities in bedrock previously filled with water and to residual clay or other unconsolidated deposits overlying openings in bedrock, (b) an increase in the velocity of movement of ground water, (c) an increase in the

amplitude of water-table fluctuations, and (d) the movement of water from the land surface to openings in underlying bedrock where recharge had previously been rejected because the openings were water filled. The same forces creating cavities and subsequent collapses also result in subsidence. The movement of unconsolidated deposits into bedrock where the strength of the overlying material is not sufficient to maintain a cavity roof, will result in subsidence at the surface (Donaldson, 1963).

To demonstrate forces that result in the development of cavities and their eventual collapse, a schematic diagram is shown in Figure 9.11.2 that illustrates changes in natural geologic and hydrologic conditions previously described and shown in Figure 9.11.1. A description of the forces triggered by a lowering of the water table follows.

The loss of buoyant support following a decline in the water table can result in an immediate collapse of the roofs of openings in bedrock or can cause a downward migration of unconsolidated deposits overlying openings in bedrock. The buoyant support exerted by water on a solid (and hypothetically) unsaturated clay overlying an opening in bedrock, for instance, would be equal to about 40 per cent of its weight. This determination is based on the specific gravities of the constituents involved. Site 1 on Figure 9.11.1 shows the unconsolidated deposit overlying a water-filled opening in bedrock. Site 1 on Figure 9.11.2 shows the decline in the water table and the resulting cavity in the deposit formed by the downward migration of the unconsolidated deposit caused by the loss of support.

The creation of a cone of depression in an area of water withdrawal results in an increased hydraulic gradient toward the point of discharge (Figure 9.11.2) and a corresponding increase in the velocity of movement of water. This force can result in the flushing out of the finer grained unconsolidated sediments that have accumulated in the interconnected openings enlarged by solution. This movement also transports unconsolidated deposits migrating downward into bedrock openings to the point of discharge or to a point of storage in openings at lower altitudes.

The increase in the velocity of ground-water movement also plays an important role in the development of cavities in unconsolidated deposits. Erosion caused by the movement of water through unobstructed openings and against joints, fractures, faults, or other openings filled with clay or other unconsolidated sediments results in the creation of cavities that enlarge and eventually collapse (Johnston, 1933; Robinson and others, 1953).

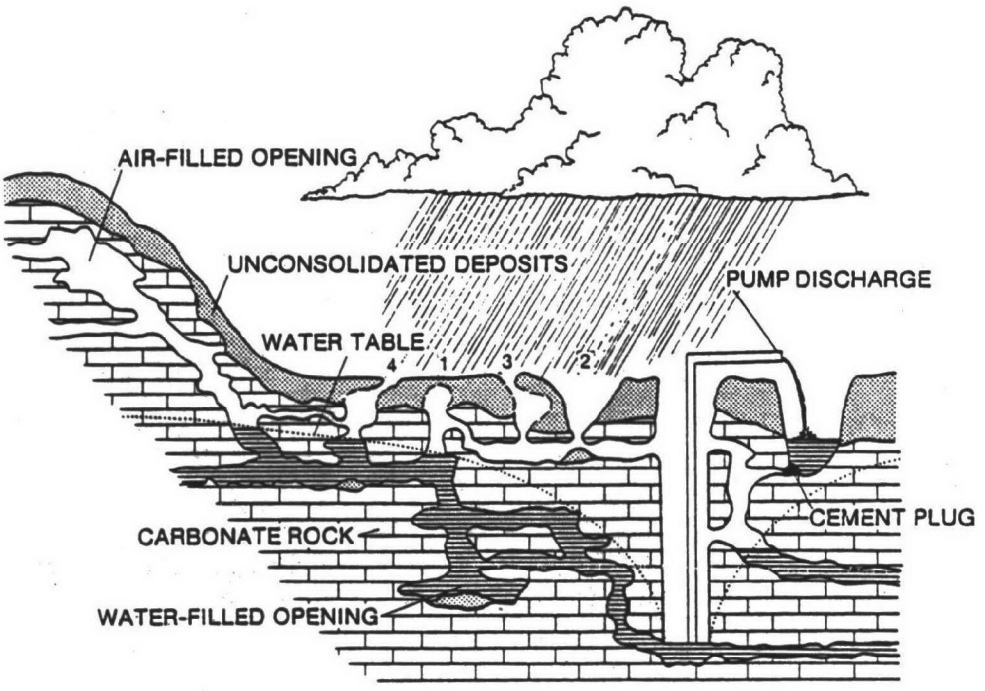

Figure 9.11.2 Schematic cross-sectional diagram of basin showing changes in geologic and hydrologic conditions resulting from water withdrawal. (Numbers apply to sites described in report.)

Pumpage results in fluctuations in ground-water levels that are of greater magnitude than those occurring under natural conditions. The magnitude of these fluctuations depends principally on variations in water withdrawal and on fluctuations in natural recharge. The repeated movement of water through openings in bedrock against overlying residuum or other unconsolidated sediments causes a repeated addition and subtraction of support to the sediments and repeated saturation and drying. This process might be best termed "erosion from below" because it results in the creation of cavities in unconsolidated deposits, their enlargement, and eventual collapse. Fluctuations of the water table against the roof of a cavity in unconsolidated deposits near Greenwood, Alabama, have been observed and photographed through a small collapse in the center of the roof. These fluctuations, in conjunction with the movement of surface water into openings in the ground, resulted in the formation of the cavity and its collapse (Newton and others, 1973).

A drastic decline of the water table in a lowland area (Figure 9.11.2) in which all openings in the underlying carbonate rock were previously water filled (Figure 9.11.1) commonly results in induced recharge of surface water. This recharge was partly rejected prior to the decline because the underlying openings were water filled. The quantity of surface water available as recharge to such an area is generally large because of the runoff moving to and through it from areas at higher altitudes.

The inducement of surface-water infiltration through openings in unconsolidated deposits interconnected with openings in underlying bedrock results in the creation of cavities where the material overlying the openings in bedrock is eroded to lower altitudes. Repeated rains result in the progressive enlargement of this type cavity. A corresponding thinning of the cavity roof due to this enlargement eventually results in a collapse. The position of the water table below unconsolidated deposits and openings in bedrock that is favorable to induced recharge is illustrated in Figure 9.11.2. Sites 2, 3, and 4 on Figure 9.11.2 illustrate a collapse and cavities in unconsolidated deposits that were formed primarily or in part by induced recharge. The creation and eventual collapse of cavities in unconsolidated deposits by induced recharge is the same process described by many authors as "piping" or "subsurface mechanical erosion" where it has been applied mainly to collapses occurring on noncarbonate rocks (Allen, 1969).

In an area of sinkhole development where a cone of depression is maintained by constant pumpage (Figure 9.11.2), all of the forces described are in operation even though only one may be principally responsible for the creation of a cavity and its collapse. For instance, the inducement of recharge from the surface (site 2 on Figure 9.11.2) where the water table is maintained at depths well below the base of unconsolidated deposits, can be solely responsible for the development of cavities and their collapse. In contrast, a cavity resulting from a loss of support (site 1 on Figure 9.11.2) can be enlarged and collapsed by induced recharge if it has intersected openings interconnected with the surface. In an area near the outer margin of the cone (site 4 on Figure 9.11.2), the creation of a cavity and its collapse can result from all forces. The cavity can originate from a loss of support; can be enlarged by the continual addition and subtraction of support and the alternate wetting and drying resulting from water-level fluctuations; can be enlarged by the increased velocity of movement of water; and can be enlarged and collapsed by water induced from the surface.

9.11.4 MAGNITUDE AND AREAL EXTENT

It is estimated that more than 4,000 induced sinkholes, areas of subsidence, or other related features have occurred in Alabama since 1900. Most of them have occurred since 1950. Almost all have resulted from a decline in the water table due to ground-water withdrawals.

Dewatering or the continuous withdrawal of large quantities of water from carbonate rocks by wells, quarries, and mines in numerous other areas in Alabama is associated with extremely active sinkhole development. Numerous collapses in these areas contrast sharply with their lack of occurrence in adjacent geologically and hydrologically similar areas where withdrawals of water are minimal. For example, in five areas examined by the author in north-central Alabama in Jefferson and Shelby Counties, an estimated 1,700 collapses, areas of subsidence, or other associated features have formed in a total combined area of about 36 km^2.

In Alabama, most induced sinkholes related to water withdrawals from wells, except those drilled specifically for dewatering purposes, were found within 150 m of the site of withdrawal. The yield of these wells commonly exceeds 22 l/s. Most sinkholes related to quarry operations were found within 600 m of the point of withdrawal; those related to mining operations can occur several kilometres from the point of withdrawal.

Recent collapses forming sinkholes in Alabama in areas in which large quantities of ground

water are being withdrawn generally range from 1 to 90 m in diameter and from 0.3 to 30 m in depth. The largest, located in a wooded area in Shelby County, apparently occurred in a matter of seconds in December 1972. The collapse was about 90 m in diameter and 30 m deep (Figure 9.11.3).

9.11.5 ECONOMIC IMPACT

Costly damage and numerous accidents have occurred or nearly occurred in Alabama as a result of collapses beneath highways, streets, railroads, buildings, sewers, gas pipelines, vehicles, animals, and people. Unfortunately, no inventory of costs or loss in property values has been made. The maintenance and protection of highways in sinkhole prone areas indicate costs resulting from their development. The cost of filling collapses, leveling pavement and monitoring subsidence along less than a kilometre of Interstate Highway 59 in Birmingham, Alabama, during the period 1972-77 is estimated to have exceeded $250,000 (L. Lockell, oral commun.). The estimated cost of bridging a part of this area, and planned safety measures for highways crossing two similar areas near Birmingham exceeds $4,660,000 (C. Kelly, oral commun.). The need for these protective measures is well illustrated by the damage to a warehouse in 1973 (Figure 9.11.4) that resulted from a collapse adjacent to Interstate Highway 59 in Birmingham.

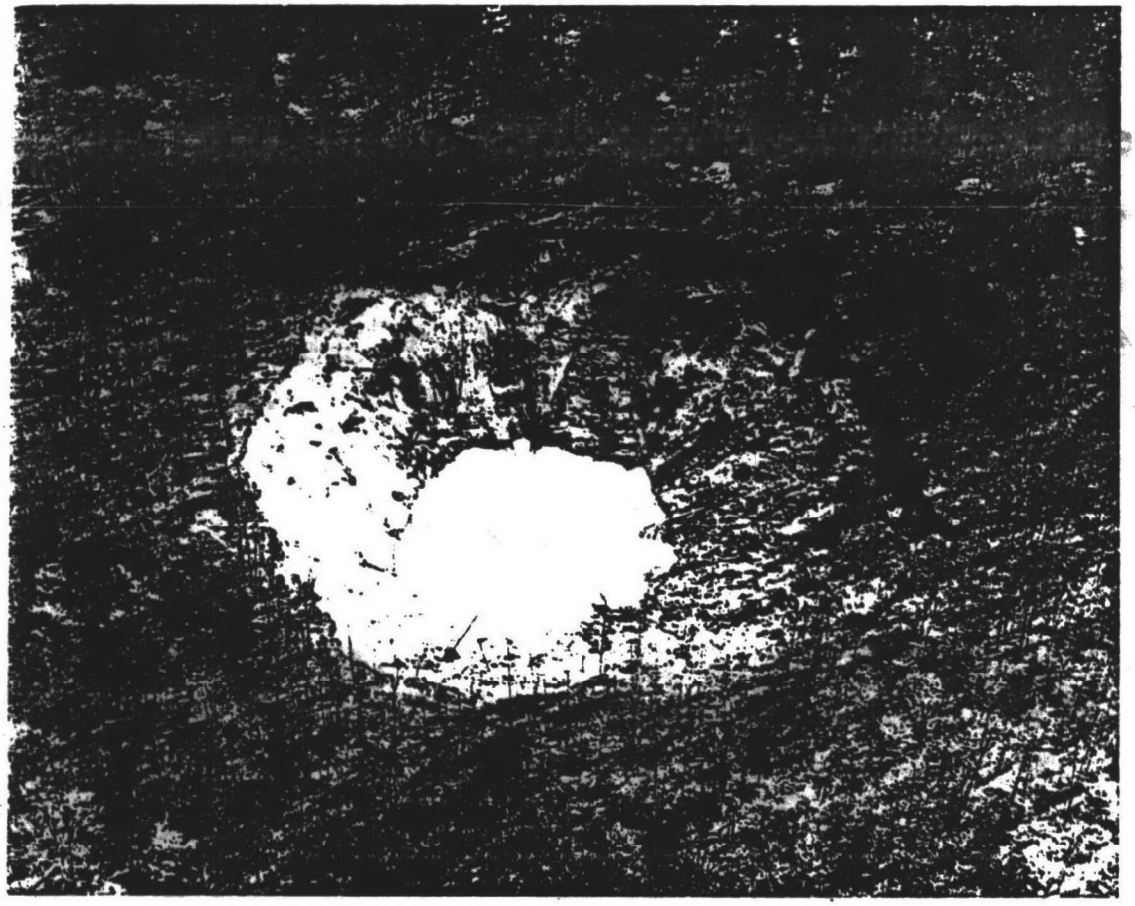

Figure 9.11.3 Sinkhole resulting from collapse near Calera in Shelby County, Alabama (photograph by Curtis Frizzell).

Figure 9.11.4 Collapse in warehouse near Interstate Highway 59 in Birmingham, Alabama (photograph by T. V. Stone).

9.11.6 CORRECTIVE MEASURES

Ideally, the development of sinkholes can be eliminated or minimized by ceasing the pumpage that causes the decline of the water table. The cessation of or drastic decrease in sinkhole activity following a recovery of the water table has been recognized previously (Foose, 1953; Newton and Hyde, 1971; Newton, 1976). Most efforts in Alabama have been directed toward measures minimizing sinkhole development and eliminating potential hazards and damage to structures rather than dealing with the cause. The measures that have been or will be utilized include bridging, adding additional support, the removal of unconsolidated deposits overlying bedrock, grouting, minimizing the diversion of natural drainage, and the construction of flumes and other impermeable drainage systems.

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Section 7.3.2

TITLE OF STUDY: (or SOURCE OF INFORMATION)	"Case History No. 9.12, The Houston-Galveston Region, Texas, U.S.A." From Guidebook to Studies of Land Subsidence Due to Ground-Water Withdrawal
AUTHOR: (or INVESTIGATOR)	R.K. Gabrysch, U.S. Geological Survey, Houston, Texas
DATE:	1984
FACILITY NAME AND LOCATION:	Houston-Galveston Region, Texas USEPA Region VI
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	Numerous reports on subsidence in the Houston-Galveston region have attributed subsidence to the compaction of fine-grained material associated with oil- and water-bearing sands. More recent reports present data and interpretations of regional subsidence and its relation to the withdrawals of groundwater for municipal supply, industrial use, and irrigation. This case study addresses geology and hydrology of the Houston-Galveston region, development of ground water, subsidence of the land surface, and future subsidence in the region.

Case History No. 9.12. The Houston-Galveston Region, Texas, U.S.A., by R. K. Gabrysch, U.S. Geological Survey, Houston, Texas

9.12.1 INTRODUCTION

The Houston-Galveston region of Texas, as described in this report, includes all of Harris and Galveston Counties and parts of Brazoria, Fort Bend, Waller, Montgomery, Liberty, and Chambers Counties (Figure 9.12.1). Land-surface subsidence has become critical in parts of the region because some low-lying areas along Galveston Bay are subject to inundation by normal tides, and an even larger part of the region may be subject to catastrophic flooding by hurricane tides. Hurricanes resulting in tides of 3.0-4.6 metres above sea level strike the Texas coast on the average of once every 10 years.

Land-surface subsidence due to fluid withdrawals was first documented in the Goose Creek oil field in Harris County (Pratt and Johnson, 1926). Since then, numerous reports on subsidence in the Houston-Galveston region have attributed subsidence to the compaction of fine-grained material associated with the oil- and water-bearing sands. The more recent reports (Winslow and Doyel, 1954; Winslow and Wood, 1959; Gabrysch, 1969; and Gabrysch and Bonnet, 1975a) present data and interpretations of regional subsidence and its relation to the withdrawals of ground water for municipal supply, industrial use, and irrigation. The authors of these reports recognized that subsidence due to the removal of oil and gas has occurred in the region, but the data are not sufficient to describe in detail the localized areas of occurrence.

9.12.2 GEOLOGY AND HYDROLOGY OF THE HOUSTON-GALVESTON REGION

The aquifers in the Houston-Galveston region are composed of sand and clay beds that are not persistent in either lithology or thickness. The beds grade into each other both laterally and vertically within short distances; consequently, differentiation of geological formations on drillers' logs and electrical logs is almost impossible. However, by use of both the logs and the hydraulic properties of the aquifers, the subsurface units have been divided into three major aquifer systems and one confining system (Jorgensen, 1975).

The age of the geological formations composing the aquifers and the confining layer ranges from Miocene to Holocene. The deepest aquifer containing freshwater is the Jasper aquifer of Miocene age, which is separated from the overlying Evangeline and Chicot aquifers by the Burkeville confining layer. The two principal aquifer systems of the region are the Chicot aquifer of Pleistocene age and the Evangeline aquifer of Pliocene age. The Burkeville confining layer is probably part of the Fleming Formation of Miocene age.

The aquifers are under artesian conditions throughout most of the region, but little information on the hydraulic properties of the Jasper aquifer is available because it is undeveloped. Reports of test holes in the Jasper (W. F. Guyton, oral commun., 1977) indicate that the hydraulic head in the Jasper is above land surface, which probably approximates the original conditions. It is assumed that with no change in head, compaction of the deposits in the Jasper system has not occurred; therefore, the discussion of subsidence in this report will be restricted to a discussion of the Evangeline and Chicot aquifer systems.

The Evangeline aquifer system is composed of the Goliad Sand and possibly the upper part of the Fleming Formation. The system contains sands that yield freshwater of good quality in about the inland two-thirds of the region. The transmissivity of the aquifer system ranges from less than 460m^2/d to about 1,400 m^2d. The horizontal hydraulic conductivity is about 4.57 metres per day, and the storage coefficient ranges from about 0.00005 to more than 0.001.

The Chicot aquifer system is composed of the Willis Sand, Bentley Formation, Montgomery Formation, Beaumont Clay, and the Quaternary alluvium and includes the deposits from the land surface to the top of the Evangeline aquifer. The transmissivity of the Chicot aquifer ranges from 0 to about 1,858 m^2/d. The horizontal hydraulic conductivity is about twice that of the Evangeline aquifer, and the storage coefficient ranges from 0.00004 to 0.20. The larger values

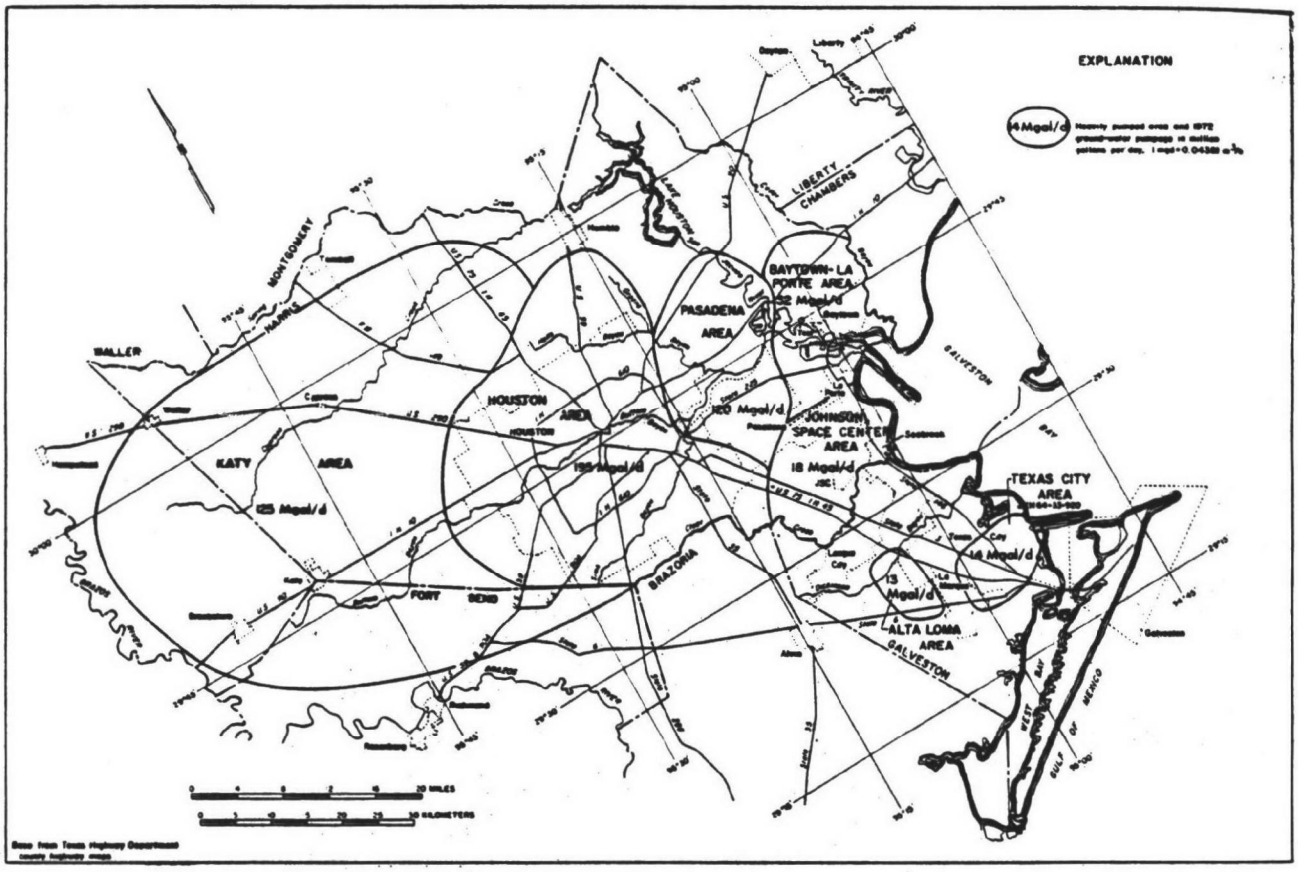

Figure 9.12.1 Locations of principal areas of ground-water withdrawals and average rates of pumping in 1972.

of the storage coefficient occur in the northern part of the region where the aquifer crops out and is partly under water-table conditions.

Both the Evangeline and the Chicot aquifer systems contain many layers of clay interbedded with the water-bearing sands. The clay beds are generally less than 6 metres thick, but locally they retard the vertical movement of water. Every sand bed, therefore, has a different hydraulic head. Data from cores of the clay beds were obtained at six sites for evaluation of subsidence in the Houston-Galveston region. The mineral composition of 27 samples from 5 sites were also determined (Gabrysch and Bonnet, 1975b and unpublished data). Montmorillonite is the principal mineral constituent of the clay beds, which also contain smaller amounts of illite, chlorite, and kaolinite.

9.12.3 DEVELOPMENT OF GROUND WATER

Development of ground water in the Houston-Galveston region for municipal supply and irrigation began in the 1890's. Ground-water withdrawals increased gradually to about 4.4 m^3/s (cubic metres per second) with population growth, increased irrigation, and industrial use until the late 1930's. Construction of the large industrial complex in the region began in 1937, and by 1954 ground-water pumping had increased to about 18 m^3/s.

Ground-water pumping decreased to about 14 m^3/s by 1959 because of the introduction of a supply of surface water in 1954 from nearby Lake Houston on the San Jacinto River. By 1962, ground-water pumping was again at a rate of about 18 m^3/s.

Pumping of ground water for municipal supply, industrial use, and irrigation was approximately 46 per cent, 33 per cent, and 21 per cent, respectively, of the total of 23 m^3/s pumped in 1972. The principal areas of pumping and the average daily rates of pumping in 1972 in each area are shown on Figure 9.12.1. Pumping in 1975 for all uses was 22 m^3/s.

The pumping of larger amounts of ground water has resulted in water-level declines during 1943-73 of as much as 61 metres in wells completed in the Chicot aquifer and as much as 99 metres in wells completed in the Evangeline aquifer (Figures 9.12.2 and 9.12.3). The maximum average annual rate of water-level decline for 1943-73 was 2.0 metres in the Chicot aquifer and 3.3 metres in the Evangeline aquifer. During 1964-73, the maximum rate of decline was 3.0 metres in the Chicot and 5.4 metres in the Evangeline.

9.12.4 SUBSIDENCE OF THE LAND SURFACE

The area of the greatest amount of subsidence coincides with the area of the greatest amount of artesian-pressure decline, which is east-southeast of Houston at Pasadena. Figure 9.12.4 shows that as much as 2.3 metres of subsidence occurred at Pasadena between 1943 and 1973. It should be noted, however, that within the entire region of subsidence, more than one center occurs. These areas are indicated by the closed contours on Figure 9.12.4.

Some of the centers of subsidence may be associated with the pumping of oil and gas and some may be associated with the pumping of ground water. Additional complications in analyzing the causes and areal distribution of subsidence result from the varying thicknesses of individual beds of fine-grained material, the varying total thickness of fine-grained material, the vertical distribution of changes in artesian head, and the relation of compressibility to depth of burial. An example of the effects of compressibility and depth of burial occurs in the southern part of Harris County where about 55 per cent of the subsidence is due to compaction in the Chicot aquifer, which composes only the upper one-fourth of the estimated compacting interval.

Figure 9.12.5 shows subsidence for 1964-73. The maximum amount of subsidence during this period was about 1.1 metres. The indicated maximum average rate for the 9-year period is about 0.12 metre per year as compared to the maximum average rate of 0.08 metre per year for the 30-year period 1943-73. During the last part of the 1943-73 period, the rate of subsidence accelerated, and the area of subsidence increased. The area in which subsidence is 0.3 metre or more increased from about 906 square kilometres in 1954 to about 6,475 square kilometres in 1973.

The maps showing the amounts of subsidence (Figures 9.12.4 through 9.12.6) were constructed from data obtained from the leveling program of the National Geodetic Survey (formerly the U.S. Coast and Geodetic Survey) supplemented by data obtained from local industries. Some subsidence occurred before 1943, but the amount is difficult to determine. However, an approximation of the amount and extent of the subsidence that occurred between 1906 and 1943 is shown on Figure 9.12.6. By 1943, four centers of subsidence were apparent. The centers at Pasadena, Baytown, and Texas City were the result of ground-water pumping; and the center in the Goose Creek oil field resulted from the production of oil, gas, and saltwater.

Because of the nature of deposition of the aquifer systems, each sand bed has a different hydraulic head, and each clay layer is under a different amount of stress. The water-level declines shown by Figures 9.12.2 and 9.12.3 are the maximum declines that have occurred in each of the aquifers. Water-level measurements indicate that the water table is approximately at its original position (about 2 to 6 metres below land surface). Piezometers installed at different depths at each of eight sites are used to define the potentiometric profiles. The differences between the measurements in the piezometers and the original potentiometric surfaces define the stress profile. As an example, at a site in the Pasadena area, the depths to water below land surface in January 1978 were as follows.

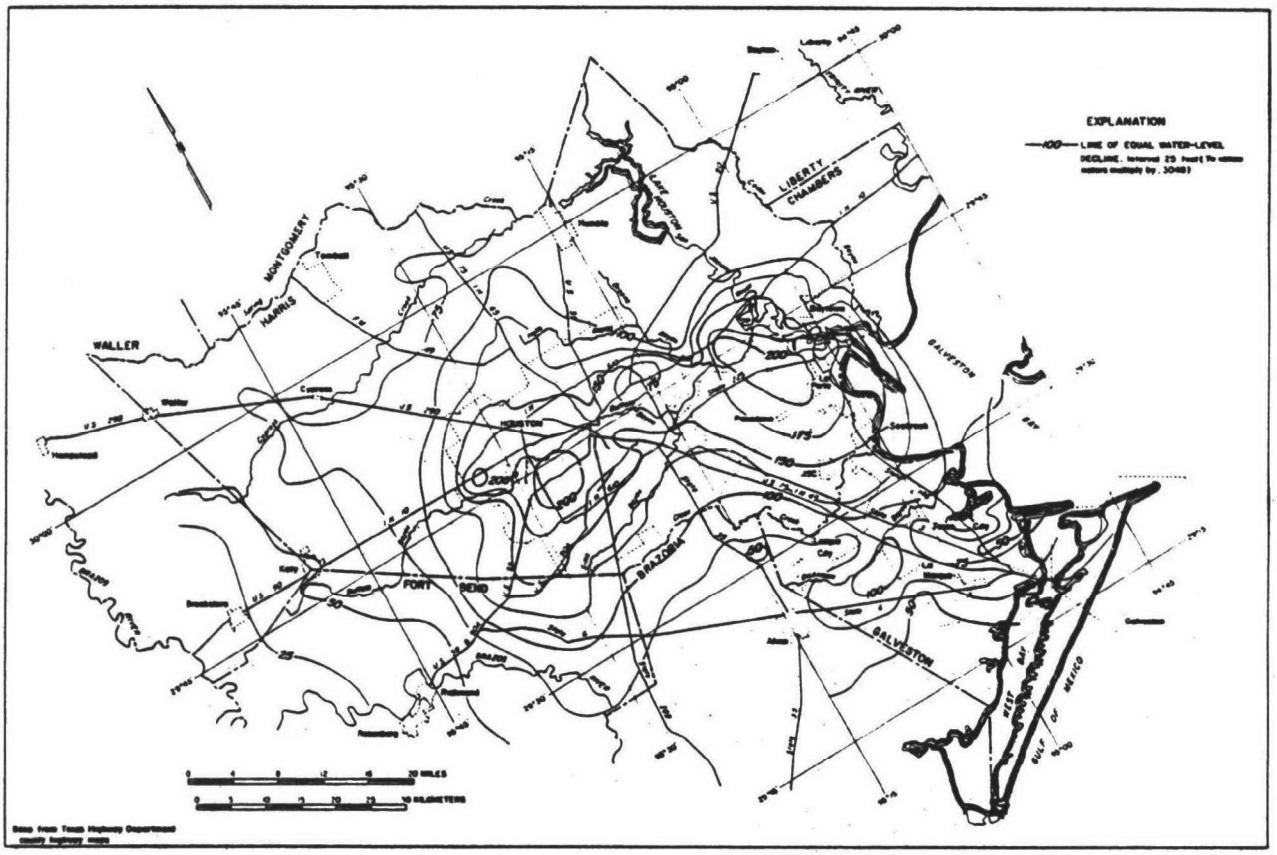

Figure 9.12.2 Approximate declines of water levels in wells completed in the Chicot aquifer, 1943-73.

Piezometer depth (metres)	Depth to water (metres)
10	1.85
30	4.31
119	45.21
221	100.31
284	102.74
403	100.44
552	93.20
828	47.28

The potentiometric surface in each of the two aquifer systems was 15 to 30 metres above land surface before large withdrawals began.

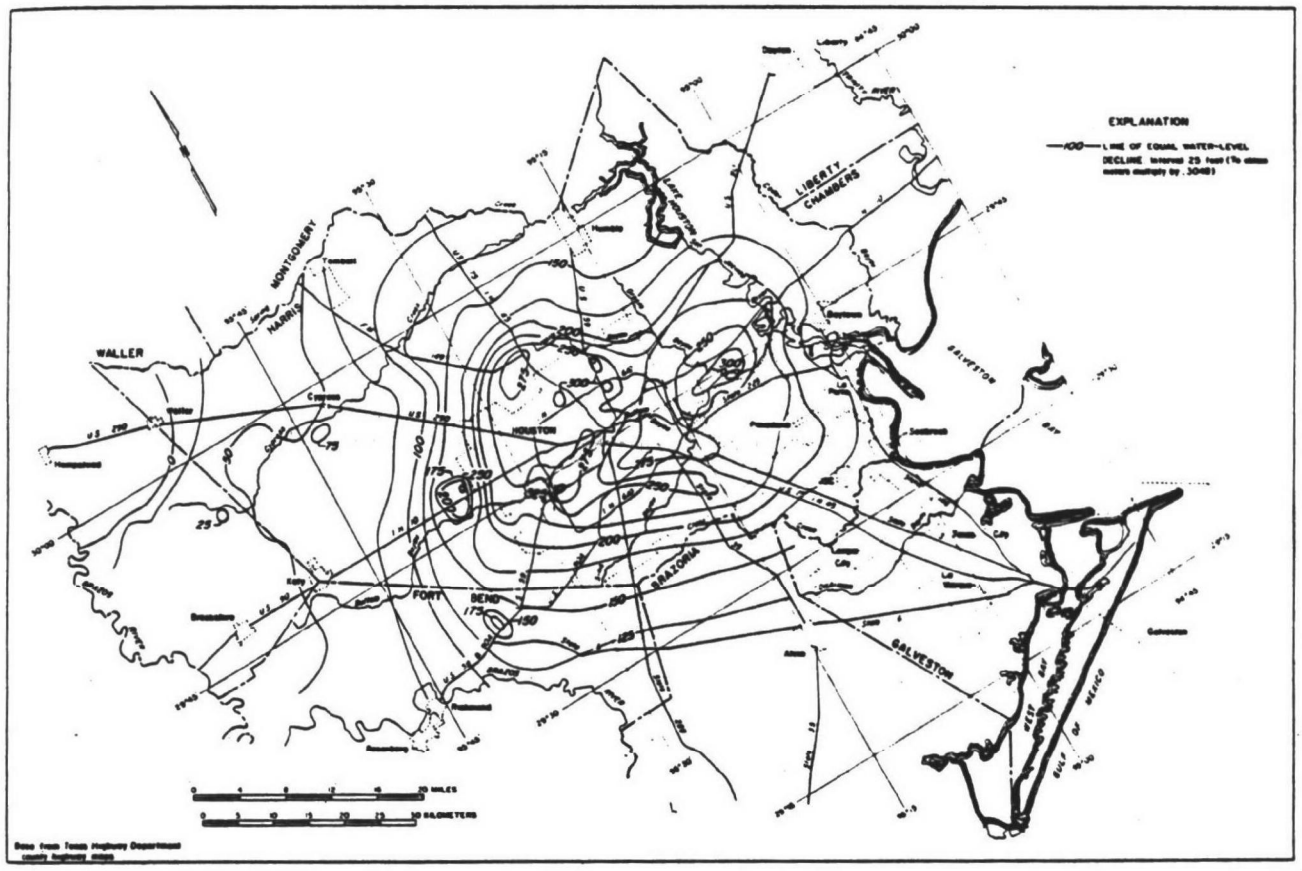

Figure 9.12.3 Approximate declines of water levels in wells completed in the Evangeline aquifer, 1943-73.

The compressibility of the aquifer system has been estimated at two locations. At Seabrook, it is assumed that no compaction due to ground-water pumping occurred below a depth of about 610 metres. Above 610 metres, the sediments include about 243.5 metres of fine-grained material, and the average stress applied to the system during 1943-73 was estimated to be a change in head of 38.6 metres of water. Subsidence during 1943-73 was 0.91 metre; therefore, the compressibility of the fine-grained materials was determined to be

$$0.91 \text{ m}/(243.5 \text{ m})\ (38.6) = 9.7 \times 10^{-5}\text{m}^{-1}.$$

At Texas City, it is assumed that no compaction due to ground-water pumping occurred below a depth of 506 metres. Above 506 metres, the sediments include about 151.5 metres of fine-

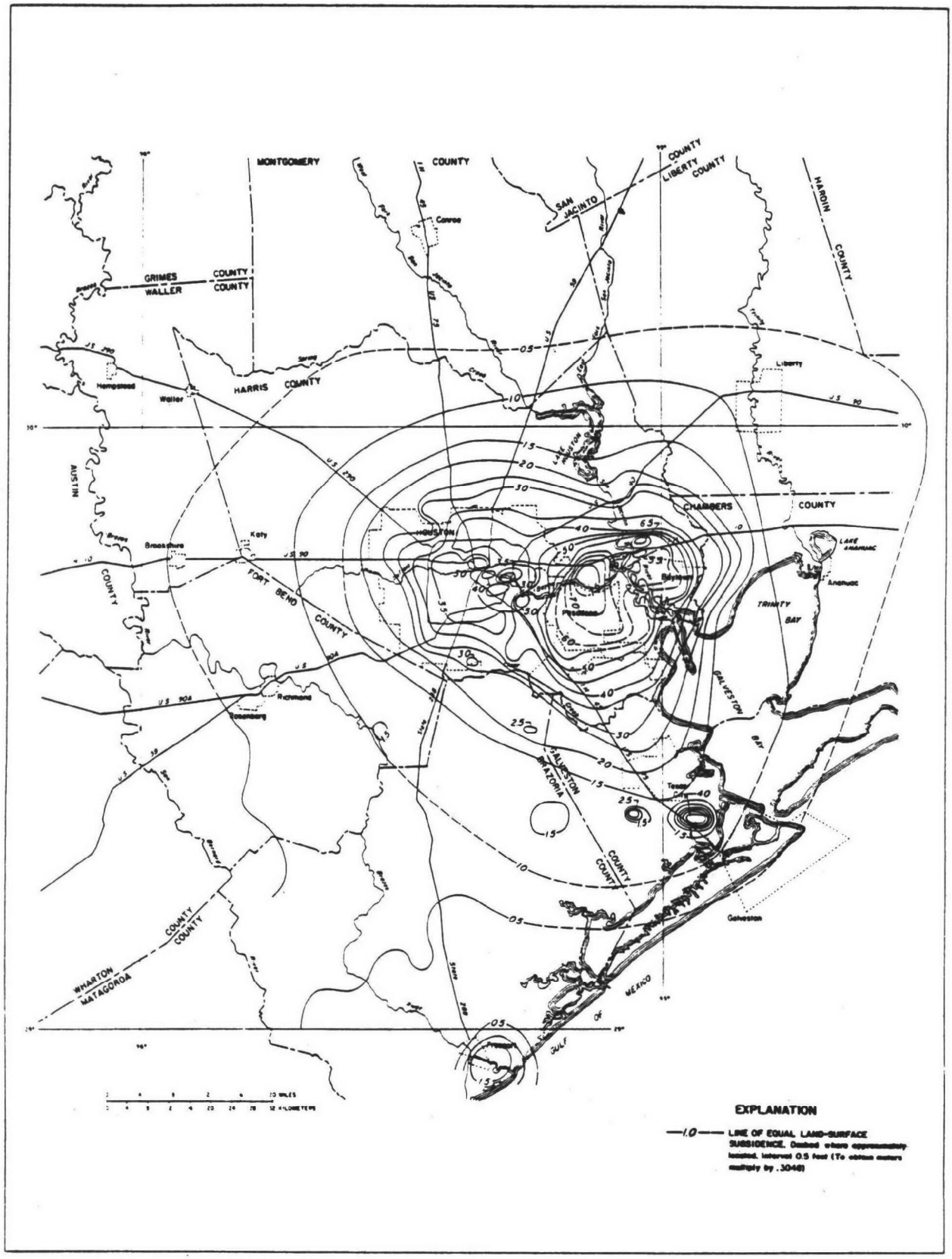

Figure 9.12.4 Subsidence of the land surface, 1943-73.

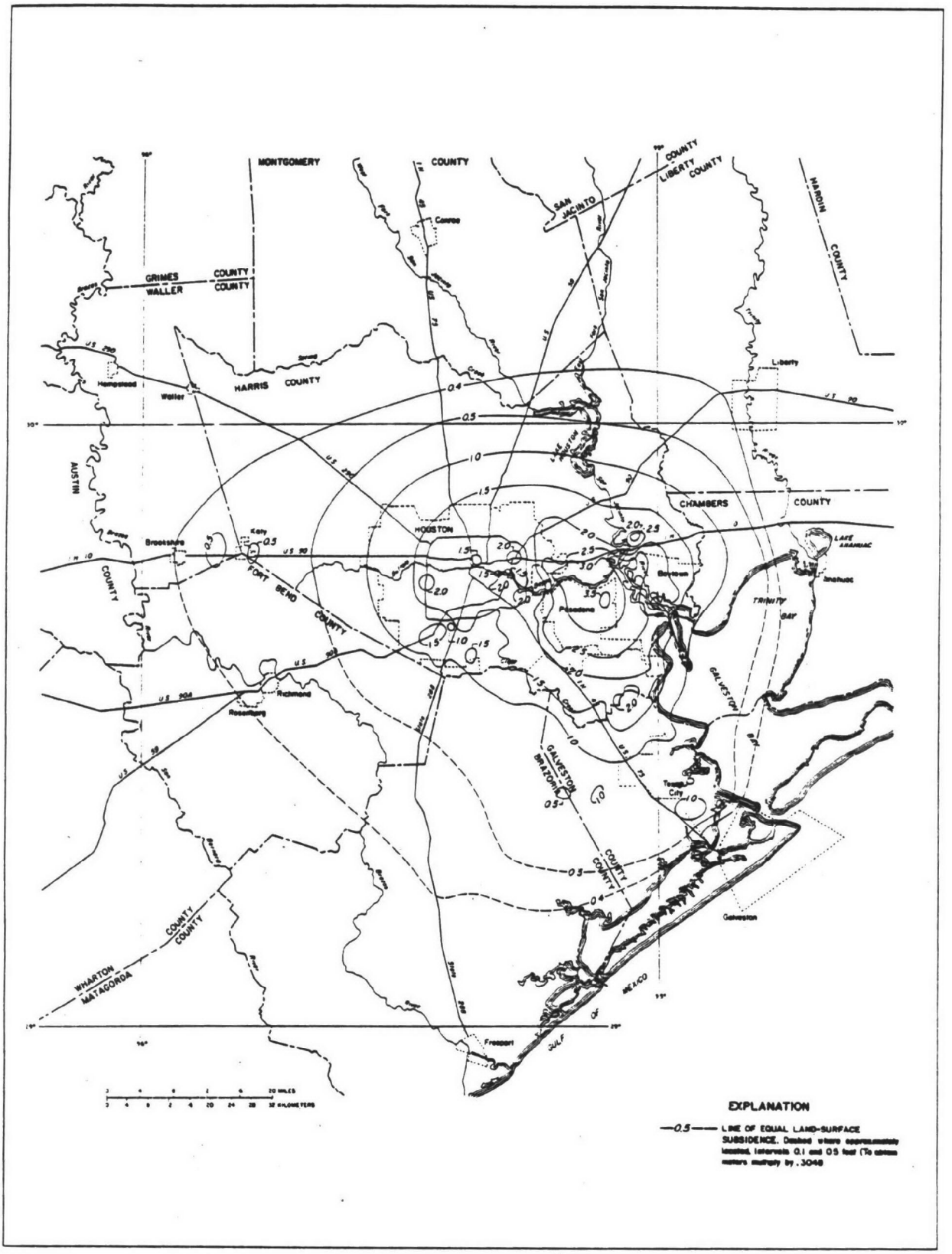

Figure 9.12.5 Subsidence of the land surface, 1964-73.

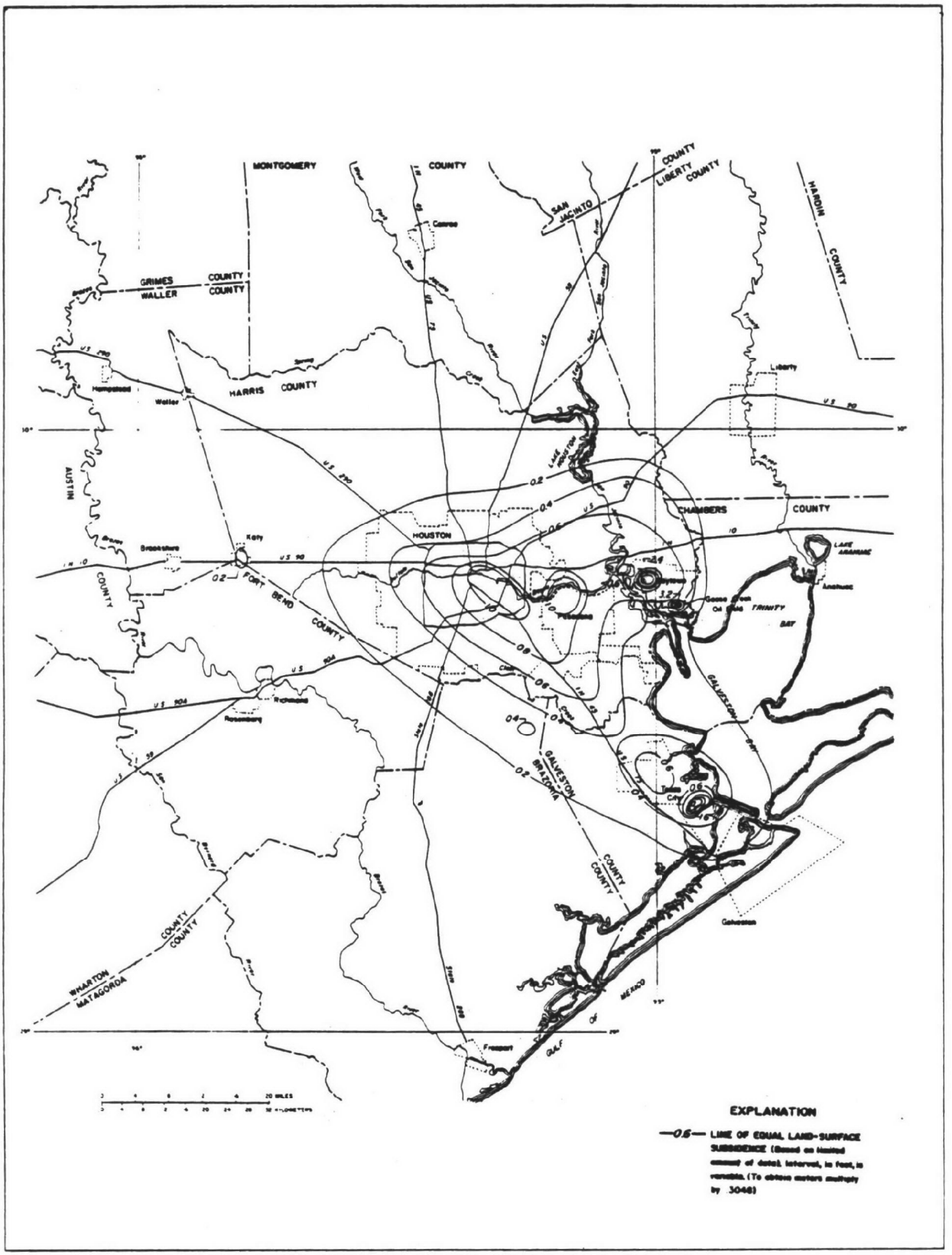

Figure 9.12.6 Approximate subsidence of the land surface, 1906-43.

grained material, and the average stress applied to the system during 1964-73 was estimated to be a change in head of 5.7 metres of water. Subsidence during 1964-73 was 0.18 metre; therefore, the compressibility of the fine-grained material was determined to be:

$$0.18/(151.5\ m)\ (5.7\ m) = 2.1 \times 10^{-4} m^{-1}.$$

The weighted average compressibility as determined by laboratory consolidation tests of 15 cores from three sites was $3.2 \times 10^{-4} m^{-1}$. Because the sediments were still undergoing compression, the compressibilities determined at the Seabrook and Texas City sites are minimum estimates of specific storage.

It has been suggested by some investigators that, in addition to inundation of land by tidal waters, some if not all of the numerous existing faults in the Houston-Galveston region are reactivated by man-caused land-surface subsidence. Attempts have been made to relate the fault activity to subsidence, but because of a lack of data the relationships are not clear.

In 1977, a network of measurement stations, about 0.6 kilometre apart, were established along a line about 70 kilometres long from the approximate center of subsidence westward along U.S. Highway 90 to the Harris County boundary. In addition, closely spaced marks for horizontal and vertical control will be established at three active faults. The purpose of this network is to measure horizontal strain associated with subsidence and to relate this strain to movement along the fault planes.

It has also been hypothesized (Kreitler, 1977) that the numerous faults act as partial barriers to ground-water flow and therefore control or "compartmentalize" subsidence; however, the data on artesian-pressure fluctuations in the area do not support this hypothesis.

Most of the damage resulting from subsidence is related to the lowering of land-surface elevations in the vicinity of Galveston Bay and the subsequent inundation by tidal waters. Several roadways have been rebuilt at higher elevations; ferry landings have been rebuilt; and levees have been constructed to reclaim or protect some areas. The cost of the damages resulting from subsidence have been estimated in some areas, but comprehensive studies for the entire region have not been made. Jones and Larson (1975, table 5) estimated the annual cost of subsidence during 1969-74 to be $31,705,040 in 2,448 square kilometres of the area most severely affected by subsidence. In their estimate of costs, Jones and Larson attributed fault-caused structural damage to man-caused subsidence.

One outstanding example of both the social and economic impacts of subsidence is in the Brownwood subdivision on the west side of Baytown. The area of the subdivision has subsided more than 2.4 metres since 1915, and some homes in the subdivision are permanently flooded by water from the bay. The U.S. Army Corps of Engineers has recommended that the entire subdivision, consisting of 448 homes occupied by 1,550 residents, be purchased by the Federal Government and the inhabitants be relocated at a cost of about $40 million.

9.12.5 FUTURE SUBSIDENCE IN THE REGION

Ground-water pumping in the Houston-Galveston region increased at a rate of about 6 per cent per year before about 1967. Since then, ground-water pumping has been at an almost stable rate, possibly because of recirculation of cooling water by industry and increased use of surface water from Lake Houston. As a result, the rate of decline in water levels has decreased significantly in many parts of the region since the early 1970's. Records from borehole extensometers (compaction monitors) indicate a decreased rate of subsidence at seven sites scattered throughout the region. The decrease in the rate of subsidence, which began about September 1976, strongly suggests a reflection of the decreased rate of water-level decline.

Water from a new source, Lake Livingston on the Trinity River, about 97 kilometres east of Houston has become available recently; and voluntary commitments to purchase this water have been made by all major industries using ground water in the southern half of Harris County. As a result, ground-water pumping will decrease by about 3.1 m^3/s in the area of maximum artesian-pressure decline and subsidence. An analog-model study of the effects of the decreased pumping suggests a maximum water-level recovery of about 30 metres in the center of the bowl of subsidence. Data are not sufficient to determine the head recovery necessary to stop subsidence, but the rate of subsidence is expected to decrease substantially. By June 1977, the increased use of surface water had caused a decrease in ground-water pumping of about 0.8 m^3/s. Locally, the recovery in artesian head has been as much as 18 metres.

The Harris-Galveston Coastal Subsidence District was created by the Texas Legislature in 1975 to "provide for the regulation of the withdrawal of ground water within the boundaries of

the District for the purpose of ending subsidence which contributes to or precipitates flooding, inundation, or overflow of any area within the District, including without limitation rising waters resulting from storms or hurricanes." The District plans to monitor the stress-strain relationships with additional compaction monitors and piezometers designed for installation prior to the expected voluntary decrease in ground-water pumping. The data collected will be the basis for controlling pumping by the issuance of well permits.

The constitutionality of the subsidence district has been tested in a Texas District Court in a suit titled Sammy Beckendorf, et al., versus the Harris-Galveston Coastal Subsidence District. The District prevailed, but Beckendorf, et al., have appealed the ruling of the court. Other lawsuits against the District have been filed but have not come to trial. Two other lawsuits (Smith-Southwest Industries, et al., versus Friendswood Development Company, et al.; and E. R. Brown, et al., versus Exxon Company, U.S.A., et al.), whereby the plaintiffs seek to establish blame and recover damages from subsidence, have not come to trial.

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Section 7.3.3

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	"Case History No. 9.13, San Joaquin Valley, California, U.S.A." From Guidebook to Studies of Land Subsidence Due to Ground-Water Withdrawals
AUTHOR: **(or INVESTIGATOR)**	Joseph F. Poland, U.S. Geological Survey, Sacramento, California, and Ben E. Lofgren, Woodward-Clyde Consultants, San Francisco, California
DATE:	1984
FACILITY NAME AND LOCATION:	San Joaquin Valley, California USEPA Region IX
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	The following case history concerning subsidence in the San Joaquin Valley is taken chiefly from the summary report by Polan, Lofgren, Ireland, and Pugh (U.S. Geological Survey Prof. Paper 437-H, 1975). This case study addresses geology, hydrology, land subsidence, compressibility and storage parameters, economic and social impacts, legal aspects, and measures taken to control or ameliorate subsidence.

Case History No. 9.13. San Joaquin Valley, California, U.S.A., by Joseph F. Poland, U.S. Geological Survey, Sacramento, California, and Ben E. Lofgren, Woodward-Clyde Consultants, San Francisco, California

9.13.1 INTRODUCTION

The principal areas of land subsidence due to ground-water withdrawal in California are in the San Joaquin Valley and the Santa Clara Valley (Figure 9.13.1). A case history for the Santa Clara Valley is included elsewhere in this publication. In the San Joaquin Valley, subsidence due to ground-water withdrawal occurs in three areas--the Los Banos-Kettleman City area on the central west side, the Tulare-Wasco area on the southeast border, and the Arvin-Maricopa area at the south end (Figure 9.13.1).

Since 1956, the U.S. Geological Survey has carried on two investigative programmes in the San Joaquin Valley. One, a study of land subsidence, was carried on in cooperation with the California Department of Water Resources. The other, a federally financed research project on the mechanics of aquifer systems, had two major goals: to determine the principles controlling the deformation of aquifer systems in response to change in grain-to-grain load, and to appraise the change in storage characteristics as the systems compact under increased effective stress. During the 20 years of research under these two projects, many of the causes and effects of land subsidence have been documented. Sixteen of the principal reports have been pub-

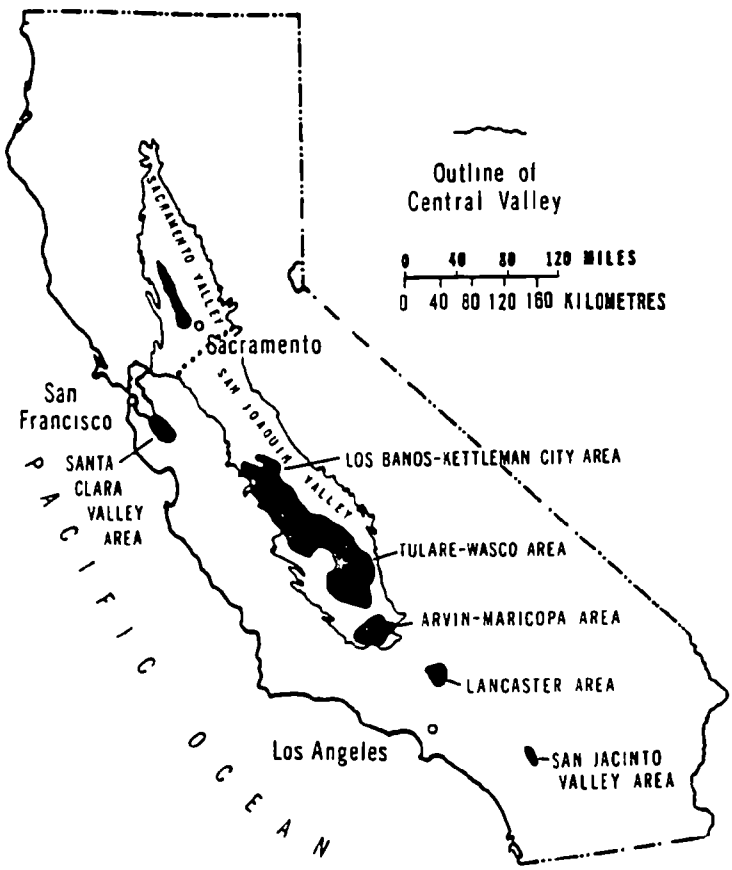

Figure 9.13.1 Areas of land subsidence in California due to ground-water withdrawal.

lished as professional papers of the Geological Survey, the subsidence reports in the Professional Paper 437 series, and the mechanics of aquifer systems papers in the Professional Paper 497 Series. The following case history concerning subsidence in the San Joaquin Valley is taken chiefly from the summary report by Poland, Lofgren, Ireland, and Pugh (U.S. Geol. Survey Prof. Paper 437-H, 1975). More detailed information is available in published reports on the three areas.

9.13.2 GEOLOGY

The San Joaquin Valley includes the southern two-thirds of the Central Valley, an area of 26,000 km^2. It is a broad structural downwarp bordered on the east by the granitic complex of the Sierra Nevada and on the west by the complexly folded and faulted Coast Ranges. The top of the basement complex of the Sierra Nevada block dips gently westward beneath the valley. Late Cenozoic continental deposits form the floor of the valley and attain maximum thickness of 5,000 m near the south edge.

The continental deposits are chiefly of fluvial origin but contain several extensive interbeds of lacustrine origin. The fluvial deposits consist of lenticular bodies of sand and gravel, sand, and silt deposited in stream channels, and sheetlike bodies of silt and clay laid down on flood plains by slow-moving overflow waters.

Along the east side of the valley the sediments deposited by the major streams issuing from the Sierra Nevada--from the Merced River south to the Kings River--have formed a series of coalescing alluvial fans, characterized by a mass of coarse permeable deposits, largely tongues and lenses of sand and gravel, that extend to and beyond the topographic trough of the valley.

In more than half of the San Joaquin Valley area that lies south of Los Banos, the deposits containing freshwater can be divided into: (1) an upper unit of clay, silt, sand, and gravel chiefly alluvial-fan and flood-plain deposits of heterogeneous character; (2) a middle unit consisting of a relatively impermeable diatomaceous lacustrine clay; and (3) a lower unit of clay, silt, sand, and some gravel, in part lacustrine deposits, that extends down to the beds containing saline water. The upper and middle units are Pleistocene age; the lower unit is of Pleistocene and Pliocene age. Together, these three units approximately constitute the Tulare Formation. The middle unit is the Corcoran Clay Member of the Tulare Formation (Miller, Green, and Davis, 1971).

9.13.3 HYDROLOGY

The continental freshwater-bearing deposits can be subdivided into two principal hydrologic units. The upper unit, a semiconfined aquifer system with a water table, also termed the "upper water-bearing zone," extends from the land surface to the top of the Corcoran Clay Member at a depth ranging from 0 to 275 m below the land surface. The lower unit, a confined aquifer system, also termed the "lower water-bearing zone," extends from the base of the Corcoran Clay Member down to the saline water body. The thickness of this confined system ranges from 60 to more than 600 m. The Corcoran Clay Member, which ranges in thickness from 0 to 40 m, is the principal confining bed beneath at least 13,000 km^2 of the San Joaquin Valley. The dotted line in Figure 9.13.2 defines the general extent of this principal confining bed in the valley. South of Bakersfield the confining bed has been designated the E clay by Croft (1972).

Yearly extraction of ground water for irrigation in the San Joaquin Valley increased slowly from 2,500 hm^3 in the middle 1920's to 3,700 hm^3 in 1940. Then, during World War II and the following two decades, the rate of extraction increased more than threefold to furnish irrigation water to rapidly expanding agricultural demands. By 1966, pumpage of ground water was 12,000 hm^3 per year.

This very large withdrawal caused substantial overdraft on the central west side and in much of the southern part of the valley, mostly within the shaded area of Figure 9.13.2. The withdrawal in these overdraft areas in the 1950's and early sixties was at least 5,000 hm^3 per year. During the period of long-continued excessive withdrawal, the head (potentiometric surface) in the confined aquifer system between Los Banos and Wasco was drawn down 60 to 180 m. South of Bakersfield the head decline was more than 100 m.

Importation of surface water to these areas of serious overdraft began in 1950 when water from the San Joaquin River was brought south through the Friant-Kern Canal, which extends to the Kern River (Figure 9.13.2). About 80 per cent of the average annual deliveries of 1,250

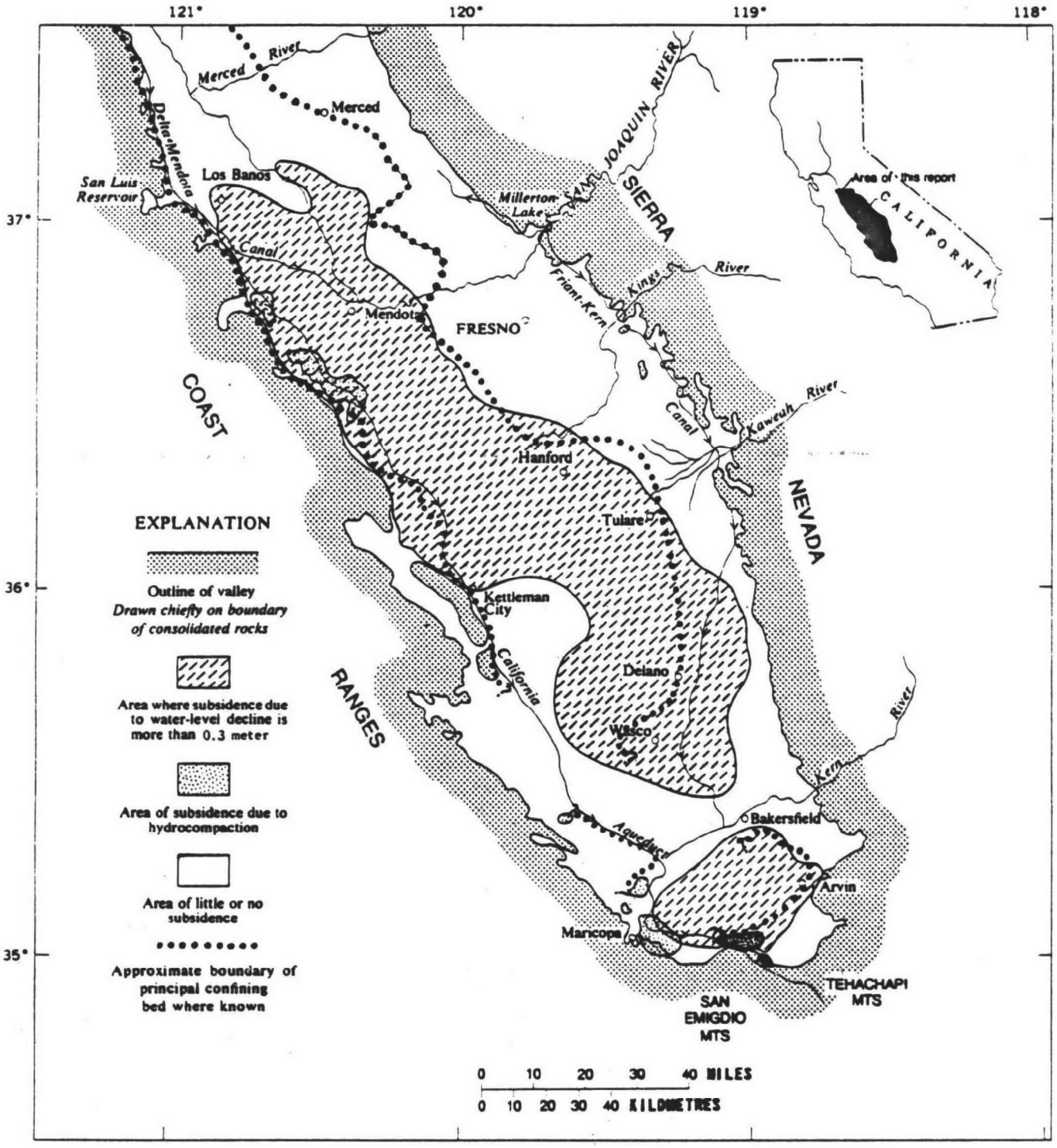

Figure 9.13.2 Pertinent geographic features of central and southern San Joaquin Valley and areas affected by subsidence.

hm^3 of water from this canal is sold to irrigation districts south of the Kaweah River, mostly in the Tulare-Wasco subsidence area.

Large surface-water imports from the northern part of the state to overdrawn areas on the west side and south end of the valley are being supplied through the California Aqueduct (Figure 9.13.2). The joint-use segment of the aqueduct between Los Banos and Kettleman City serves the San Luis project area of the U.S. Bureau of Reclamation and transports State-owned water south of Kettleman City. Surface-water deliveries to the San Luis project area increased from 250 hm^3 in 1968, the first year, to about 1,360 hm^3 in 1974. Also, by 1973 the California Aqueduct delivered 860 hm^3 to the southern part of the San Joaquin Valley (south of Kettleman City), and is scheduled eventually to supply 1,670 hm^3 under long-term contracts.

As a result of these large surface-water imports, the rate of ground-water withdrawal decreased sharply and the decline of artesian head was reversed in most of the areas of overdraft. By the early 1970's many hundreds of irrigation wells were unused, artesian heads were recovering at a rapid rate, and rates of subsidence were sharply reduced.

9.13.4 LAND SUBSIDENCE

Subsidence in the San Joaquin Valley is of three types. In descending order of importance these are (1) subsidence due to the compaction of aquifer systems caused by the excessive withdrawal of ground water; (2) subsidence due to the compaction of moisture-deficient deposits when water is first applied--a process known as hydrocompaction; and (3) local subsidence caused by the extraction of fluids from several oil fields.

Oil-field subsidence is due to the same process as subsidence caused by excessive pumping of ground water--a lowering of fluid level and consequent increase of effective stress on the sediments within and adjacent to the producing beds. However, measured oil-field subsidence in the San Joaquin Valley, which has been discussed briefly by Lofgren (1975), is less than 0.6 m at the few oil fields where periodic releveling has defined its magnitude. This type of subsidence has not created any problems in the valley.

Hydrocompactible deposits occur locally on the west and south flanks of the valley (see Figure 9.13.2). These are near-surface alluvial-fan deposits, largely mud flows, still above the water table. They have been moisture deficient ever since deposition, chiefly because of the low rainfall in the area. When water is first applied, the clay bond is weakened and the deposits compact. Subsidence of 1.5 to 3 m is common and locally it exceeds 4.5 m (Lofgren, 1960; Bull, 1964). The California Aqueduct (Figure 9.13.2) passes through at least 65 km of deposits susceptible to hydrocompaction, and precompaction by prolonged wetting of the aqueduct alinement was carried on for about one year prior to the placing of the concrete lining.

Subsidence due to the compaction of aquifer systems in response to excessive decline of water levels had affected about 13,500 km^2 of the San Joaquin Valley by 1970. Figure 9.13.3 depicts the distribution and magnitude of subsidence exceeding 1 foot (0.3 m) that had occurred by 1970--affecting an area of 11,100 km^2. Three centers of subsidence are conspicuous on this map. The most conspicuous is the long narrow trough west of Fresno that extends 140 km from Los Banos to Kettleman City (referred to subsequently as the west-side area). Maximum subsidence in this area to 1977 was 29.5 feet (9.0 m), 16 km west of Mendota. The second center, between Tulare and Wasco, is defined by two closed 12-foot (3.7-m) lines of equal subsidence, 32 and 48 km south of Tulare, respectively. Maximum subsidence to 1970 was 4.3 m, at a benchmark 32 km south of Tulare. The third center, 32 km south of Bakersfield, has subsided a maximum of 9.2 feet (2.8 m), mostly since World War II. Note that the California Aqueduct was constructed through the full 140 km of the subsidence trough extending from Los Banos to Kettleman City, as well as through the southwestern edge of the subsidence bowl south of Bakersfield.

The cumulative volume of subsidence in the San Joaquin Valley (Figure 9.13.4) grew slowly until the end of World War II. With the great increase in ground-water extraction in the 1940's and 1950's, however, the cumulative volume of subsidence soared to 12,350 hm^3 by 1960, and reached 19,250 hm^3 by 1970. This very large volume is equal to one-half the initial storage capacity of Lake Mead or to the total discharge from all water wells in the San Joaquin Valley for 1.5 years at the 1966 rate. This volume of subsidence represents water of compaction derived almost wholly from compaction of the fine-grained highly compressible clayey interbeds (aquitards), in response to the increase in effective stress as artesian head in the confined system declined. The volume of subsidence for any interval of leveling control was obtained by planimetry of the subsidence map for that period. All leveling data used in the preparation of subsidence maps and graphs were by the National Geodetic Survey (formerly the Coast and Geodetic Survey).

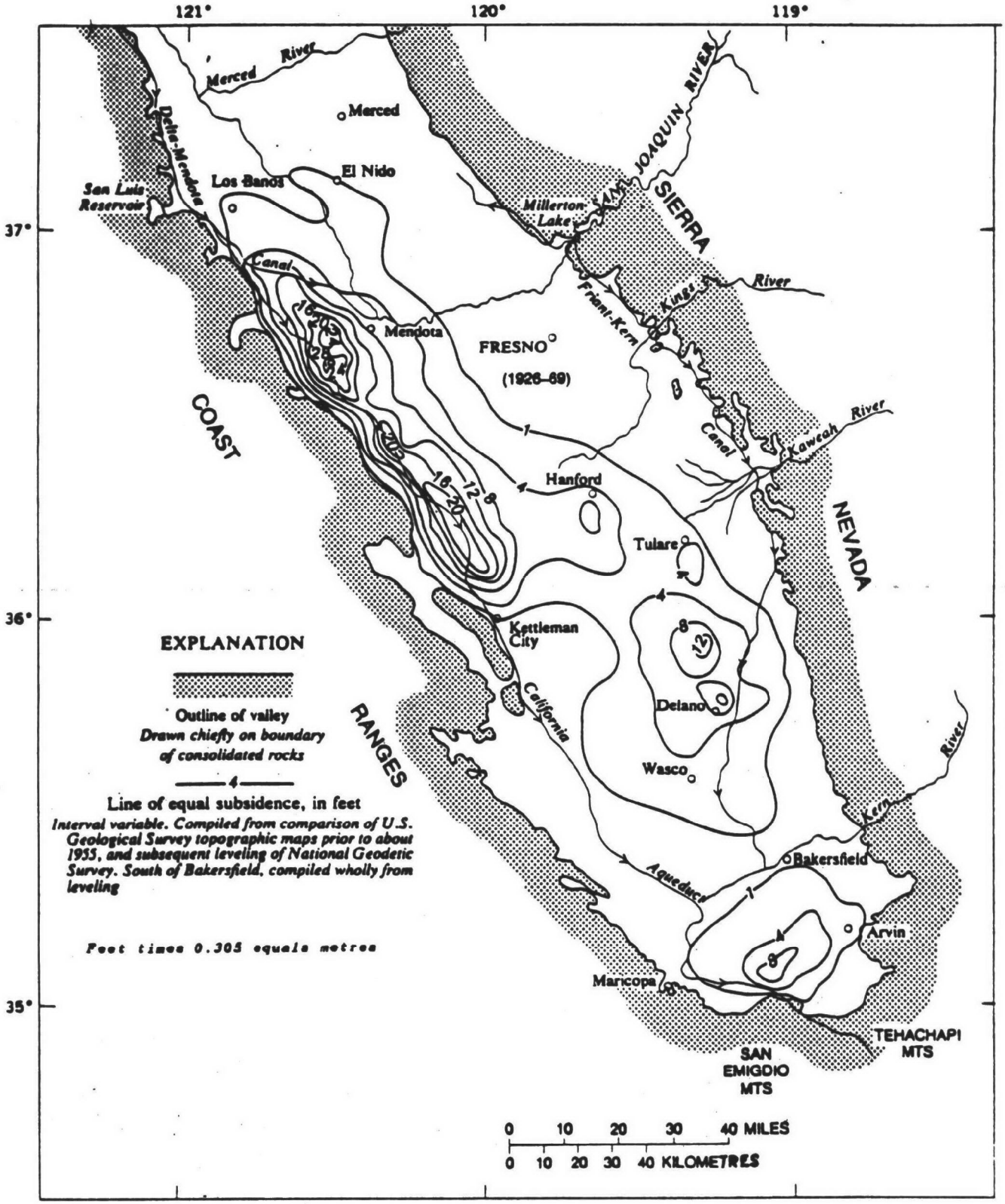

Figure 9.13.3 Land subsidence in the San Joaquin Valley, California, 1926-1970.

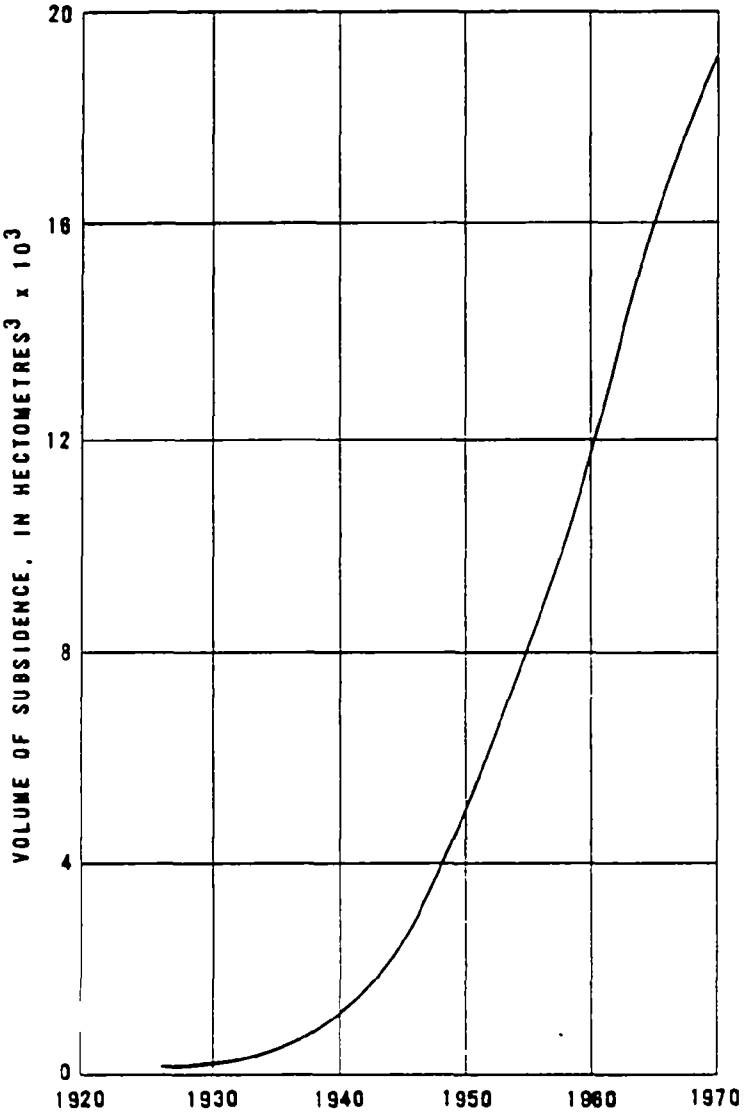

Figure 9.13.4 Cumulative volume of subsidence, San Joaquin Valley, California, 1926-70.

The west-side area has experienced the most severe subsidence (Figure 9.13.5); therefore several illustrations will be presented to show the relation between water-level change (stress change) and compaction or subsidence in that area. Subsidence has affected about 6,200 km^2 and the volume of subsidence, 1926-69, was about 11,850 hm^3, about two-thirds of the valley total. The cumulative volume of ground-water pumpage in the west-side area through March 1969 is estimated as 35,200 hm^3 (Figure 9.13.6). This cumulative pumpage has been plotted with cumulative subsidence at a scale of 3 to 1. The correlation is remarkably consistent, indicating that throughout the 43 years since subsidence began (1926 into 1969), about one-third of the water pumped has been water of compaction derived from the permanent reduction of pore space in the fine-grained compressible aquitards.

Figure 9.13.7 illustrates the relation of subsidence to artesian-head change since 1943 at a site 16 km southwest of Mendota. Bench mark S661, located within the 28-foot (8.5-m) line of equal subsidence in Figure 9.13.5, subsided 8 m from 1943 to 1969, in response to a water-level decline of nearly 125 m as measured in nearby wells. The rate of subsidence at this site reached a maximum of 0.54 m per year between 1953 and 1955 but decreased to 0.04 m per year between 1972 and 1975, due chiefly to substantial recovery of artesian head. Static water level began to recover in 1969 and by 1977 had risen 73 m above the 1968 summer low level because of

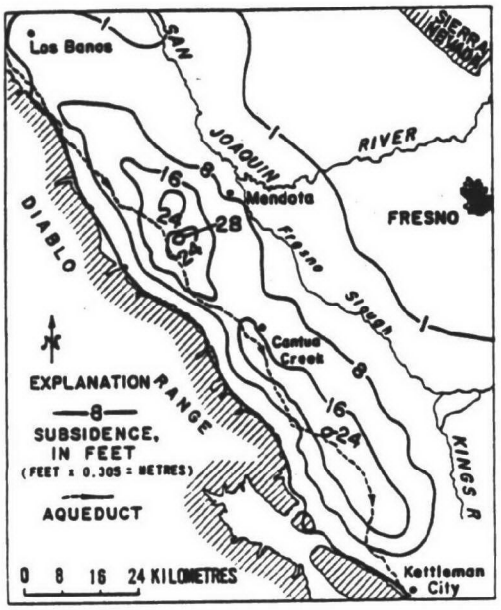

Figure 9.13.5 Land subsidence in the Los Banos-Kettleman City area, California, 1926-69.

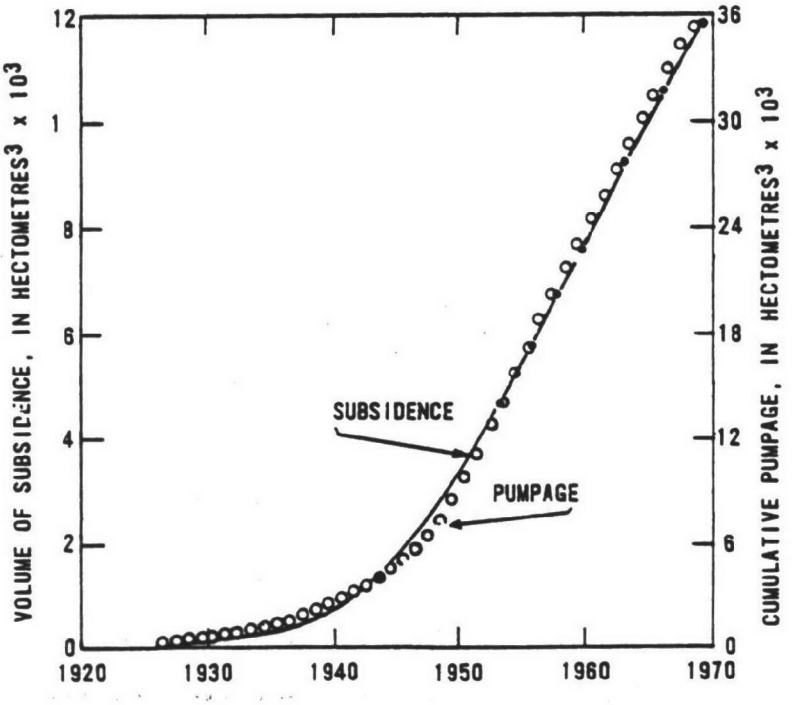

Figure 9.13.6 Cumulative volume of subsidence and pumpage, Los Banos-Kettleman City area, California. Points on subsidence curve indicate times of leveling control.

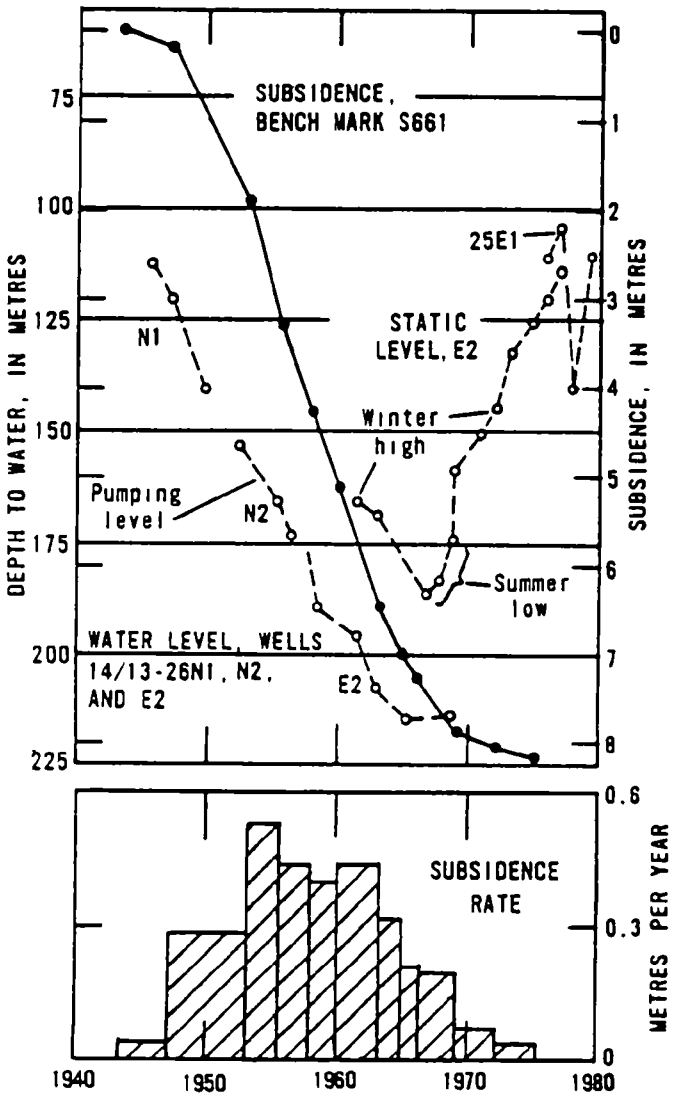

Figure 9.13.7 Subsidence and artesian-head change 16 kilometres southwest of Mendota.

the large imports of surface water through the California Aqueduct and the consequent reduction in pumpage.

If two or more extensometers (compaction recorders) are installed in adjacent wells of different depths, the records from the multiple-depth installation will indicate the magnitude and rate of compaction (or expansion), not only within the total depths of individual wells but also for the depth intervals between well bottoms. Figure 9.13.8 shows the record of compaction from 1958 through 1971 in three adjacent extensometer wells in the west-side area. The site is adjacent to the California Aqueduct at the north end of the southern 16-foot (4.9-m) line of equal subsidence in Figure 9.13.5. The wells are 152, 213, and 610 m deep. Measured compaction in the 13 years was about 0.42 m, 0.97 m, and 3.40 m, respectively. Thus the compaction in the 213-610-m depth interval was 2.43 m. The dashed line represents subsidence of a surface bench mark at this site as determined by repeated leveling from stable bench marks (black dotes on the dashed line show dates of leveling). In the early 1960's the rate of compaction measured in the 610-m well (N1) was nearly equal to the rate of subsidence. Subsequently the rate of compaction of deposits below the 610-m depth gradually increased, due to increased pumping and declining pore pressures in deeper wells drilled in the 1960's. This deeper compaction caused the departure of the subsidence plot from the compaction plot for well N1.

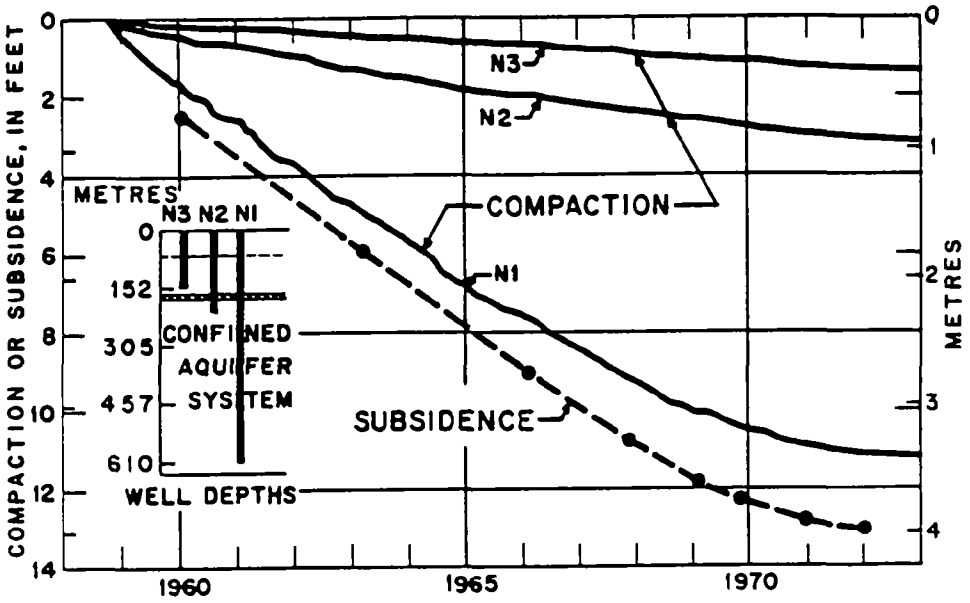

Figure 9.13.8 Compaction and subsidence at Cantua site, 65 kilometres southwest of Fresno, California.

9.13.5 COMPRESSIBILITY AND STORAGE PARAMETERS

In the late 1950's, as one phase of the research on land subsidence and compaction of aquifer systems, the Geological Survey drilled four core holes in the Los Banos-Kettleman City (west side) area ranging in depth from 305 to 670 m, and two core holes in the Tulare-Wasco area to depths of 232 and 670 m.. Cores were tested in the Hydrologic Laboratory for particle-size distribution, specific gravity of solids, dry unit weight, porosity and void ratio, hydraulic conductivity (normal and parallel to bedding) and Atterberg limits. Results have been published (Johnson, Moston, and Morris, 1968). X-ray diffraction studies of 85 samples from the westside cores and 26 samples from the Tulare-Wasco cores indicated that about 70 per cent of the clay-mineral assemblage in these deposits of Pliocene to Holocene age consists of montomorillonite (Meade, 1967, Tables 11-13).

Laboratory consolidation tests were made by the Bureau of Reclamation on 60 fine-grained cores from the four core holes in the west-side area and on 22 fine-grained cores from the two core holes in the Tulare-Wasco area. Parameters tested included the compression index, C_c, a measure of the compressibility of the sample, and the coefficient of consolidation, C_v, a measure of the time-rate of consolidation. Results have been published (Johnson and others, 1968, Tables 8 and 9). The range of the compression index, C_c, was much wider than for samples from the Santa Clara Valley: In the Los Banos-Kettleman City area the range was 0.09 to 1.13; in the Tulare-Wasco area it was 0.25 to 1.53. However, all values greater than 0.47 were either from lacustrine clays or from the fine-grained marine siltstone in the Richgrove core hole 12 km east of Delano.

The subsidence volume represents pore-space reduction occurring chiefly in the *fine-grained compressible aquitards. In the west-side area, the volume of subsidence* from 1926 to 1969 was about 11,850 hm^3, distributed over 6,200 km^2. If the subsidence had been distributed evenly over this area, it would average about 1.9 m. Roughly half the sediments in the principal aquifer system are fine-grained compressible aquitards. Assuming the average composite thickness of the compacting aquitard is 150 m and the average initial porosity is 40 per cent, a mean subsidence of 1.9 m would represent an average reduction in porosity of roughly 1 per cent in these fine-grained beds (from 40 to 39.2 per cent). In the small area where the maximum 8.8 m of subsidence has occurred, the local reduction in pore space of aquitards would be roughly 4 per cent (from 40 to 36.3 per cent).

The subsidence/head-decline ratio (specific subsidence) is the ratio between land subsidence and the hydraulic head decline in the coarse-grained permeable beds of the compacting aquifer system, for a common time interval. It can be expressed as the change in thickness per

unit change in effective stress ($\Delta b/\Delta p'$). This ratio is useful as a first approximation of compressibility; it is also useful for predicting a lower limit for the magnitude of subsidence in response to a step increase in virgin stress (stress greater than past maximum). If pore pressures in the fine-grained aquitards were eventually to reach equilibrium with those in adjacent aquifers after a step increase beyond preconsolidation stress, compaction would cease and the subsidence/head-decline ratio would indicate the true virgin compressibility of the system.

In the west-side area during the period 1943-60 the decline of artesian head for the lower zone ranged from 30 to 120 m (Bull and Poland, 1975, Figure 25), resulting in subsidence in the 17-year period of 0.3 to 4.9 m (Bull, 1975, Figure 10). The subsidence/head-decline ratio for that same period ranged areally from 0.01 to 0.08 (Bull and Poland, 1975, Figure 32). In other words, the head decline required to produce 1 metre of subsidence ranged from 100 to 12 m. A subsidence/head-decline ratio can be derived from Figure 9.13.7 for the period 1947 to 1965. In the 18 years, bench mark S661 subsided 6.86 m, and the pumping level in nearby wells declined 95 m. Thus, for that time span the ratio at that site equaled 0.07.

In the Tulare-Wasco area, the subsidence/head-decline ratio ranged from 0.01 to 0.06 (Lofgren and Klausing, 1969, Figure 69). In the Arvin-Maricopa area, the subsidence/head-decline ratio for the 8-year period 1957-65 ranged from 0.01 to 0.05 (Lofgren, 1975, Plate 5B).

Areal variation in the subsidence/head-decline ratio can be produced by one or more of several factors. These include variation in the individual and gross aggregate thickness of the compacting aquitards and variation in compressibility and vertical hydraulic conductivity of the individual aquitards. Such areal variation in compressibility and hydraulic conductivity can be caused by variation in grain size, in depth of compacting beds (in overburden load), in geologic formation tapped, in existing preconsolidation stress, in clay-mineral assemblage, and in other diagenetic effects. Furthermore, because the subsidence values available for computing the ratio seldom represent ultimate subsidence for a designated change in stress within aquifers, time is an important factor. According to soil-consolidation theory, the time required for an aquitard that is draining to adjacent aquifers to reach a specified percentage of ultimate compaction varies directly as (1) the square of the draining thickness and (2) the ratio of compressibility to vertical hydraulic conductivity. Variation in the thicknesses of the many vertical-draining aquitards encountered at any selected site obviously makes that site unique in its rate of compaction, even if all other factors are equal. In the depth interval 214 to 610 m at west-side well 16/15-34N1, for example, interpretation of the microlog defined 60 aquitards ranging in thickness from 0.6 m to 15 m and averaging 4.5 m.

One other factor directly affecting the accuracy of the subsidence/head-decline ratio is the appropriateness or the accuracy of the change-in-stress value used. Even in a ground-water basin containing a single confined aquifer system it is difficult to obtain measurements of head change that truly represent the average stress change on aquitard boundaries within the full well-depth interval experiencing a measured compaction or subsidence. Thus, observation wells used to derive stress-change values, whether for subsidence/head-change ratios or for stress-strain plots, should be selected or constructed very carefully.

Bull (1975, p. 49-82) made a study of geologic factors that caused areal differences in specific unit compaction in the Los Banos-Kettleman City area for the period 1943-60. The factors included total applied stress, lithofacies, and source and mode of deposition.

Field measurements of compaction or expansion of sediments and the correlative change in fluid pressure(s) can be utilized to construct stress-strain curves and to derive storage and compressibility parameters. One example (Figure 9.13.9) is for a well 176 m deep on the west

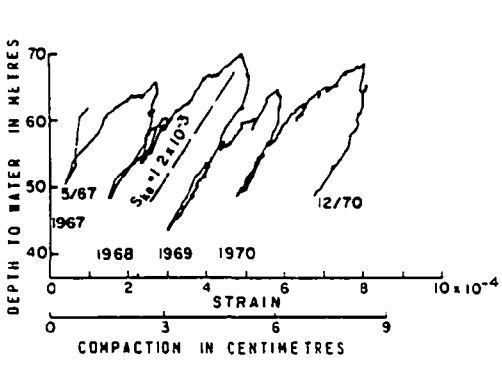

Figure 9.13.9 Stress change, compaction, and strain for a well in western Fresno County, California.

side of the valley. Depth to water is plotted increasing upward (increasing stress). Change in depth to water represents change in effective stress in the aquifers in the confined aquifer system (upper zone) that is 106 m thick. Along the abscissa the lower scale is the measured compaction and the upper scale is the strain (measured compaction/compacting thickness). The yearly fluctuation of water level caused by the seasonal irrigation demand and the permanent compaction that occurs each summer during the heavy pumping season when the depth to water is greatest produce a series of stress-strain loops. The lower parts of the descending segments of the annual loops for the three winters 1967-68 to 1969-70 are approximately parallel straight lines, indicating that the response is essentially elastic in both aquifers and aquitards when the depth to water is less than about 55 m. The heavy dashed line in the 1968 loop represents the average slope of the segments in the elastic range of stress. The reciprocal of the slope of the line is the component of the storage coefficient due to deformation of the aquifer-system skeleton, S_{ke}, and equals 1.2×10^{-3}. The component of average specific storage due to elastic deformation, S_{ske}, equals $S_{ke}/106$ m = $1.1 \times 10^{-5} m^{-1}$. The average elastic compressibility of the aquifer system skeleton, α_{ke}, is S_{ske}/γ_w; if γ_w (the unit weight of water) equals 1, the numerical values of α_{ke} and S_{ske} are identical.

For increase in effective stress in the range of loading exceeding preconsolidation stress, the "virgin" compaction of aquitards is chiefly inelastic--nonrecoverable upon decrease in stress. At Pixley, 27 km south of Tulare (Figure 9.13.3), compaction and change in stress for a confined aquifer system 108-231 m below land surface has been measured since 1958. Riley (1969) showed from a stress-strain plot that the mean virgin compressibility of the aquitards (aggregate thickness 75 m) in this confined aquifer segment 123 metres thick was $7.5 \times 10^{-4} m^{-1}$ and the mean elastic compressibility of the aquifer system was $9.3 \times 10^{-6} m^{-1}$. Thus, for the aquifer system segment 123 metres thick at this site, the mean virgin compressibility of the aquitards is about 80 times as large as the mean elastic compressibility of the confined system.

Figure 9.13.10 shows a generalized plot of water level for the confined aquifer system 32 km south of Mendota (Figure 9.13.5) from 1905 to 1964 and the seasonal high and low in observation well 16/15-34N4 for 1961-77. This well taps the confined system. The regional water level declined about 120 m from 1905 to 1960 and the rate of decline accelerated as the groundwater withdrawal increased. By 1960 the seasonal low had declined below the base of the confining clay, producing a water-table condition. Surface-water imports to the west-side area began in 1968. As the imports increased, ground-water pumpage decreased and water levels recovered sharply. From 1968 to 1976 the water level at well 34N4 rose 82 metres. Then, during 1977, the second of two severe drought years, the imports decreased to 370 hm^3 and pumping draft from both old and newly drilled wells soared to about three times the 1976 rate. As a result the water level in well 34N4 fell 50 m in the 8 months to August 1977.

The changing stress as indicated by the hydrograph of well 34N4 and the resulting strain at this site as measured by an extensometer in well 34N1 since 1959 are clearly displayed in Figure 9.13.11. Well 16/15-34N1, 610 m deep, is equipped with an anchored-cable extensometer. A time plot of cumulative measured compaction at this site was introduced earlier (Figure 9.13.8). In Figure 9.13.11, the measured compaction is plotted as an annual bar graph for comparison with the fluctuations of the water level in well N4. Note that the water level in well N4 began a sharp rise late in 1968 as surface-water imports began. In response to the sharp recovery of water level, compaction decreased rapidly after 1968 but did not cease until 1975. During this period of rising water levels in the coarse-grained aquifers, nonrecoverable virgin compaction continued through 1974 in the central parts of the thicker aquitards, exceeding the continuing small elastic expansion of the preconsolidated aquifers and the thinner aquitards. The water level in well N4 reached a seasonal high of 107 m below land surface in November 1976. Early in February 1977, when water level was 112 m below land surface (only 5 m below the seasonal high), virgin compaction resumed in well N1. By March 30, 1977, when water level was 15 m below the seasonal high, the maximum compaction rate of the season was attained. The early February water level 112 m below land surface clearly defined the preconsolidation stress in the central segments of the thickest or least permeable aquitards or both. As the drawdown increased, more and more of the slow draining compressible beds began to contribute water of compaction. By yearend, about 12 cm of renewed nonrecoverable compaction had occurred.

During the first period of water-level decline (1905-68 in Figure 9.13.10), water of compaction represented about one-third of the total water pumped from west-side wells (Figure 9.13.6). By 1968, many of the aquitards were preconsolidated nearly to the 1968 stress level. Early in the second period of water-level decline (in 1977), the response of the preconsolidated sediments was chiefly elastic and the contribution of water of compaction was much less than one-third of the total pumpage. Hence the water level fell very rapidly.

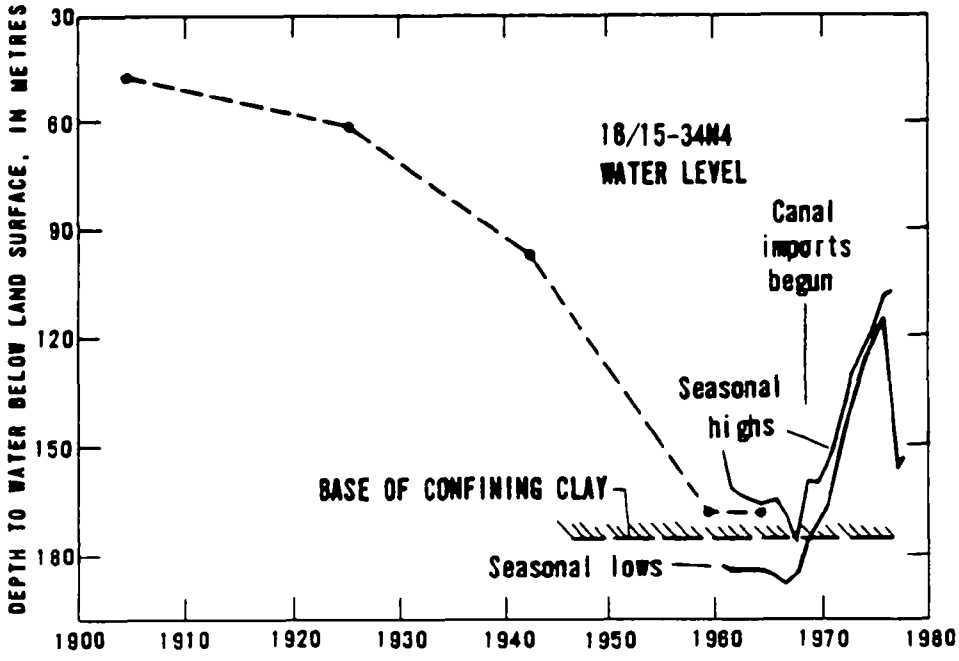

Figure 9.13.10 Long-term trend of water levels near Cantua Creek, and seasonal high and low levels in observation well 16/15-34N4 since 1960. (Modified from Lofgren, 1979, Figure 8.)

Figure 9.13.12 displays a similar trend of water-level recovery and reduced compaction, followed by an abrupt head decline and renewed compaction during 1977. Observation well 20/18-6D1 is 25 km north of Kettleman City (Figure 9.13.4) and adjacent to the California Aqueduct. The abrupt head decline of 76 m in 1977 momentarily increased the stress in the aquifers to 1967 levels and stresses in the central parts of the aquitards once again exceeded preconsolidation stresses. In response, virgin compaction of the aquitards exceeded that of 1968. Such stressing and differential compaction in the vicinity of the aqueduct is of concern in sustaining the integrity of such structures. This particular problem appears to be of local extent, however--the intensity of the head decline in well 6D1 is due largely to pumping of a new irrigation well drilled early in 1977 within 60 m of the aqueduct.

9.13.6 ECONOMIC AND SOCIAL IMPACTS

The extensive major subsidence in the San Joaquin Valley has caused several problems. The differential change in elevation of the land surface has created problems in maintenance of water-transport structures, including canals, irrigation and drainage systems, and stream channels. Both the Delta-Mendota Canal and the Friant-Kern Canal (Figure 9.13.3), two major structures of the Central Valley Project of the Bureau of Reclamation, have required remedial work because of subsidence. Also in the period 1926-72, differential subsidence has steepened the channel of the San Joaquin River about 2 m in the 24 km before it reaches the valley trough and has flattened the channel about 2 m in the next 50 km downstream. These changes have affected the transport characteristics of the river and have altered levee requirements.

Another problem common to the subsiding areas in the San Joaquin Valley is the failure of water wells as a result of compressive rupture of casings caused by the compaction of the aquifer systems. In the west-side area, where subsidence has been greatest, many hundreds of deep irrigation wells have required costly repair or replacement. According to Wilson (1968), during 1950-61 approximately 1,200 casing failures were reported in 275 irrigation wells in an area of 1,600 km^2 that spans the region of most intensive subsidence. Well repair and replacement costs attributable to subsidence in the three subsiding areas have been many millions of dollars.

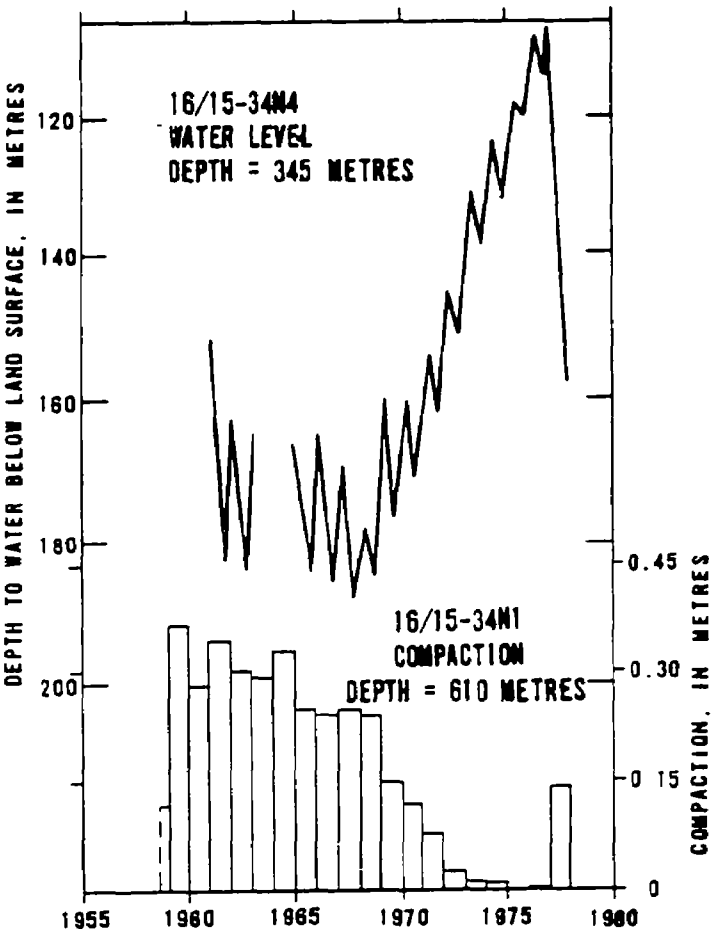

Figure 9.13.11 Seasonal fluctuations of water level in well 16/15-34N4 and measured compaction in observation well 16/15-34N1 near Cantua Creek. (Modified from Lofgren, 1979, Figure 10.)

The need for preconsolidation of deposits susceptible to hydrocompaction substantially increased the construction costs of the California Aqueduct. The aqueduct passes through about 65 km of susceptible deposits. The approximate cost for treatment by prewetting for the reach from Kettleman City to the Tehachapi Mountains has been estimated as $20 million (Lucas and James, 1976, p. 541). Preconsolidation of the susceptible areas between Los Banos and Kettleman City cost an additional estimated $5 million.

The subsidences have increased considerably the number and cost of surveys made by governmental agencies and by private engineering firms to determine the elevations of bench marks or construction sites and to establish grades. In addition, revision of topographic maps has been more frequent and more expensive than in nonsubsiding areas.

9.13.7 LEGAL ASPECTS

So far as known, no legal actions have been taken as a result of the subsidence.

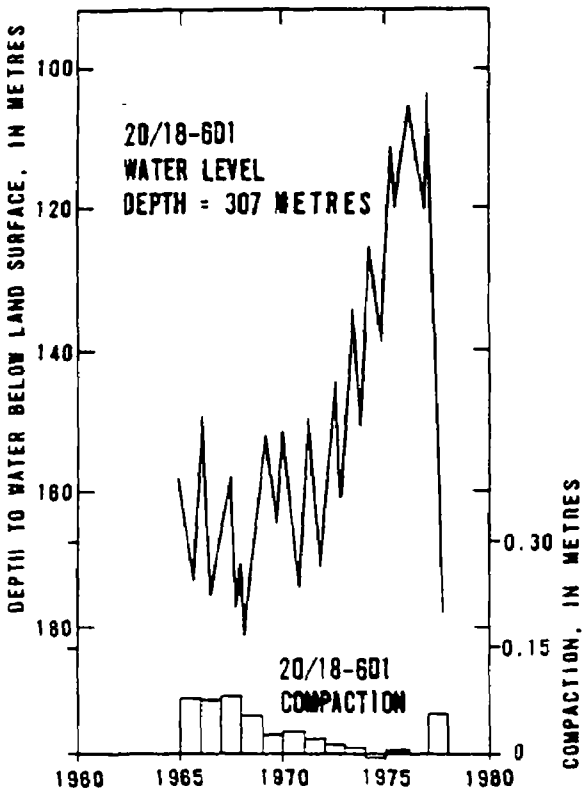

Figure 9.13.12 Seasonal fluctuations of water level and measured compaction in observation well 20/18-6D1 northeast of Huron.

9.13.8 MEASURES TAKEN TO CONTROL OR AMELIORATE SUBSIDENCE

The severe subsidence in all three areas in the San Joaquin Valley has been greatly reduced by the importation of surface water and the consequent decrease in ground-water pumping, as described earlier in this case history.

In the Tulare-Wasco area, the import of surface water from the San Joaquin River through the Friant-Kern Canal began in 1950. In the next 23 years, 1950-1972, the deliveries to this area from the canal averaged about 830 hm^3 per year, roughly 80 per cent of the surface-water supply to the area (Lofgren and Klausing, 1969). In the first 13 years of this period (1950-62), ground-water pumpage averaged about 1,230 hm^3 per year and continued at about this rate into the 1970's. Thus, the water imported from the San Joaquin River to the area during the 23-year period 1950-72 equaled about one-quarter of the total water supply and two-thirds of the ground-water pumpage.

Hydrographs of wells tapping the semiconfined to confined aquifer system in the eastern part of the Tulare-Wasco area show a water-level recovery of about 60 m from 1950 to 1970. As a result, subsidence decreased to less than 3 cm per year in most of the eastern area as 1962-70. On the other hand, hydrographs for wells tapping the confined aquifer system in the western part of the Tulare-Wasco area show continued decline of water levels since the 1950's; the supplemental irrigation supply from the Friant-Kern Canal to the western part has been insufficient to achieve a balance with ground-water pumping. As a result, subsidence has continued at rates locally exceeding 9 cm per year.

In the west-side area, the import of surface water through the California Aqueduct, which began in 1968, soon replaced most of the ground-water pumpage. For example, ground-water pumpage in the west-side area averaged 1,300 hm^3 per year from 1960 to 1967, before the imports began. By 1974, surface water imports to the west-side area reached 1,400 hm^3 per year and pumpage had decreased to roughly 250 hm^3 per year. The great decrease in ground-water pumpage and the consequent recovery of the artesian head in the confined aquifer system have nearly

eliminated the subsidence problem for the present. However, any deficiency in surface-water imports could trigger renewed pumping, renewed head decline, and renewed subsidence, as in the severe drought year of 1977.

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Section 7.3.4

TITLE OF STUDY: (or SOURCE OF INFORMATION)	"Case Study No. 9.14, Santa Clara Valley, California" From Guidebook to Studies of Land Subsidence Due to Ground-Water Withdrawals
AUTHOR: (or INVESTIGATOR)	Joseph F. Polland, U.S. Geological Survey, Sacramento, California
DATE:	1984
FACILITY NAME AND LOCATION:	Santa Clara Valley, California USEPA Region IX
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	Land subsidence in the central part of the Santa Clara Valley was first recognized in 1932-33, and is attributed to a historical increase in withdrawal of groundwater. This case study of the area addresses geology, hydrology, land subsidence, extensometers to measure compaction, measures taken to control subsidence, compressibility and storage parameters, economic and social impacts, legal aspects, and conclusions.

Case History No. 9.14. Santa Clara Valley, California, U.S.A., by Joseph F. Poland, U.S. Geological Survey, Sacramento, California

9.14.1 INTRODUCTION

Land subsidence in the central part of the Santa Clara Valley--beneath the southern part of San Francisco Bay and extending to the southern edge of San Jose--was first recognized in 1932-33. Releveling of a line of first-order levels established by the National Geodetic Survey in 1912 showed about 1.2 m of subsidence in downtown San Jose in 1933. The subsiding area extends southward about 40 km from Redwood City and Niles past San Jose, has a maximum width of 22 km, and includes about 750 km^2. As shown by Figure 9.14.1, most of this central area experienced 0.3 to 2.4 m (1 to 8 feet) of subsidence from 1934 to 1967.

9.14.2 GEOLOGY

The Santa Clara Valley is a structural trough extending 110 km southeast from San Francisco. The valley is bounded on the southwest by the Santa Cruz Mountains and the San Andreas fault and on the northeast by the Diablo Range and the Hayward fault. The consolidated bedrock bordering the valley is shown as a single unit in Figure 9.14.1; it ranges in age from Cretaceous to Pliocene and consists largely of sedimentary rocks but includes areas of metamorphic and igneous rocks.

The fresh-water-bearing deposits forming the ground-water reservoir within the valley are chiefly of Quaternary age. They include (1) the semiconsolidated Santa Clara Formation and associated deposits of Pliocene and Pleistocene age and (2) the unconsolidated alluvial and bay deposits of Pleistocene and Holocene age. The Santa Clara Formation, which crops out on the southwest and northeast flanks of the valley, consists of poorly sorted conglomerate, sandstone, siltstone, and clay as much as 600 m thick in outcrop (Dibblee, 1966). Where exposed, this formation has a low transmissivity and yields only small to moderate quantities of water to wells (1 to 6 l/s)--rarely enough for irrigation purposes.

The unconsolidated alluvial and bay deposits of clay, silt, sand, and gravel overlie the Santa Clara Formation and associated deposits; their upper surface forms the valley floor. They contain the most productive aquifers of the ground-water reservoir. Wells range in depth from 90 to 360 m. The deeper wells probably tap the upper part of the Santa Clara Formation although the contact with the overlying alluvium has not been distinguished in well logs. Well yields in the valley range from 20 to 160 l/s (Calif. Dept. Water Resources, 1967, pl. 6). The alluvial deposits are at least 460 m thick beneath central San Jose. However, the log of a well drilled to a depth of 468 m revealed a lack of water-bearing material below a depth of 300 m. Coarse-grained deposits predominate on the alluvial fans near the valley margins where the stream gradients are steeper. The proportion of clay and silt layers increases bayward. For example, a well-log section extending 20 km northward from Campbell to Alviso (Tolman and Poland, 1940, Figure 3) shows that to a depth of 150 m, the cumulative thickness of clay layers in the deposits increases from 25 per cent near Campbell to 80 per cent near Alviso.

In 1960, the U.S. Geological Survey drilled core holes to a depth of 305 m at the two centers of subsidence, in San Jose (well 16C6) and in Sunnyvale (well 24C7). (For location, see Figure 9.14.1.) The 305-m depth was chosen because it was the maximum depth of nearby water wells. Cores were tested in the laboratory for particle-size distribution, specific gravity of solids, dry unit weight, porosity and void ratio, hydraulic conductivity (normal and parallel to bedding), Atterberg limits, and one-dimensional consolidation and rebound (Johnson, Moston, and Morris, 1968).

X-ray diffraction studies of 20 samples from the two core holes indicate that montmorillonite composes about 70 per cent of the clay-mineral assemblage in these deposits. Other constituents are chlorite, 20 per cent, and illite, 5-10 per cent (Meade, 1967, p. 44).

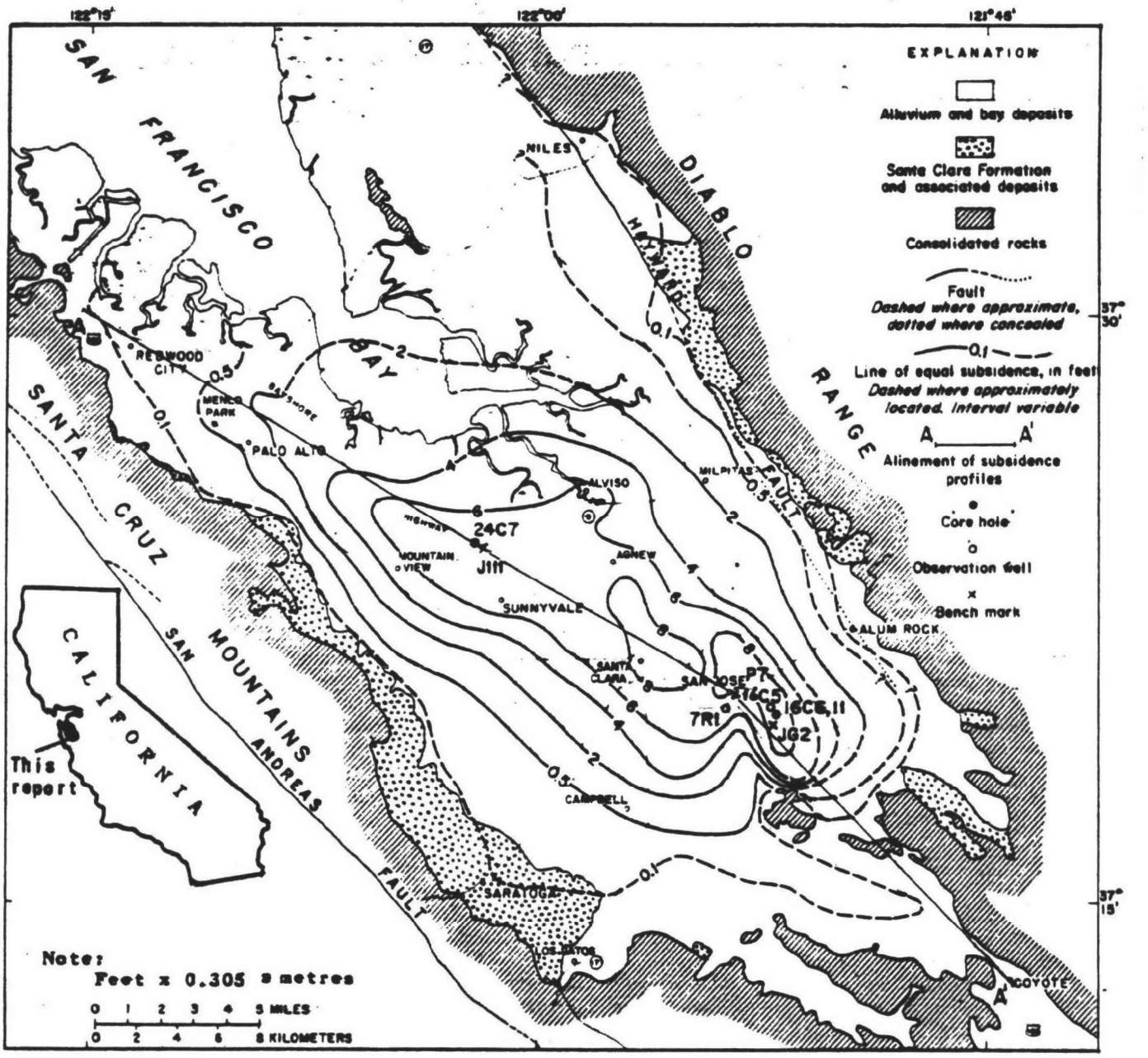

Figure 9.14.1 Land subsidence from 1934 to 1967, Santa Clara Valley, California. Compiled from leveling of National Geodetic Survey in 1934 and 1967.

9.14.3 HYDROLOGY

In the central part of Figure 9.14.1 and below a depth of 50 to 60 m, ground water is confined. The extent of the confined aquifer system is defined roughly by the 0.6 m (2-ft) line of equal subsidence in Figure 9.14.1. The area of confinement extends southward from beneath San Francisco Bay to San Jose, also west to Palo Alto and east to Milpitas. In the early years of development, wells as far south as San Jose and more than 60 m deep flowed (Clark, 1924, pl. XV), demonstrating by their areal distribution a minimal extent of the confining sediments. The confined aquifer system is as much as 245 m thick. Around the valley margins, ground water is chiefly unconfined and most of the natural recharge to the ground-water reservoir percolates from stream channels in alluvial-fan deposits.

The confining member overlying the confined aquifer system has a thickness ranging from 45 to 60 m. Although predominantly composed of lenses and tongues of clay and silt, it contains some channel fillings and lenses of permeable sand and gravel. This confining member supports a shallow water table distinguished by an irregular surface. As of 1965-70, the shallow water table overlying much of the confined system was less than 10 m below the land surface (Webster, 1973). At least near the Bay, the shallow water table did not fluctuate appreciably during the period of prolonged artesian-head decline terminating in 1966.

The development of irrigated agriculture in the valley began about 1900 and expanded to a maximum about the end of World War II. After 1945, population pressures caused a great transition of land use from agricultural to urban and industrial development. Agricultural pumpage increased from about 50 hm^3 per year in 1915-20 to a maximum of 127 hm^3 per year in 1945-50 (1 cubic hectometre, hm^3, = 1 x $10^6 m^3$ = 810.7 acre-feet). By 1970-75 most of the orchards had been replaced by houses, and agricultural pumpage had decreased to 25 hm^3 per year. Municipal and industrial pumpage, on the other hand, increased from 27 hm^3 per year in 1940-45 to 162 hm^3 per year in 1970-75. Total pumpage (Figure 9.14.2, bottom graph) increased nearly fourfold from 1915-20 to 1960-65--from 60 to 228 hm^3per year--but then decreased 19 per cent to 185 hm^3 by 1970-75, in response to a rapid increase in surface-water imports, discussed later.

The historical increase in withdrawal of ground water was a principal factor in causing a fairly continuous and severe 50-year decline of artesian head. In the spring of 1916, the artesian head in index well 7R1 in San Jose was 3.7 m above land surface (Figure 9.14.2); by the autumn of 1966 it was 55 m below land surface. The second major factor in this 50-year decline of 59 m was the negative trend of the local water supply. The upper line in Figure 9.14.2 is a plot of the cumulative departure, in per cent, of the seasonal rainfall at San Jose from the 50-year seasonal mean, 1897-98 to 1946-47 (Calif. State Water Resources Board, 1955, p. 26). The 50-year mean is 34.85 cm. Except for the 6-year wet period 1936-42, the departure in the

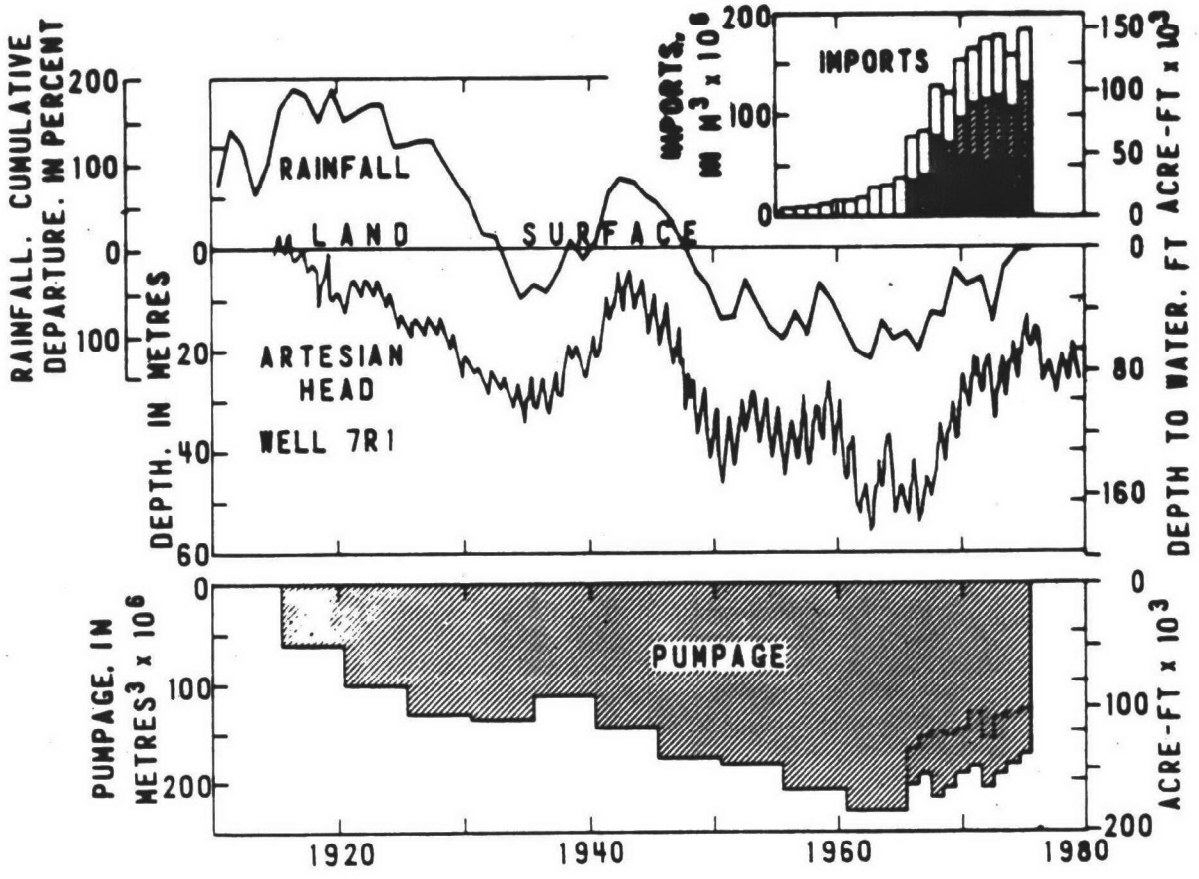

Figure 9.14.2 Artesian-head change in San Jose in response to rainfall, pumpage, and imports.

50 years 1916-66 was generally negative; the cumulative departure of 310 per cent from 1916 to 1966 represents a cumulative "deficiency" in rainfall of about 108 cm.

The 50-year decline in artesian head from 1916 to 1966 clearly was caused by the cumulative effect of generally deficient rainfall and runoff and a fourfold increase in withdrawals. The plot of artesian-head decline at index well 7R1 conforms in general with the cumulative departure of rainfall at San Jose.

9.14.4 LAND SUBSIDENCE

Land subsidence was first noted in 1932-33 when bench mark P7 in San Jose, established in 1912, was resurveyed and found to have subsided 1.2 m. As a result, a valleywide network of bench marks was established in 1934 (Poland and Green, 1962, Figure 3). The total length of survey lines comprising this bench-mark net was about 400 km. From 1934 to 1967 the National Geodetic Survey (formerly the U.S. Coast and Geodetic Survey) resurveyed the network from "stable" bedrock ties a dozen times to determine changes in elevation of the bench marks; the latest full survey of the network was in 1967. In the 33 years 1934-67, subsidence along lines of bench-mark control ranged from 0.3 to 1.2 m under the Bay to 2.4 m in San Jose (Figure 9.14.1). About 260 km^2 subsided more than 1 m. The subsidence record for bench mark P7 in central San Jose is plotted in Figure 9.14.3, together with the artesian head in nearby index well 7R1, taken from Figure 9.14.2. The black dots on the subsidence curve indicate times of bench-mark surveys. The fluctuations of artesian head represent the change in stress on the confined aquifer system; the subsidence is the resulting strain. Subsidence of bench mark P7 began about 1918 (note dotted inferred segment of subsidence plot representing the period 1912 to 1919) and reached 1.4 m in 1934. From 1938 to 1947 subsidence stopped, during a period of artesian-head recovery, in response to above-normal rainfall and recharge. (The natural recharge was supplemented by controlled percolation releases from newly constructed detention reservoirs on the larger streams.) Subsidence resumed in 1947 as a consequence of a rapidly declining artesian head due to deficient rainfall and increasing demand for ground water (Figure 9.14.2); it attained its fastest average rate in 1960-63 (0.22 m/year), in response to the rapid head decline of 1959-62 during a drought period (see Figure 9.14.2). By 1967 bench mark P7 had subsided 3.86 m.

Figure 9.14.4 shows land-subsidence profiles along line A-A' from Redwood City to Coyote from 1912 through 1969 (for location, see Figure 9.14.1). The spring 1934 leveling was used as a reference base because this was the first complete leveling of the net. Note that from 1934 to 1967, maximum subsidence of 2.6 m was near bench mark W111, 4.8 km northwest of bench mark P7, also that from 1934 to 1960 the greatest subsidence along line A-A' was 1.7 m, at bench

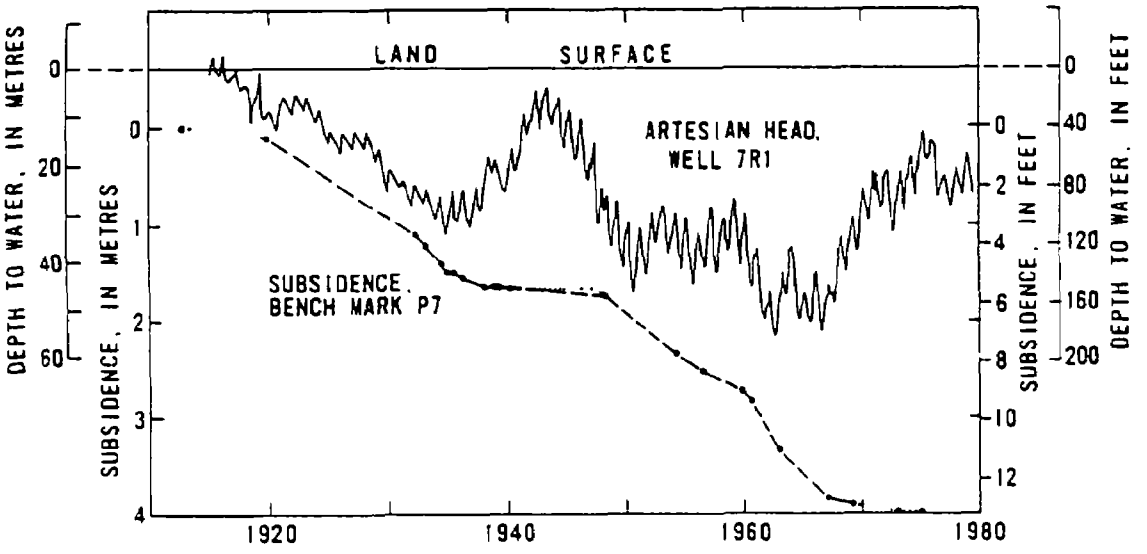

Figure 9.14.3 Artesian-head change and land subsidence, San Jose.

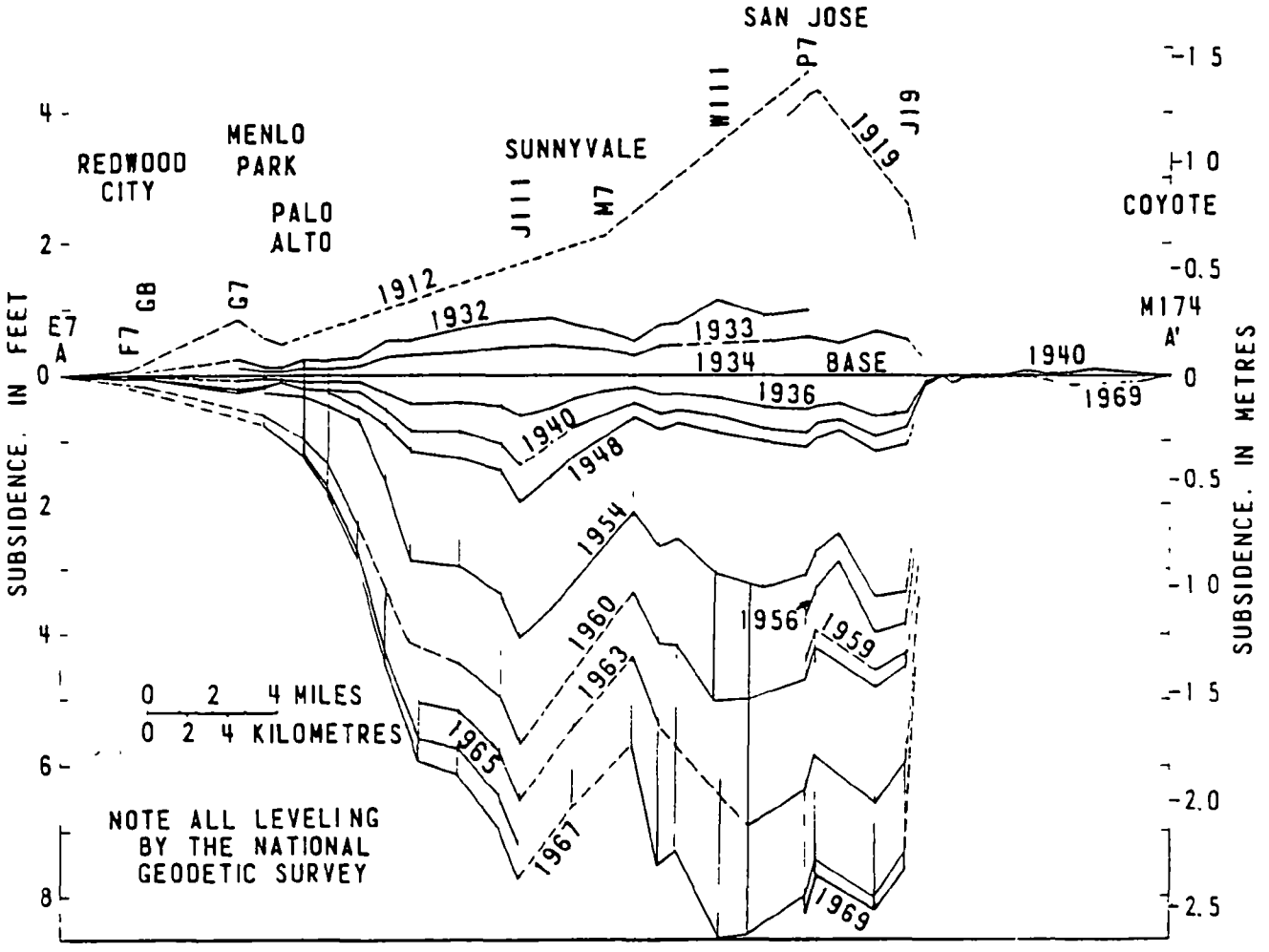

Figure 9.14.4 Profiles of land subsidence, Redwood City to Coyote, California, 1912-69.

mark J111 in Sunnyvale. Changes in the rate and magnitude of artesian-head decline doubtless have caused such geographic variations in subsidence rate and magnitude with time.

The volume of subsidence (pore-space reduction) planimetered from the 1934-67 subsidence map (Figure 9.14.1) was about 617 hm^3. If the ratio of the pre-1934 subsidence volume to the 1934-67 subsidence volume is assumed to be equal to the ratio of the pre-1934 subsidence of bench mark P7 to the 1934-67 subsidence of that bench mark, then the total subsidence volume from 1912 to 1967 is about 975 hm^3.

Protrusion of well casings above the land surface and inundation of lands near the south end of San Francisco Bay also have furnished evidence of subsidence. Protrusion of well casings has been common in the subsiding area (Tolman, 1937, p. 345). Many of the casings gradually protruded 0.6-1 m above ground level but usually were cut off before protruding higher. This protrusion indicates that compaction of the deposits occurred in the depth interval above the bottom of the protruding casing. However, such protrusion often is accompanied by compression and rupture of the casing at depth and thus supplies only a minimal value of subsidence. In general, the deeper the compacting interval, the smaller will be the protrusion in proportion to the subsidence, because the frictional drag of the formation or the gravel-pack on the casing wall should increase proportionately with depth.

Although some horizontal movement doubtless has occurred in the subsidence area in association with the subsidence, no surveys or evidence of horizontal movement are known to the author.

The comparison of artesian-head change and subsidence from 1916 to 1967 (Figure 9.14.3) demonstrates beyond a reasonable doubt that the increase in effective stress resulting from the declining artesian head caused the compaction and the subsidence.

9.14.5 EXTENSOMETERS TO MEASURE COMPACTION

Extensometers (compaction recorders) were installed by the Geological Survey in 1960 in the cased core holes 305 m deep in San Jose (16C6) and in Sunnyvale (24C7) and in several unused water-supply wells. (For location, see Figure 9.14.1.) The purpose of this equipment was to measure the rate and magnitude of compaction occurring between the land surface and the well bottom. When first installed, the extensometer consisted of an anchor placed in the formation below the casing bottom, attached to a cable that passed over sheaves at the land surface and was counterweighted to maintain constant tension (Figure 2.5A). A recorder actuated by cable movement yields a time graph of the movement of land surface with respect to the anchor--the compaction or expansion of the deposits within that depth range. To reduce friction and increase the accuracy of measurement four of the extensometers were modified in 1972 by replacing the cable with a free-standing pipe of 3.8-cm diameter (Figure 2.5B) within the well casing of 10-cm diameter. The records obtained from these instruments show that the measured compaction to the depth of 305 m is nearly equal to the land subsidence as measured periodically by leveling of the bench-mark network. Thus, these instruments function as continuous subsidence monitors.

Figure 9.14.5 shows the measured compaction in the 305-m well in San Jose (well 16C6) and the compaction and artesian-head fluctuation in adjacent unused well 16C5 (depth 277 m) through 1975. The dashed line represents subsidence of adjacent bench mark JG2 as determined by periodic releveling from stable bench marks. Measured compaction of the confined aquifer system to the 305-m depth from July 1, 1960, to December 31, 1976, was 1.4 m.

9.14.6 MEASURES TAKEN TO CONTROL SUBSIDENCE

Local agencies have been working since the 1930's to conserve water and to obtain water supplies adequate to stop the ground-water overdraft and raise the artesian head. Their program has involved (1) salvage of flood waters from local streams that would otherwise waste to the Bay and (2) importation of water from outside the valley. In 1935-36 five storage dams were built on local streams to provide detention reservoirs with combined storage capacity of about 62 hm^3 to retain floodwaters and permit controlled releases to increase streambed percolation (Hunt, 1940). The storage capacity of detention reservoirs was increased to 178 hm^3 in the early 1950's (Calif. State Water Resources Board, 1955, p. 51).

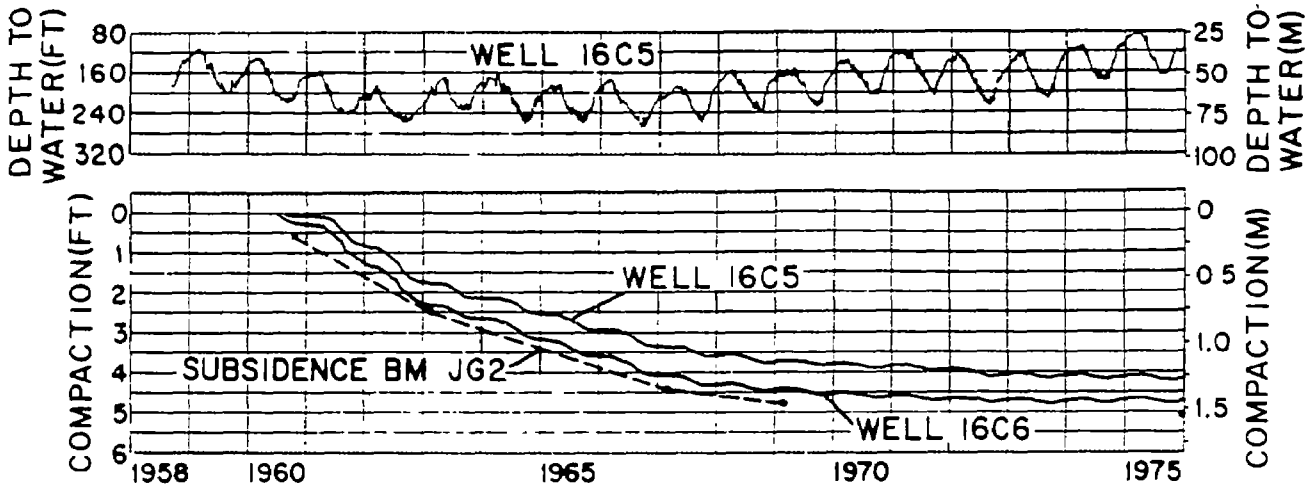

Figure 9.14.5 Measured water-level change, compaction, and subsidence in San Jose.

By 1960, sharply declining water levels furnished evidence that local resources were not adequate to supply present and future water needs. Steps were taken to increase water imports to the County. The import of surface water to Santa Clara County began about 1940 when San Francisco commenced selling water imported from the Sierra Nevada to several municipalities. This import increased to 15 hm^3 in 1960 and to 54 hm^3 by 1975 (see blank segments of yearly bars, upper right graph, Figure 9.14.2). Surface water imported from the Central Valley through the State's South Bay Aqueduct first became available in 1965; by 1974-75, the aqueduct import was 128 hm^3 (see cross-hatched plus diagonally ruled segments of yearly bars, upper right graph, Figure 9.14.2). As a result, total imports to Santa Clara County increased five-fold from 1964-65 to 1974-75--from 37 to 183 hm^3 per year.

The recovery of water level since 1967 has been dramatic. By 1975, the spring high water level at index well 7R1 (Figure 9.14.2) was 32 m above that of 1967, and about equal to the level in this well in 1925. This major recovery of head was due primarily to the fivefold increase in imports from the Central Valley. Two other favorable factors were the above-normal rainfall and the decreased pumpage (Figure 9.14.2).

The average seasonal rainfall at San Jose was 13 per cent above normal in the period 1966-75. The cumulative departure graph (Figure 9.14.2) indicates an increase of 120 per cent or a cumulative excess of about 41 cm above normal in the 9-year period.

The average yearly pumpage of ground water, which had reached its peak of 228 hm^3 in 1960-65, decreased to 185 hm^3 in 1970-75. A principal reason for this 19-per cent decrease was a use tax levied on ground-water pumpage since 1964. In 1977, for example, the ground-water tax was levied at \$8.50 per unit (1 acre-ft. or 1234 m^3) for ground water extracted for agricultural purposes and at \$34 per unit for ground water extracted for other uses. The energy cost to the consumer for pumping ground water in the Santa Clara Valley at 1977 prices was \$10 to \$15 per unit. Thus, the average total cost for ground water pumped for agricultural purposes was about \$20 per unit and for other uses was about \$45 per unit. The price for surface water delivered in lieu of extraction was \$14 per unit for water used for agriculture and \$39.50 per unit for water used for other purposes. The economic advantage of buying surface water, where available, is obvious.

Recharge to the ground-water reservoir from regulated local runoff released to stream channels and percolation ponds has been augmented since 1965 by water from the South Bay Aqueduct that could not be delivered directly to the user. The quantity diverted to recharge areas (cross-hatched segment of yearly bars, upper right graph, Figure 9.14.2) in the 10 years to 1975 averaged about 50 hm^3 per year and represents 56 per cent of the total import from the South Bay Aqueduct.

The marked decrease in rate of subsidence in response to the dramatic head recovery from 1967 to 1975 is demonstrated graphically by the compaction records from the two deep extensometers in San Jose and Sunnyvale (Figure 9.14.6). The rate of measured compaction in well 16C6 in San Jose decreased from about 30 cm per year in 1961 to 7.3 cm in 1967 and to 0.3 cm in 1973. Net expansion (land-surface rebound) of 0.6 cm occurred in 1974. In Sunnyvale, compaction of the sediments above the 305-m anchor in well 24C7 decreased from about 15 cm per year in 1961 to 1.2 cm in 1973; net expansion of 0.5 cm and 1.1 cm occurred in 1974 and 1975, respectively. Very deficient rainfall in 1975-76 and in 1976-77 virtually eliminated runoff and recharge from local sources, and water levels started to decline once more in 1976. In response, compaction and subsidence resumed once again. In San Jose at well 16C6, compaction in 1976 was 3.5 cm, about equal to that in 1968; in Sunnyvale, compaction was 1.6 cm.

9.14.7 COMPRESSIBILITY AND STORAGE PARAMETERS

Compressibility characteristics of fine-grained compressible layers (aquitards) can be obtained by making one-dimensional consolidation tests of "undisturbed" cores in the laboratory. As one phase of the research on compaction of the aquifer system, laboratory consolidation tests were made on 21 selected fine-grained cores from the two core holes. These tests were made in the Earth Laboratory of the United States Bureau of Reclamation at Denver, Colorado. Parameters tested included the compression index, C_c, a measure of the nonlinear compressibility of the sample, and the coefficient of consolidation, C_v, a measure of the time rate of consolidation. Complete results of these laboratory tests have been published (Johnson and others, 1968, Tables 8 and 9 and Figure 21). The 21 samples tested spanned a depth range from 43 to 292 m below land surface. The range of the compression index, C_c, was small compared to the range in the San Joaquin Valley· the maximum value was 0.33, the minimum 0.13, and the mean was 0.24. Of the 21 samples, 15 had C_c values falling between 0.20 and 0.30. This suggests

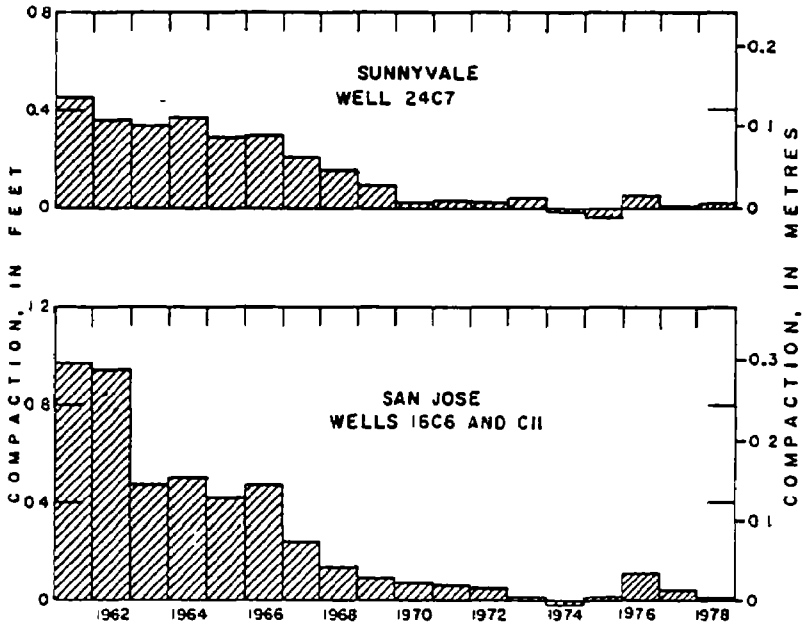

Figure 9.14.6 Measured annual compaction to 305-m (1,000-ft) depth.

that the nonlinear compressibility characteristics of the aquitards in the confined aquifer system do not vary widely.

The plot of void ratio against the log of load (effective stress), known as the e-log p plot, can be used to obtain a graphic plot of compressibility versus effective stress. Such a graph can be used to estimate ultimate compaction due to a step increase in effective stress. This procedure applied to the laboratory consolidation tests at the Sunnyvale and San Jose core holes produced estimates of ultimate compaction that were only about one-third to one-half the values obtained by summing field measurements of compaction to date with residual compaction estimated from a one-dimensional simulation of the field observations (Helm, 1976). The reason for this disparity is not known. Apparently the samples tested were not representative of the aquitards that contributed most to the observed compaction.

Subsidence represents pore-space reduction which occurs almost wholly in the fine-grained compressible aquitards. At well 16C6 in San Jose the confined aquifer system is 244 m thick, from 61 to 305 m below land surface. Based on study of the microlog, the confined system contained 38 aquitards with a combined thickness of 145 m. The mean porosity of 27 core samples, determined in the laboratory, was 37 per cent. The total subsidence to date at well 16C6 is about 4 m. A reduction of 4 m in the thickness of the confined system requires about 1.8 per cent reduction in the porosity of the aquitards--for example, from 37 to 35.2 per cent.

The subsidence/head-decline ratio is a useful parameter in subsidence studies. The ratio is a rough approximation of the response of the aquifer system to a given change in stress. At San Jose, referring to the plot of subsidence for bench mark P7 and the artesian-head change in well 7R1 (Figure 9.14.3), the artesian head declined from 6 m below land surface in 1918 (approximate preconsolidation stress) to 55 m below land surface in 1966, for a net change of 49 m. Subsidence at bench mark P7 from 1918-66 was about 3.84 m. This means that as of 1966 the empirical ratio is 3.84 m/49 m = 0.08. The ratio of ultimate subsidence to head decline must therefore be larger than 0.08 at this site. Artesian head as measured in a well casing represents a composite pore pressure of all aquifers in the confined system that are tapped by the observation well. If and when the pore pressures in fine-grained aquitards reach equilibrium with those in the adjacent aquifers, compaction will cease, and the ratio of ultimate subsidence to head decline will be a true measure of virgin compressibility for the entire interval being stressed. Such an ultimate value is analogous to a storage coefficient.

Helm (1977), by means of a one-dimensional simulation of the long-term field observations of subsidence at bench march P7 and artesian head at well 7R1, provided the parameters used for estimating the ultimate compaction (subsidence) resulting from a step change in head of 49 m;

the computed compaction is about 5.3 m. Thus, on the basis of Helm's parameter values, the ultimate subsidence/head-decline ratio would be 5.3 m/49 m = 0.11. If we divide the ratio by the thickness of compacting aquitards, 145 m, we obtain the virgin compressibility (for stress increase beyond preconsolidation stress) of the aquitards:

$$5.3 \text{ m}/(145 \text{ m} \times 49 \text{ m}) = 7.4 \times 10^{-4}\text{m}^{-1}$$

As the water levels in the San Jose area rose rapidly after 1967 (Figure 9.14.2), the stress-strain curves obtained from paired measurements of compaction and artesian head began to show seasonal expansion during the winter months when the water level was highest and the effective stress on the confined system was lowest. These stress-strain loops can be used to obtain the compressibility of the confined system in the recoverable or elastic range of stresses (less than preconsolidation stress). One example (Figure 9.14.7) shows the stress-compaction plot for a pair of wells in San Jose from 1967 through 1974. Compaction was measured in well 16C6,11, 305 m deep, and stress in nearby well 16C5. Depth to water is plotted increasing upward. Change in depth to water represents an average change in stress in all aquifers of the confined aquifer system tapped by well 16C5. The lower parts of the descending segments of the annual loops for the winters of 1967-68, 1969-70, and 1970-71 are approximately parallel, as shown by the dotted lines, indicating that the response is essentially elastic in both aquifers and aquitards when the depth to water is less than about 55 m. The heavy dashed line drawn parallel to the dotted lines represents the average slope of the segments in the range of stresses less than preconsolidation stress. The reciprocal of the slope of this line is the component of the storage coefficient attributable to elastic or recoverable deformation of the aquifer-system skeleton, S_{ke}, and equals 1.5×10^{-3}. The component of average specific storage due to elastic deformation, S_{ske}, equals $S_{ke}/244 \text{ m} = 6.15 \times 10^{-6}\text{m}^{-1}$. If stresses are expressed in metres of water, and if γ_w (the unit weight of water) = 1, the average elastic compressibility of the aquifer system skeleton, α_{ke}, is equal numerically to S_{ske}.

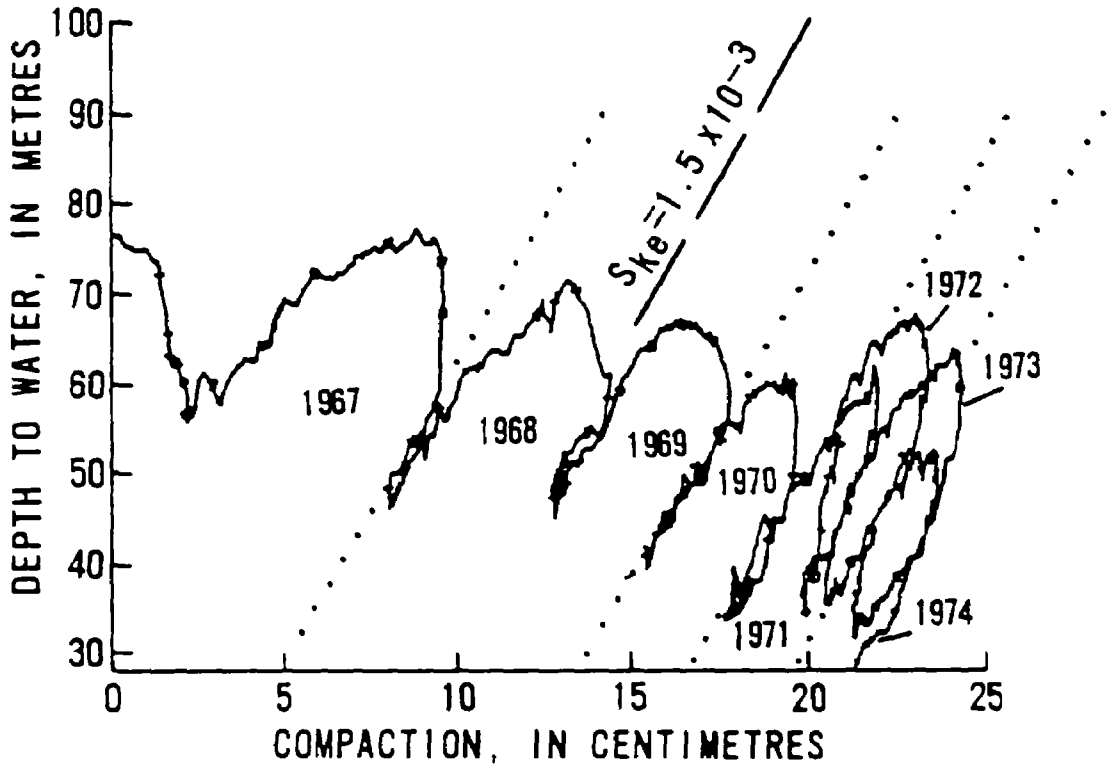

Figure 9.14.7 Stress change and compaction, San Jose site.

In these computations I have assumed that in the range of stresses less than preconsolidation stress, the compressibility of the aquitards and the aquifers is the same. Therefore, the full thickness of the confined aquifer system, 244 m, was used to derive the specific storage component, S_{ske}, in the elastic range of stress.

At these San Jose sites, then, the average compressibility of the aquitards in the virgin range of stress, 7.4×10^{-4} m^{-1}, is 120 times as large as the average compressibility of the confined aquifer system in the elastic range of stress, 6.15×10^{-6} m^{-1}. **This great difference in response to stressing should be kept in mind when considering use of aquifer tests to derive hydrologic parameters, as well as in appraisal of subsidence potential.**

9.14.8 ECONOMIC AND SOCIAL IMPACTS

Subsidence has created several major problems. Lands adjacent to San Francisco Bay have sunk as much as 2.4 m since 1912, requiring construction and repeated raising of levees to restrain landward movement of the saline bay water onto 44 km^2 of land below high-tide level in 1967. Also, flood-control levees have been built and maintained near the bayward ends of the depressed stream channels. About $9 million of public funds had been spent to 1974 on such flood-control levees to correct for subsidence effects, according to Lloyd Fowler, former Chief Engineer of the Santa Clara Valley Water District. In addition, a major salt company has spent an unknown but substantial amount maintaining levees on 78 km^2 of salt ponds to counter as much as 2.4 m of subsidence. Several hundred water-well casings have failed in vertical compression, due to compaction of the sediments. The cost of repair or replacement of such damaged wells has been estimated as at least $4 million (Roll, 1967). Including funds spent on maintaining the salt-pond levees, establishing and resurveying the bench-mark net, repairing railroads, roads, and bridges, replacing or increasing the size of storm and sanitary sewers, and making private engineering surveys, the direct costs of subsidence must have been at least 35 million dollars to date.

A major earthquake could cause failure of the bay-margin levees, resulting in the flooding of areas presently below sea level. The levees were constructed of locally derived weak materials and were designed only to retain salt-pond water under static conditions (Rogers and Williams, 1974). The potential for such an earthquake poses a continuing threat to flooding of the estimated 44 km^2 (4400 hectares) of land standing below high tide level as of 1967. Such a threat must have reduced the value of this land very substantially compared to the value if it all still stood above mean sea level as it did in 1912. This decrease in land value should be included in the gross costs of subsidence.

9.14.9 LEGAL ASPECTS

The successful management of a highly variable water supply to achieve a balance with an ever-increasing demand for water in Santa Clara County (not shown on map) has been remarkable for several reasons. First, maximum development of local water supplies and importation of water from two sources have momentarily brought supply and demand into balance. Secondly, by building up the ground-water storage in the recharge area, and thus the artesian head in the confined system, land subsidence was stopped, at least temporarily, by 1973. Thirdly, all this has been accomplished by bond issues, revenue from taxes, and water charges, thus avoiding a drawn-out expensive legal adjudication of the ground-water supply such as occurred in southern California, in the Raymond Basin (Pasadena vs. Alhambra, 1949).

9.14.10 CONCLUSIONS

Both the cause of subsidence and the means of its control are known. The evidence given here proves that the subsidence is caused by decline of the artesian head and the resulting increase in effective overburden load or grain-to-grain stress on the water-bearing beds in the confined system. The sediments compact under the increasing stress and the land surface sinks. Most of the compaction occurs in the fine-grained clayey beds (aquitards) which are the most compressible but have low permeability. Therefore, the escape of water from these slow draining aquitards (decay of excess pore pressure) and the increase in effective stress are slow and time-dependent, but the ultimate compaction is large and chiefly permanent.

The subsidence has been stopped by raising the artesian head in the aquifers until it equaled or exceeded the maximum pore pressures in the aquitards. The compaction and water-level records being obtained by the Geological Survey indicate that if the artesian head can be maintained 3 to 6 m above the levels of 1971-73, subsidence will not recur. On the other hand, subsidence will recommence if artesian head is drawn down as much as 6 to 9 m below the 1971-73 levels.

9.14.11 EPILOGUE

Recently the Santa Clara Valley Water District was given Historical Landmark status by the American Society of Civil Engineers for its major contributions to the development of the region. It was acknowledged that the district's system is "the first and only instance of a major water supply being developed in a single ground-water basin involving the control of numerous independent tributaries to effectuate almost optimal conservation of practically all of the sources of water flowing into the basin."

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SECTION 8

Miscellaneous Wells

Section 8.1

Radioactive Waste Disposal Wells Supporting Data

Section 8.1.1

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Subsurface Disposal of Liquid Low-Level Radioactive Wastes at Oak Ridge, Tennessee
AUTHOR: (or INVESTIGATOR)	Stephen H. Stow and C. Stephen Haase
DATE:	1986
FACILITY NAME AND LOCATION:	Oak Ridge National Laboratory Oak Ridge, Tennessee USEPA Region IV
NATURE OF BUSINESS:	
BRIEF SUMMARY/NOTES:	At Oak Ridge National Laboratory (ORNL) subsurface injection has been used to dispose of low-level liquid nuclear waste for the last two decades. Investigations are underway to determine the long-term hydrologic isolation of the injection zone and the geochemical impact of saline groundwater on nuclide mobility. This report addresses the hydrofracture process, principle of waste isolation, site selection criteria, characteristics of the ORNL site, development of monitoring procedures, federal and state regulations, and future directions.

From: Proceedings of the International Symposium: Subsurface Injection of Liquid Wastes, March 3-5 1986, New Orleans, LA National Water Well Association, Dublin, OH

SUBSURFACE DISPOSAL OF LIQUID LOW-LEVEL RADIOACTIVE WASTES AT OAK RIDGE, TENNESSEE

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Abstract

At Oak Ridge National Laboratory (ORNL) subsurface injection has been used to dispose of low-level liquid nuclear waste for the last two decades. The process consists of mixing liquid waste with cement and other additives to form a slurry that is injected under pressure through a cased well into a low-permeability shale at a depth of 300 m (1000 ft). The slurry spreads from the injection well along bedding plane fractures and forms solid grout sheets of up to 200 m (660 ft) in radius.

Using this process, ORNL has disposed of over 1.5×10^6 Ci of activity; the principal nuclides are ^{90}Sr and ^{137}Cs. In 1982, a new injection facility was put into operation. Each injection, which lasts some two days, results in the emplacement of approximately 750,000 l (180,000 gal) of slurry. Disposal cost per liter is approximately $0.30, including capital costs of the facility.

This subsurface disposal process is fundamentally different from other operations. Wastes are injected into a low-permeability aquitard, and the process is designed to isolate nuclides, preventing dispersion in groundwaters. The porosity into which wastes are injected is created by hydraulically fracturing the host formation along bedding planes.

The site is in the structurally complex Valley and Ridge Province. The stratigraphy consists of lower Paleozoic rocks. Investigations are under way to determine the long-term hydrologic isolation of the injection zone and the geochemical impact of saline groundwater on

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nuclide mobility. Injections are monitored by gamma-ray logging of cased observation wells to determine grout sheet orientation after an injection. Recent monitoring work has involved the use of tiltmeters, surface uplift surveys, and seismic arrays.

Recent regulatory constraints may cause permanent cessation of the operation. Federal and state statutes, written for other types of injection facilities, impact the ORNL facility. This disposal process, which may have great applicability for disposal of many wastes, including hazardous wastes, may not be developed for future use.

Introduction and Purpose

At Oak Ridge National Laboratory (ORNL), low-level radioactive wastes are routinely disposed of by a subsurface injection process termed "hydrofracture." The liquid wastes are mixed with cement and other solids to form a slurry that is pumped under pressure through an injection well into underlying strata. The slurry follows fractures in the strata and sets to form a solid grout, which contains and immobilizes the radioelements.

This process has been successfully developed at ORNL over the last quarter century (de Laguna et al., 1968). Initial development work was performed at test facilities; in the mid-1960s, the process became operational. A new injection facility was put into operation in 1982. A total of over 1.5 million curies of radioelements has been disposed of; the principal nuclides are Sr^{90} and Cs^{137}, although others, including H^{3}, Co^{60}, Ru^{106}, and isotopes of Eu, Cm, Mn, U, Am, and Pu, also occur in the wastes. This process represents the only permanent geologic disposal of nuclear wastes in the United States.

The disposal operation is unique and is based on the common practice of hydrofracturing, which is routinely used by the petroleum industry to increase porosity and permeability in reservoir rocks by fracturing the rocks with water injected under pressure. This technique has potential application to the management of many kinds of wastes. Our purpose is to discuss the basic principles of the subsurface injection program at ORNL, to discuss development of monitoring techniques, and to review the application of existing regulatory requirements to the ORNL process.

The Hydrofracture Process

A complete review of the history of the subsurface injection operation and a description of the process can be found in previously published works (deLaguna, et al., 1968; Weeren, et al., 1982; IAEA, 1983). The process is a large-scale batch operation (Fig. 1). Liquid wastes are stored in underground tanks and disposed of typically every one to two years. The waste solutions, which are alkaline and

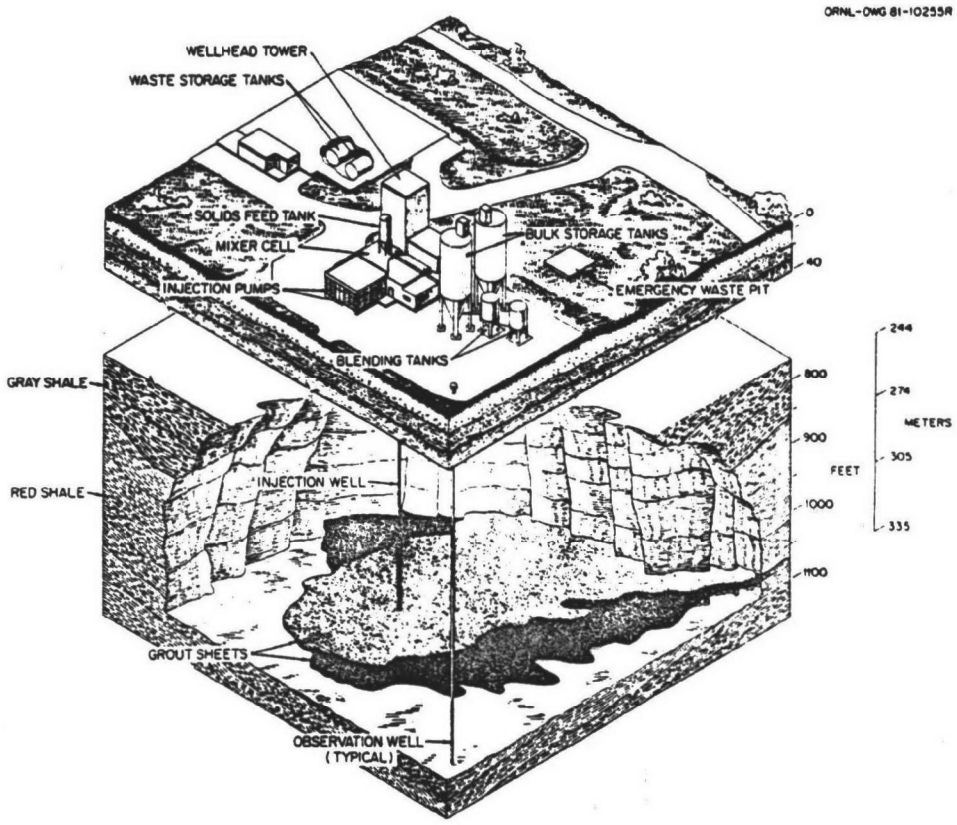

Figure 1. Conceptual drawing of the Hydrofracture Facility at Oak Ridge National Laboratory. Surface facilities, the injection well, one cased observation well, and grout sheets are depicted.

nitrate-rich (1-2 M $NaNO_3$), are blended with cement and other additives to form a slurry, which is pumped under approximately 21-MPa (3000 psi) pressure into the cased injection well. The casing is slotted at a depth of approximately 300 m (1000 ft). Fractures in the host rock, a shale of low permeability, are initiated along bedding planes by pumping a few thousand liters of water into the well; this is followed immediately by the slurry, which spreads radially from the injection well along the fractures. The slurry sets to form a thin (less than a few cm) grout sheet that extends up to several hundred meters from the well. No grout sheet has been detected more than 220 m (725 ft) from the injection point. Later injections are made through slots cut at shallower depths in the well, thus allowing maximum use of the host injection strata.

Disposal is normally done over a two-day period in two eight to ten-hour shifts. The total volume disposed of ranges from 350,000 to 700,000 l (88,000 to 175,000 gal). Although some operational problems (Weeren et al., 1984) have arisen over the years, the technique has been

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highly successful. A major reason for this success is that the engineering and operational aspects of this technique are not unique but rather are standard practice in the petroleum industry.

The costs for disposal at ORNL are approximately $0.30/l ($1.20/gal). About half of this is operational cost, including dry solids and personnel. The other half represents amortization of the capital cost ($5.4 million) of the facility prorated for disposal of 40×10^6 l (10^7 gal) of waste. The costs are sensitive to process parameters (batch size, injection rate, etc.), which were chosen to fit ORNL requirements.

Principle of Waste Isolation

The basic objective of the ORNL subsurface injection program is to effectively isolate the wastes from the accessible environment. This is achieved through immobilization of the wastes in a variety of ways. The cementitious waste carrier is the primary barrier and is tailored to retard the two principal isotopes that occur in the wastes, Sr^{90} and Cs^{137}. Highly sorbing illitic clay is added to help retain the Cs^{137}. Most of the Sr^{90} occurs as a fine-grained precipitate in the waste; this precipitate is physically entrapped in the cement, and Sr^{90} is largely immobilized in this fashion. The secondary barrier is the shale, which has a high content of illite. If isotopes such as Cs^{137} should escape the grout, they should readily be sorbed by the shale. Equally important is the fact that the 100-m-thick (330 ft) host shale formation is of low permeability, contains small amounts of groundwater, and is removed from any fresh-water aquifer by over 100 m (330 ft) of intervening strata.

One of the most significant aspects of the waste isolation operation at ORNL is the generation of bedding plane fractures. It is critical that the radioactive slurry remain in the impervious host horizon and not travel through vertical fractures into strata that might have hydrologic communication with the environment. As noted later, the great mechanical anisotropy of the shale and the fact that the injections are apparently shallow enough so that the least principal stress is vertical are factors that cause the nearly horizontal bedding plane fractures. The production of fractures with a nearly horizontal orientation represents one of the most significant differences with the standard hydrofracture methods used in industry, where the fracturing is done at much greater depths with the intent of producing vertical fractures that cross many strata.

Site Selection Criteria

Idealized Criteria

A set of idealized geologic criteria that should be considered in selecting a site for a hydraulic-fracturing subsurface injection

facility has been developed (Weeren et al., 1982; IAEA, 1983). The criteria are similar to many used in the selection of repository sites for high-level commercial nuclear wastes (CFR, 1984). For instance, a properly located subsurface injection facility should be in an area that is tectonically stable and has few, if any, natural resources that might be sought in the future. The injection horizon should be thick and laterally extensive enough to contain and to help isolate the wastes, and it should be hydrologically isolated from the accessible environment. The host strata and waters contained within should have geochemical characteristics that enhance immobility of the wastes through retardation and should produce uniform and predictably oriented fractures. Because of the importance of the host formation to the success of hydraulic-fracturing subsurface waste disposal, the role of the host formation is discussed below.

Host Formation Considerations

After injection, the grout acts as a waste package for the radioactive waste. The grout is the primary containment feature and is responsible for retention and isolation of the radioactive wastes. The role of the host formation is as an isolation medium for the wastes. Because of the host formation's important role in enhancing and augmenting the isolation and containment functions of the grout, several specific criteria for the evaluation of potential host formations have been formulated. In general, host formation must have the ability to (1) hydraulically fracture in a predictable manner, (2) hydrologically isolate the grout sheets, and (3) retard radionuclide migration and promote long-term grout stability. The importance of each of these properties is briefly discussed below.

To ensure that all injected grout sheets stay within the host formation, it must have properties that result in hydraulic fractures oriented parallel to its top and bottom contacts. Ideally, such fractures should maintain a constant orientation throughout their extent and remain in the particular stratigraphic interval in which they were initiated.

The host formation should have low porosity and low permeability. Such properties minimize the quantities of groundwater that could come into contact with the grouts and prevent the flow of fluids introduced during injection operations.

The mineralogy and geochemistry of the host formation should promote the retention of radionuclides contained in the grout sheets. Clay minerals, such as illite and smectite, which have large capacities to sorb radionuclides, should be abundant. The geochemical environment within the host formation also must be compatible with the chemical and physical stability of the radionuclide-bearing grouts.

Characteristics of the ORNL Site

The site at ORNL, although selected prior to systematic identification of these idealized siting parameters, conforms to them fairly well. A summary of the site geology of the ORNL subsurface injection facility is included below. A more comprehensive description of site geology and a discussion of the relationship between geological features and subsurface waste injection is presented by Haase et al. (1985).

Geologic Setting

The ORNL site is located in the Valley and Ridge Province of the Appalachian orogenic belt (Fig. 2). The Valley and Ridge Province in east Tennessee is characterized by a series of regional thrust faults that strike parallel to the borders of the province. Motion along these faults during the Alleghanian orogeny (230 to 250 My ago) resulted in southeast to northwest crustal shortening of 100 to 150 km (60 to 90 mi) (Harris and Milici, 1977). Within the sediments on each of the thrust sheets, a significant amount of small-scale folding and faulting results in a complex structural fabric within all rocks.

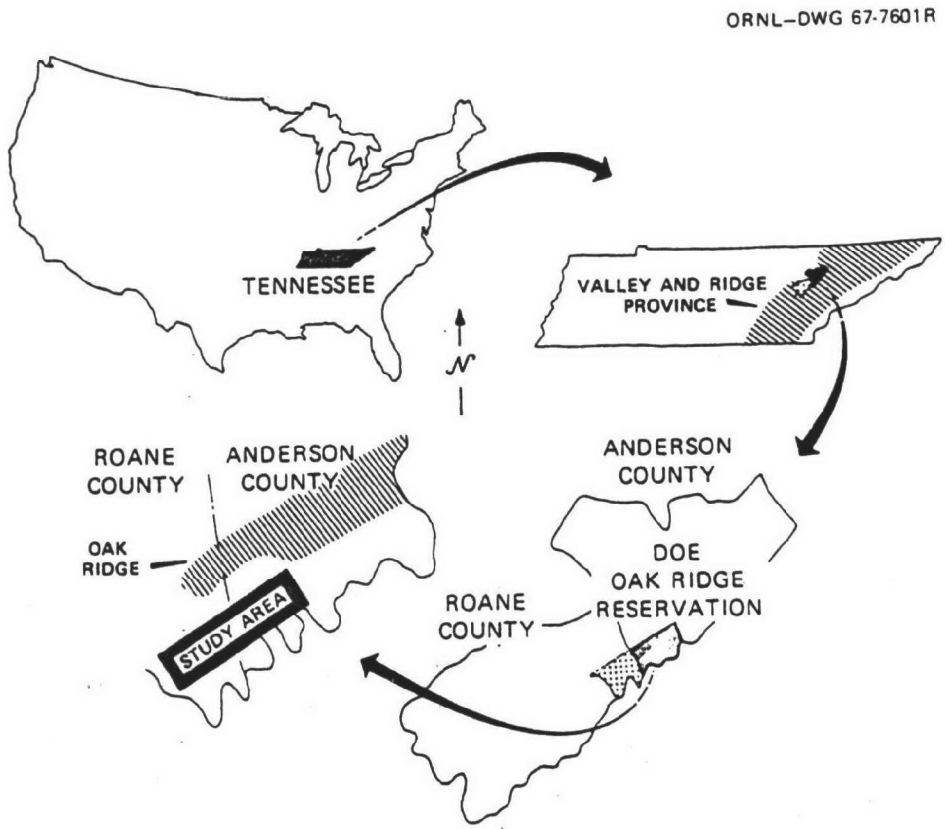

Figure 2. Location maps for Oak Ridge National Laboratory.

The ORNL subsurface injection site is on the leading edge of the Copper Creek thrust sheet within 1 km (0.6 mi) of where the fault comes to the surface (Fig. 3). The strike of strata at the site is N 45° to 55° E and the dip of the strata is variable. Within 500 m (1600 ft) of the fault trace, dip values range from 45°to 90°to the SE. At the injection facility, dip values range from 10°to 20°to the SE.

The stratigraphic sequence in the basal portion of the Copper Creek fault block consists of, from bottom to top, the Rome Formation, the Conasauga Group (which includes the host formation), and the Knox Group. The Rome Formation ranges from 100 to 150 m (330 to 500 ft) in

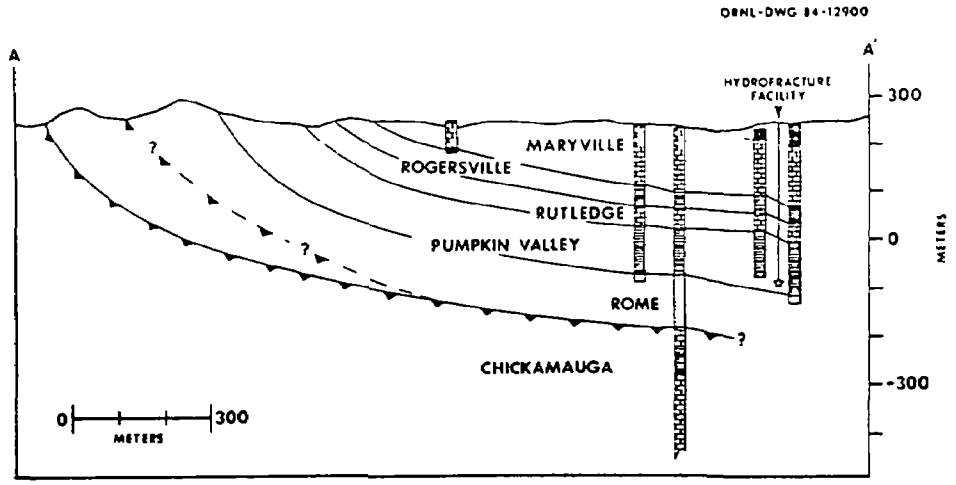

Figure 3. Cross section along a NW-SE trending line through the hydrofracture facility. The distributions of the Conasauga Group, the Rome Formation, and the Copper Creek fault in the vicinity of the ORNL hydrofracture facility are illustrated.

thickness and consists of sandstones, siltstones, shales, and mudstones. The Conasauga Group ranges from 550 to 600 m (1800 to 2000 ft) in thickness and consists of six formations, that are, in ascending order, the Pumpkin Valley Shale (the host formation), the Rutledge Limestone, the Rogersville Shale, the Maryville Limestone, the Nolichucky Shale, and the Maynardville Limestone. The clastic-rich formations, including the Pumpkin Valley Shale, consist of thinly bedded siltstones and laminated shales and mudstones. The carbonate-rich formations consist of coarse- to fine-grained limestones, conglomerates, and calcareous siltstones and shales (Haase et al., 1985). The Knox Group consists of carbonates and locally abundant sandstones.

The Pumpkin Valley Shale Host Formation

The Pumpkin Valley Shale is 105 m (345 ft) thick and can be divided into a siltstone-rich, lower member that is 45 m (150 ft) thick and a shale-rich, upper member that is 60 m (195 ft) thick (Haase, 1982; Haase et al., 1985). The lower contact of the formation is gradational into sandstones of the upper Rome Formation. The upper contact is also gradational into limestones and calcareous shales of the Rutledge Limestone. The Pumpkin Valley Shale is composed of mudstones, shales, and siltstones. The two members differ principally in the relative proportions of the different lithologies, in the character of the interstratification sequences of the different lithologies throughout the member, and in the nature of the primary bedding structures within the constituent lithologies (Haase et al., 1985; Haase, 1982, 1983).

Shales and mudstones from throughout the Pumpkin Valley Shale contain 75 to 95% clay-sized material composed of illite/vermiculite + illite $\pm$ kaolinite $\pm$ chlorite + quartz. The shales typically contain 5 to 25% silt-sized material composed of detrital quartz, plagioclase and potassium feldspars, muscovite, and biotite. The mudstones contain up to 5% silt-sized material and have the same clay mineral assemblage as do the shales (Haase 1982, 1983).

Deformation features are ubiquitous in the Pumpkin Valley Shale. Joint sets, fractures, folds, and faults occur throughout the shale (Ossi, 1979; Sledz and Huff, 1981). At least two and, locally, as many as four joint sets have been identified (Sledz and Huff, 1981). All of these can be related to major structures, such as the Copper Creek thrust fault or specific folding events. Joint spacing, length, and density are variable within lateral distances of several hundreds of meters

Small-scale folds and faults are common throughout much of the Pumpkin Valley Shale. Folds have amplitudes of 0.5 to 3 m (1.5 to 10 ft) and are tight and rarely isoclinal. Many folds are associated with small-scale faults that occur throughout the shale. Such fault zones are 0.1 to 3 m (0.3 to 10 ft) thick and typically have nearly vertical dips, although lower-angle faults have been observed (Haase et al., 1985; Sledz and Huff, 1981).

The hydrology of the ORNL hydraulic-fracturing subsurface injection facility site is complex and not understood in detail. Available data suggest that the subsurface groundwater regime consists of a shallow freshwater system and a deep saline system (Haase et al, 1985). The permeability (values typically less than 0.1 md) and porosity (values from less than 0.1 to 3.0%) of the Conasauga Group are low, and flow directions for much of the shallow groundwater system are influenced by structural fabric elements, such as joints and fractures (Sledz and Huff, 1981; Vaughan et al., 1982; Rothschild et al., 1985). The shallow groundwater system at the site extends to depths of 30 to 150 m (100 to 500 ft). Groundwater within this system is fresh, with TDS values less

than 5000 ppm. Within the upper portions of the zone of shallow fresh groundwater, at depths of less than 30 m (100 ft), the weathered portions of the Conasauga Group strata contain moderate amounts of groundwater. Below this depth, borehole geophysical logs suggest that fresh groundwater is increasingly confined to fracture and fault zones. At present, little is known about the behavior of groundwater at the bottom of the shallow zone.

The nature of the deep, saline groundwater system within the lower portions of the strata of the Conasauga Group is not known. Waters within this deeper system appear to be high-TDS fluids with chloride concentrations ranging from 100,000 to 120,000 ppm (Switek et al., in press). Because of the dramatic compositional differences between shallow and deep groundwaters, the deep system is thought to be largely separate from the shallow system. Details of possible coupling between the two systems are not known. By analogy with the shallow groundwater system, it is hypothesized that the flow directions of the deep system are largely controlled by the fracture permeability related to structural fabric elements.

Summary

Empirical data gathered largely from operational experience over the past 25 years at the ORNL site (Weeren, 1974, 1976, 1980, 1984) suggest that the Pumpkin Valley Shale has many of the necessary attributes required of a successful host formation. The formation fractures in a regular fashion so that injected grout sheets have predictable orientations and remain within the stratigraphic extent of the formation. The formation has low intrinsic permeability. The ambient groundwater in the formation is saline and therefore not in rapid communication with overlying freshwater groundwater systems. The mineralogy of the formation is an efficient sorption agent for some radionuclides, especially ^{137}Cs, that occurs in the ORNL waste.

Development of Monitoring Procedures

Monitoring Methods

A variety of techniques can be used to determine the location of a grout sheet. The most accurate method involves drilling a large number of boreholes to intersect the emplaced grout. Such a method, however, is expensive, time-consuming, and jeopardizes the ability of the site to geologically isolate future slurry injections. Therefore, it is desirable to consider other methods of determining the orientation and extent of the grout sheets. Methods being developed at ORNL entail both post-injection and real-time monitoring. Post-injection methods consist of gamma-ray logging of cased observation wells and accurate leveling of benchmarks in the vicinity of the hydrofracture facility. Real-time monitoring methods entail use of tiltmeters installed at the ground

surface and geophone arrays at the surface and in deep wells at the site. Stow et al. (1985) reported on these monitoring techniques.

When wastes are injected at 300 m (1,000 ft) depth, the ground surface undergoes slight, but measurable, deformation. (Davis 1983; Pollard and Holzhausen 1979) The shape and location of this ground deformation reflect the orientation and extent of the subsurface grout sheet. By accurately measuring the surface deformation, either during or after an injection, and comparing it to elastic models, the geometry and orientation of the subsurface sheet can be estimated.

Leveling Surveys

At ORNL, a series of 75 benchmarks has been installed along roads in a radial pattern up to 650 m (2000 ft) from the injection facility (Fig. 4). During eight bimonthly injections in 1982 and 1983, precise leveling surveys were made before and after each injection to determine the amount of surface deformation.

Systematic uplift patterns were observed after each of the injections. The uplift pattern from the October, 1983, injection is shown in Fig. 4. This pattern is representative of those associated with other injections, although the extent and shape of the surface deformations vary with each injection. For the October injection, the area of maximum uplift is offset by some 100 m (330 ft) to the southwest from the injection well and that the maximum uplift is over 2.5 cm (1 in). The uplift decreases in a fairly systematic way outward from the highest point and, although not shown in Fig. 4, extends beyond the 600-m (2,000-ft) limit of the benchmarks. The volume of the uplift significantly exceeds the volume of the injected grout.

The geometry of the uplift pattern indicates that the grout sheet spread to the north, which is in an updip direction. This orientation would be expected because the slurry should preferentially migrate in the direction of least lithostatic pressure, i.e., in an updip direction along bedding planes. Post-injection gamma-ray logging in the observation wells within 150 m (500 ft) of the injection well confirms the extension of the grout sheet in a northerly direction.

Thirty days after the October injection, the leveling survey was rerun; noticeable changes had occurred over this time period (Fig. 5), similar to those detected after other waste injections. The area of maximum uplift was found to correspond to the location of the downhole injection point and the maximum uplift had decreased to approximately 10 mm (0.4 in) in this area. The subsidence of the uplift after the injections is thought to result from a complex set of factors including an attempt toward mechanical relaxation of the stressed strata and dissipation of pressure following the injection. As noted later, microseismic signals continue for weeks after an injection. It is important to note that the volume of the uplift measured 30 days after an injection roughly corresponds to the volume of radioactive slurry injected.

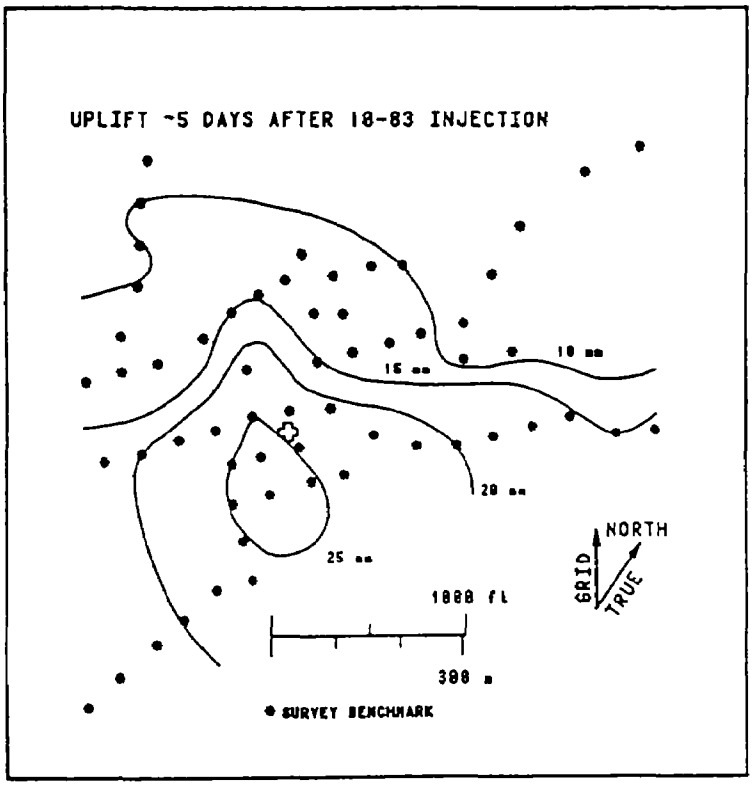

Figure 4. Net surface uplift immediately after the October 1983 waste injection at ORNL. The cross indicates the projected position at the ground surface of the injection point, some 300 m (1000 ft) below ground surface. Contour interval is 5 mm (0.4 in).

Tiltmeter Surveys

Tiltmeter measurements represent a monitoring technique that provides information on the ground deformation that occurs during and after an injection. (Evans and Holzhausen 1983; Riley 1961). Eight tiltmeters were installed in September 1983 in shallow wells at radii of 120 and 180 m (400 and 600 ft) from the injection point. Measurements were taken for the October and November injections and for the intervening period. The net ground deformation resulting from the October injection is shown in Fig. 5. The arrows indicate the vector tilt of the ground surface at each site. The length of each arrow is proportional to the amount of tilting, measured in microradians. The October injection covered two days. Tilt rates for the second day significantly exceeded those of the first day, suggesting a nonlinear response of the strata over the injection zone. The data reveal that

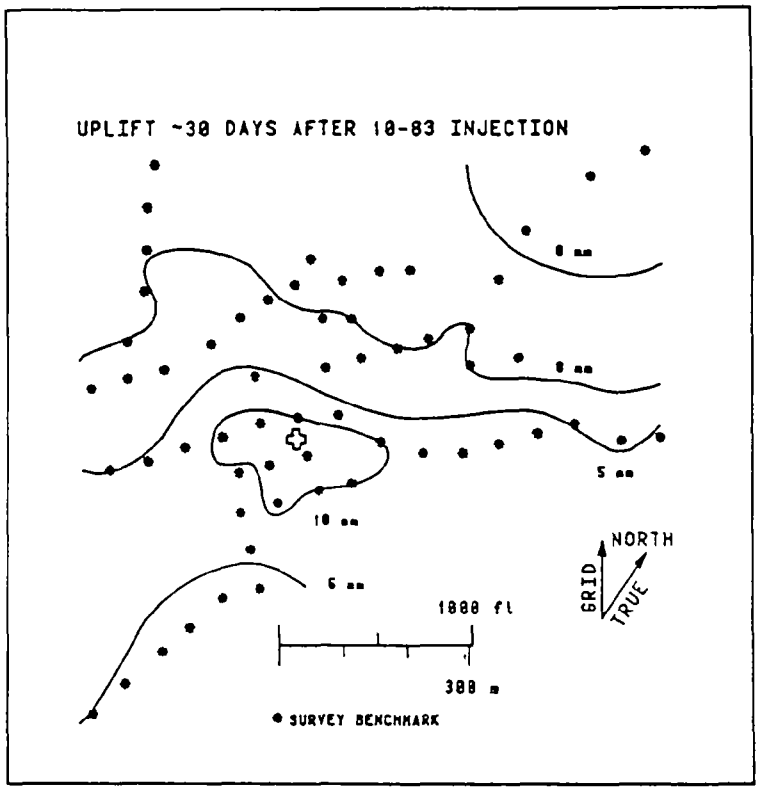

Figure 5. Net surface uplift 30 days after the October 1983 waste injection at ORNL. Map symbols are the same as in Figure 4.

maximum uplift is slightly north of the injection point. Elastic modeling of a purely dilatational fracture would suggest that this uplift pattern corresponds to a grout sheet that propagated upward and to the south (Davis 1983). This result is obtained using both an isotropic elastic model and a transversely isotropic model in which rock stiffness parallel to bedding is five times greater than stiffness perpendicular to bedding. This conclusion does not, however, agree with that drawn on the basis of leveling surveys and on the gamma-ray logging of observation wells.

A possible explanation for this northward shift of the center of uplift may be related to shear induced in the hydraulic-fracture plane during grout injection. Horizontal crustal compression in the Oak Ridge area should induce an in-plane shear component because the grout sheets are inclined to this inferred principal stress direction. In-plane shear on a southward-dipping fracture would result in maximum uplift to the north of the injection well. When added to the uplift caused by

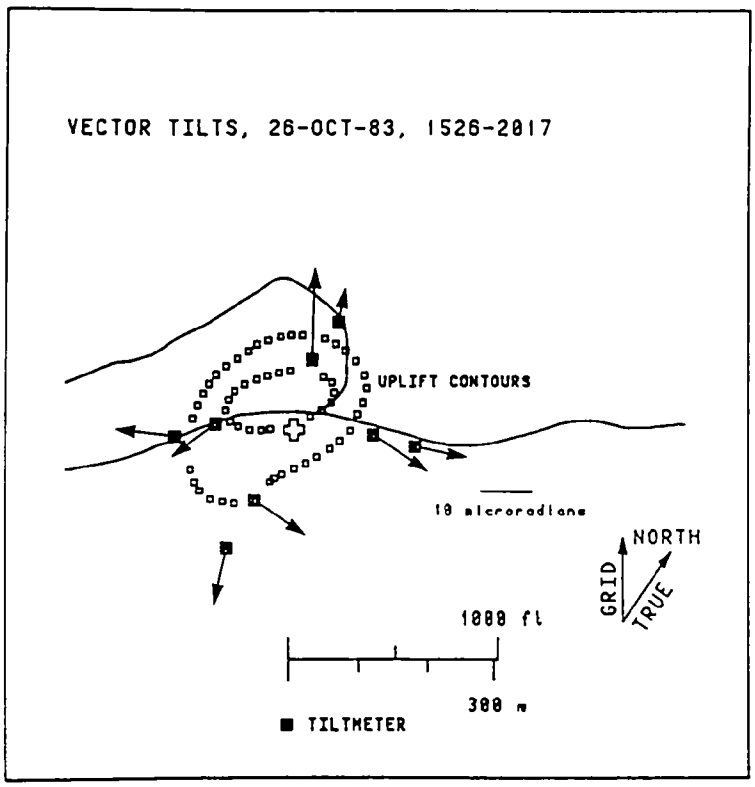

Figure 6. Net ground tilting resulting from the October 1983 waste injection at ORNL. The arrows for each tiltmeter represent the net vector of tilt measured in an X and Y direction. Solid lines represent roads. Other map symbols are the same as in Figure 4.

fracture dilation, the net tilt would resemble that measured during the October and November 1983 injections. A more complete discussion of the interpretation of the tiltmeter data are found in a recent article by Holzhausen et al. (1985).

Tiltmeter data were also gathered between the October and November injections. Figure 7 shows the net tilt change for the first eight days of this period. Vector directions indicate that subsidence occurred, an observation that corresponds closely with the results of the leveling surveys (Fig. 5). Apparently, this subsidence caused a shift in the center of uplift from slightly north of the injection point to slightly south of the injection point.

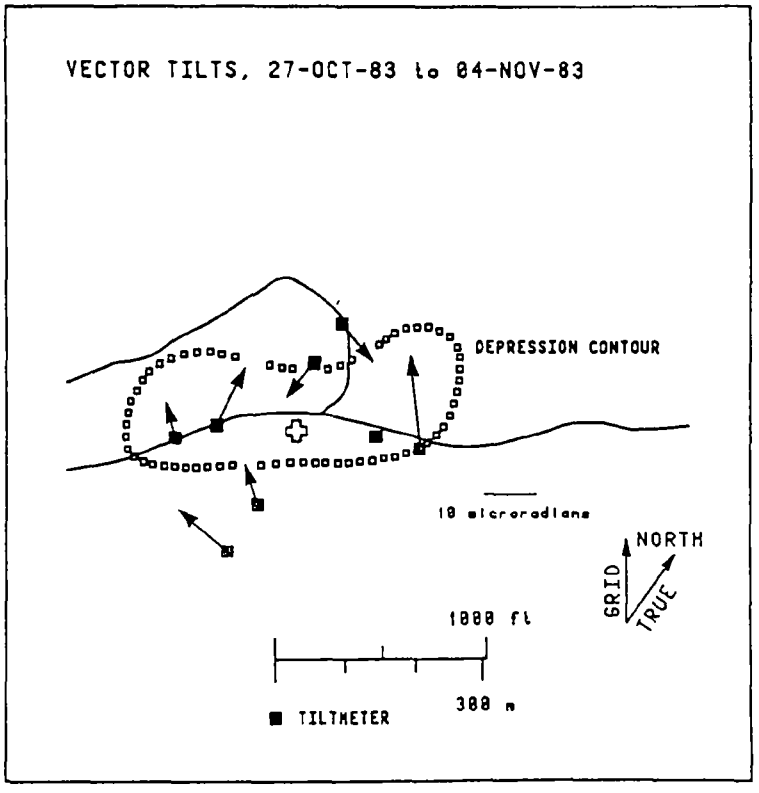

Figure 7. Net ground tilting during an eight-day period following the October 1983 waste injection at ORNL. Map symbols are the same as in Figures 4 and 6.

Because the tiltmeter data are acquired on a continuous basis, it is possible to monitor ground deformation in real time during an injection. During the October and November injections, it was observed that surface deformation patterns changed continuously with time and that areas of maximum deformation shifted frequently. These observations suggest that the injected grout sheet forms in a discontinuous fashion as lobes that are extended in different directions at different times during an injection.

In evaluating their use for monitoring, it is important to note the sensitivity of the tiltmeters. The instruments used during the October and November injections can resolve 5 nanoradians (5×10^{-9} radian) of movement. On October 25, fracture initiation was caused by injection of a few thousand liters of water at the 300-m (1,000-ft) depth; tilting was immediately detected. Cessation of tilting was noted immediately when injections were ceased, and a slight reversal of tilt was noted between the night of October 25 and the morning of October 26. These data indicate that tiltmeters are a very sensitive indicator of surface deformation associated with subsurface injections. With appropriate modeling of the data, tiltmeters may represent a feasible method of real-time monitoring of the orientation and extent of the grout sheet.

Microseismic Monitoring

It was anticipated that detection of microseismic signals resulting from a propagating fracture might provide a basis for determination of the location and rate of formation of the fracture and for the failure mechanism by which the fracture propagates. Three geophone arrays were used; two high-frequency (20-250 Hz) arrays were placed 125 to 180 m (415 to 600 ft) down in drillholes overlying the injection zone. The geophones were "sanded into" the wells to ensure good transmission of signals from the rock. A third array was placed at the ground surface. Low-frequency (0.03 Hz) signals were also recorded with a surface-mounted vertical component seismometer.

Numerous microseismic events occurred during the injection; most represent shear failure associated with stress field changes in the rock envelope surrounding the fracture. Few tensile events--those that could be created by bedding plane opening--were detected. Long-period events occurred throughout the injection and correlated closely with slight decreases in pumping pressure. Events also were noted for days after an injection ceased, suggesting that a physical readjustment of the slurry and/or overlying strata was taking place. These post-injection events gradually decreased with time.

Mapping the fractures as they form has not been successful to date. The chief reason for this is that the events associated with fracture propagation are of very low energy and geophones must be close to the fracture for detection of the events. In the case at ORNL, the geophones were over 100 m (330 ft) above the fracture; most of the energy from the fracturing apparently was absorbed by the intervening strata.

Overview

There is considerable work yet to be done on development of monitoring techniques, especially those that provide real-time data during an injection. The two methods that do provide such data (tiltmeter, microseismic) show promise; of the two, the tiltmeter method appears to be better developed at present. Stow et al. (1985) provide more detail on the relative evaluation of the techniques. While it is anticipated that future subsurface disposal operations may require installation of real-time monitoring systems, direct techniques, such as gamma-ray logging, will probably also be required.

Federal and State Regulations

Comparison of ORNL's Injection Process with Other

It has recently been determined that ORNL's subsurface injection facility is regulated by federal and state statutes. These are the EPA UIC Program (40 CFR 124, 144, 146, 147) and the State of Tennessee UIC regulations of the Water Quality Control Board (Chapter 1200-4-6).

Although the state regulations are more stringent than the federal ones, Tennessee does not yet have primacy. Both of these statutes were written for the more commonly practiced subsurface injection techniques rather than for the ORNL process.

It is important to compare the ORNL process with those for which the legislation was written because there are significant similarities and differences. Such aspects as the intent to prevent contamination of potable groundwater, the desire for high integrity of the injection well, and monitoring of the injection operations represent facets where the legislation is in full concert with the ORNL process. However, a number of characteristics of the ORNL process make it apparent that the legislation was written for injection operations radically different from that at ORNL (Table 1). [redacted]

Table 1

Comparison of the ORNL Subsurface Injection Well with Other Types of Injection Wells

Factor	ORNL	Others
Waste Form	Solid-cement	Liquid
Waste Fate	Isolated, retarded	Diluted
Host Stratum	Aquitard	Aquifer
Porosity	Created by Fracturing	Natural
Structure of Host	Dipping	Horizontal
Volume of Waste	Small	Large
Frequency	One-two Years	Continuous

[redacted]. Most hazardous waste injection operations do not operate at pressures sufficient to fracture the host strata because the strata have inherent high porosity and permeability. [redacted]

Well Classification

[redacted] established. [redacted] In all likelihood the well would be Class I, except that the application of injection pressures sufficient to initiate fracturing at the host shale is not allowed for Class I wells. For obvious reasons, the well cannot be a Class II, III, or IV; thus a Class V assignment will probably be made.

Present Status

For a variety of reasons, it has been decided by the Department of Energy, for which ORNL works, that [redacted] Also, the status of Class I wells relative to the 1988 "hammer" clause in the RCRA has created significant uncertainty from a regulatory viewpoint as to the future of the facility.

Future Directions

Use of the Technique for Hazardous Wastes

[redacted] Because the operational aspects of the disposal operation are fairly routine, attention is directed here toward waste forms and carriers that are compatible with the injection process and typical host formations.

[redacted] For instance, chromium could be precipitated as a highly insoluble sulfate, or other transition metals might be fixed by chelating agents. [redacted]

[redacted] might prove to be chemically compatible with certain wastes and thus offer sufficient

waste isolation potential. Alternatively, [redacted] might be developed as waste forms and carriers that [redacted]

[redacted]

Need for Regulatory Reconsideration

As discussed previously in the regulatory considerations section, the subsurface injection of waste by the hydraulic-fracturing technique differs substantially from the technologies for which current regulations were adopted. For the merits of the hydraulic-fracturing techniques to be fully evaluated, some regulatory reconsideration must be granted. The need for regulatory reconsideration is reflected in the current "on hold" status of the facility at ORNL. It is hoped that after 1988 and resolution of the RCRA "hammer" clause decision for Class I wells, research on and progress toward permitting the hydraulic-fracturing subsurface injection technology can be resumed. Such action would be helped by expansion and/or modification of existing underground injection regulations. [redacted]

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Section 8.1.2

TITLE OF STUDY: (or SOURCE OF INFORMATION)	"Subclass 5N-Nuclear Waste Disposal Wells," From Underground Injection Control Class V Inventory
AUTHOR: (or INVESTIGATOR)	G. Koschal, K. Lambert, S. Sares
DATE:	March, 1987
FACILITY NAME AND LOCATION:	Uranium mill site Bluewater, New Mexico USEPA Region VI
NATURE OF BUSINESS:	Uranium Mill
BRIEF SUMMARY/NOTES:	The excerpt from New Mexico's Class V report discusses inventory, well construction and operating practices, and potential groundwater impacts. According to the report, the well is no longer in use and will present little potential impact on the groundwater resources when the well is properly abandoned.

SUBCLASS 5N - NUCLEAR WASTE DISPOSAL WELLS

7.1. Types of Subclass 5N Wells

One type of Subclass 5N well has been defined:

5N24. Radioactive Waste Disposal Wells - All radioactive waste disposal wells other than Class IV wells.

Wells in type 5N24 include wells that dispose of radioactive wastes below the lowest formation that contains an USDW.

7.2. Inventory

The UIC inventory identified one 5N24 well in New Mexico. This well is located at an uranium mill site (Figure 7-1) and was used to dispose of radioactive millstream wastes. The well was taken out-of-service in 1977 and was not regulated by EID or UIC regulations.

7.3. Well Construction and Operating Practices

The 5N24 well in New Mexico was drilled and put into service in 1960. The well was drilled to a depth of 2511 feet and bottomed in the Permian Abo Formation. The diameter of the drilled hole is 17 inches to 730 feet and 11 inches to TD.

The hole was plugged to 1830 feet, 6-5/8 316 stainless steel casing was set and the casing was perforated through the injection zone.

Uranium mill process wastes were injected from 1960 to 1977 at a average rate of 65,000,000 gallons per year. The waste stream contained a TDS concentration of 4060 ppm. Radioactive contaminants in the injected fluid were uranium, thorium, and radium.

The well was taken out-of-service in 1977 and mill wastes were diverted to surface ponds. The well was permanently plugged, but will be permanently abandoned under the closure plan for the mill. The procedure for abandoning the hole will be:

1. Circulate fresh water in the hole,

2. Set tremie pipe and inject cement to seal perforated

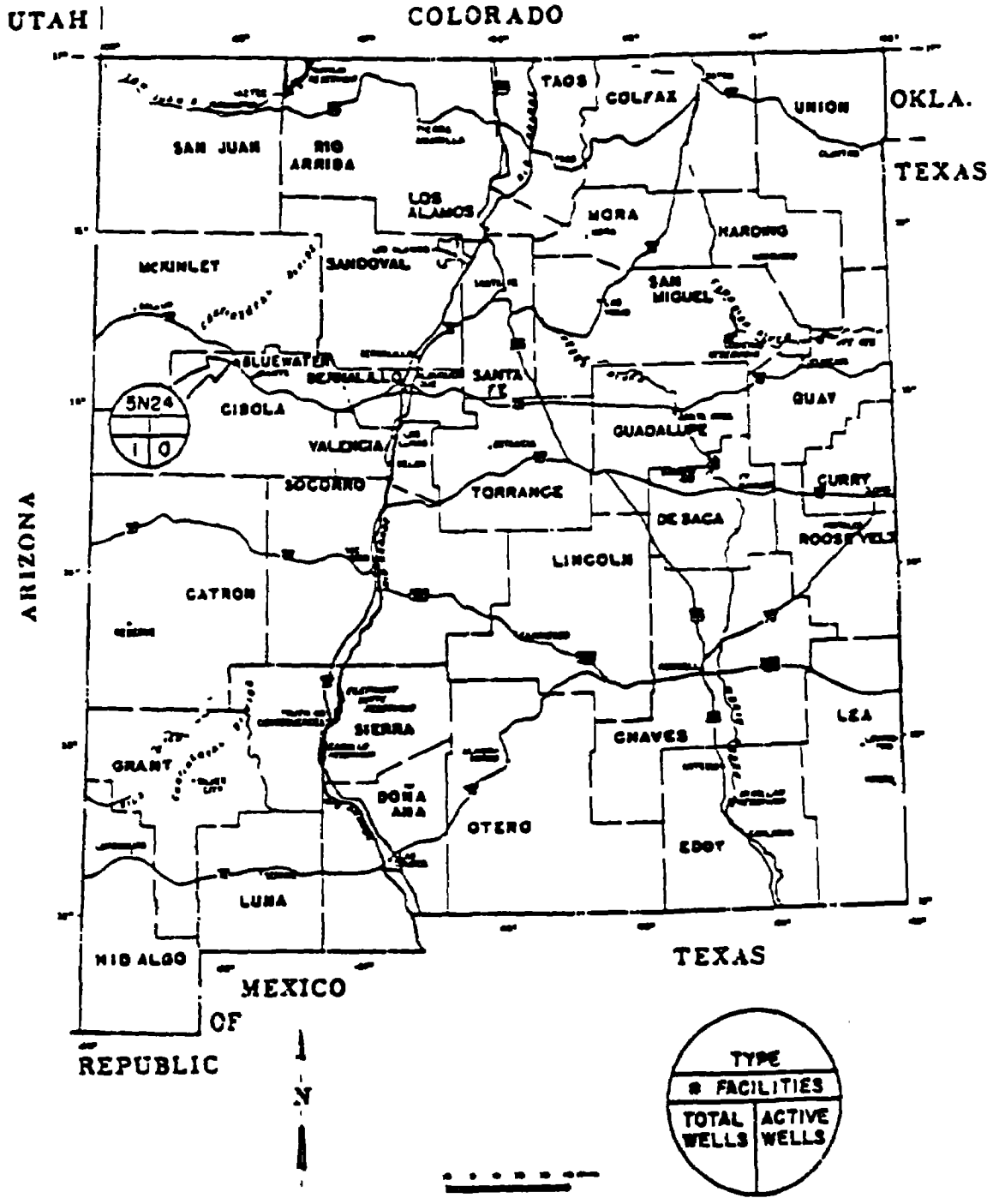

Figure 7-1 Location of Subclass 5N Well

zone,

3. Perforate casing at a depth of 900 feet,

4. Inject cement to surface.

7.4. Potential Ground Water Impacts

The ground water in the area of the injection well is in the Permian San Andres Formation. When the well is properly adandoned, there will be little potential impact on the ground water resources. The Mill tails and ponds present a much grater threat to ground water.

7.5. Conclusion

Subclass 5N wells are high priority wells in New Mexico. The WQCC regulations are adequate to regulate any new wells. The paucity of these wells in New Mexico allows these high prority wells to have only a minor impact on ground water.

Section 8.1.3

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	"Low-Level Radioactive Waste Disposal Well" From Idaho Assessment of Class V Wells
AUTHOR: **(or INVESTIGATOR)**	W.G. Graham, L.G. Campbell, I. Sather
DATE:	January, 1987
FACILITY NAME AND LOCATION:	Idaho National Engineering Laboratory Idaho USEPA Region X
NATURE OF BUSINESS:	Chemical Processing Plant
BRIEF SUMMARY/NOTES:	This excerpt from the Idaho Class V report describes well construction, quality and quantity of injected fluids, impact of nuclear injection practices on the receiving groundwater system, and alternatives. The description indicates that injection of chemical contaminants has not resulted in serious degradation in the quality of ground water.

LOW-LEVEL RADIOACTIVE WASTE DISPOSAL WELL (CLASS VN-24)

Introduction

The U.S. Department of Energy currently maintains one low-level radioactive waste disposal well at their chemical processing plant (ICPP) on the Idaho National Engineering Laboratory reservation. This well is maintained as a backup to the facility's service waste percolation pond disposal system, and is used only for short periods of time during system pump failures.

Well Construction

The ICPP well was initially drilled to 588 feet and was cased from 15 feet below land surface (bottom of well pit) to the well bottom with 12-inch diameter steel casing. The casing was perforated from 450 feet to 588 feet. The well was subsequently lined with 10-inch PVC pipe and backfilled to 520 feet in 1983. The well passes through roughly 40 feet of overburden, then penetrates basalts and associated sedimentary interbeds to the bottom of the borehole. Depth to ground water is approximately 440 feet.

Quality and Quantity of Injected Fluids

Considerable data are available defining the sources and quality of the ICPP service waste stream that would be injected with activation of the well. Sources of the waste stream include heat exchange condensate and cooling water, boiler blowdown, deionizer regeneration solutions, chemical makeup solutions, process equipment waste condensate, nonradioactive wastes from laboratory drains, and fluids from pilot plant drains. The overall quality is reported to meet the radiologic standards for release to an uncontrolled area (IDHW, 1981) and the chemical limits for characterization as nonhazardous waste under 40 CFR Part 261. However, concentrations of radiochemical contaminants, nitrate as nitrogen, and mercury are reported to exceed primary drinking-water standards, and therefore, the discharge quality standards of the Idaho Injection Well Regulations.

Approximately 136,000 gallons of fluid were injected in 1985. However, from January 1 to October 1, 1986, only one recharge event was conducted at which time 850 gallons were injected.

Impact of Nuclear Injection Practices on the Receiving Ground-Water System

Past injection well practices at the ICPP have resulted in the formation of a tritium plume within the Snake Plain Aquifer (Radioactive Waste Task Force, 1979). With continued full-time use of the injection well, the plume was predicted to reach the INEL site boundary by the year 2000. Other injected isotopes

are more susceptible to attenuation and are remaining near the point of injection. Concentrations of radioisotopes and radiation dosage limits in samples of ground water from the underlying plume are below the radiochemical maximum contaminant levels for drinking water.

Injection of chemical contaminants has not resulted in serious degradation in the quality of ground water. Maximum reported concentrations of nitrate-nitrogen in the ICPP service waste stream are roughly twice the drinking-water standard, and mercury concentrations are reported to occasionally exceed the drinking-water standard by up to a factor of ten. However, concentrations of these contaminants in samples from site monitoring wells have never been reported to exceed drinking-water standards.

Alternatives

Prior to the Radioactive Waste Task Force report in 1979, four injection wells were used on the INEL reservation for the disposal of low-level nuclear wastes. Three were subsequently abandoned and the fourth is maintained at the ICPP facility on standby for system backup. Current plans call for the eventual termination of all low-level nuclear waste disposal by injection.

Section 8.1.4

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	From Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Volume 3
AUTHOR: **(or INVESTIGATOR)**	Not Available
DATE:	March, 1986 (Environmental Impact Statement)
FACILITY NAME AND LOCATION:	Hanford Site Washington USEPA Region X
NATURE OF BUSINESS:	Irradiated nuclear fuels processing
BRIEF SUMMARY/NOTES:	This excerpt describes disposal of liquid, radioactive waste through a reverse well. According to the discussion, plutonium was introduced directly to the aquifer, but little migration has been observed. The 90 Sr and 137 Cs are more widespread. However, the zone of contamination around the reverse well appears to be stable with no apparent further migration of radionuclides.

V.5 REVERSE WELLS

One reverse well, 216-B-5, has been characterized (Smith 1980, 1981). The 216-B-5 reverse well is located approximately 370 m northeast of the 221-B (B-Plant) building in 200 East Area. Low-salt, alkaline, radioactive liquid wastes from cell washings were discharged to the 216-B-5 reverse well via the 241-B-361 settling tank. The reverse well was used from April 1945 to September 1947. The wastes were discharged to the settling tank and overflowed to the reverse well. The system was designed to remove particulate material from the waste before discharge to the reverse well and thus reduce the chance of plugging the well. The estimated waste inventory discharged to the 241-B-361 settling tank and 216-B-5 reverse well is reported in Table V.4.

TABLE V.4. Estimated Waste Inventory Released to the 241-B-361 Settling Tank and 216-B-5 Reverse Well (Hanson et al. 1973)

	Amount Discharged			Total Amount Discharged	Total Amount Decayed (1979)
	1945	1946	1947		
Volume, L	9.18×10^6	1.22×10^7	9.18×10^6	3.06×10^7	3.06×10^7
Pu, g	1.28×10^3	1.71×10^3	1.28×10^3	4.27×10^3	4.27×10^3
Beta, Ci	1.14×10^3	1.52×10^3	1.14×10^3	3.80×10^3	$<1.39 \times 10^2$
^{90}Sr, Ci	2.27×10^1	3.02×10^1	2.27×10^1	7.56×10^1	3.32×10^1
^{137}Cs, Ci	2.42×10^1	3.23×10^1	2.42×10^1	8.07×10^1	3.73×10^1
^{106}Ru, Ci	4.88×10^1	6.51×10^1	4.88×10^1	1.63×10^2	1.72×10^{-8}

The 216-B-5 reverse well was removed from service in September 1947 when a water sample from a well located 655 m north of the reverse well indicated the presence of alpha contamination in the groundwater. Two days later, the waste that was being discharged to the reverse well was rerouted to other waste disposal facilities. The monitoring well was resampled, and the results of this analysis indicated that the first analysis was incorrect and the groundwater in that area was not contaminated with radionuclides. Analyses of additional samples supported the results of the second water analysis.

The 216-B-5 reverse well was drilled using a telescoping casing technique; 40-cm-dia casing was installed to 4 m, 30-cm-dia casing to 31 m, 25-cm-dia casing to 74 m, and 20-cm-dia casing to 92 m. A diagram of the reverse well is shown in Figure V.14. The 20-cm-dia casing was perforated from the 74-m level to the bottom of the well, providing the means for distributing waste solutions into the surrounding sediments. Waste entered the reverse well at approximately 3.7 m below ground surface. A 1.3-cm-dia pipe (gageline) extended from the ground surface to within 15 m from the bottom of the well for the purpose of liquid-level measurements. The gageline served as a warning system to indicate that the reverse well was filling with liquid waste.

Drilling logs from other wells drilled near the reverse well indicated that the water table at the 216-B-5 reverse well was approximately 90 m, which indicated that the reverse well penetrated the water table and radioactive liquid wastes were discharged directly into the saturated sediments below the water table. These findings provided the impetus for a full-scale groundwater contamination investigation of the 216-B-5 reverse well from 1947 to 1950 (Brown and Ruppert 1948, 1950).

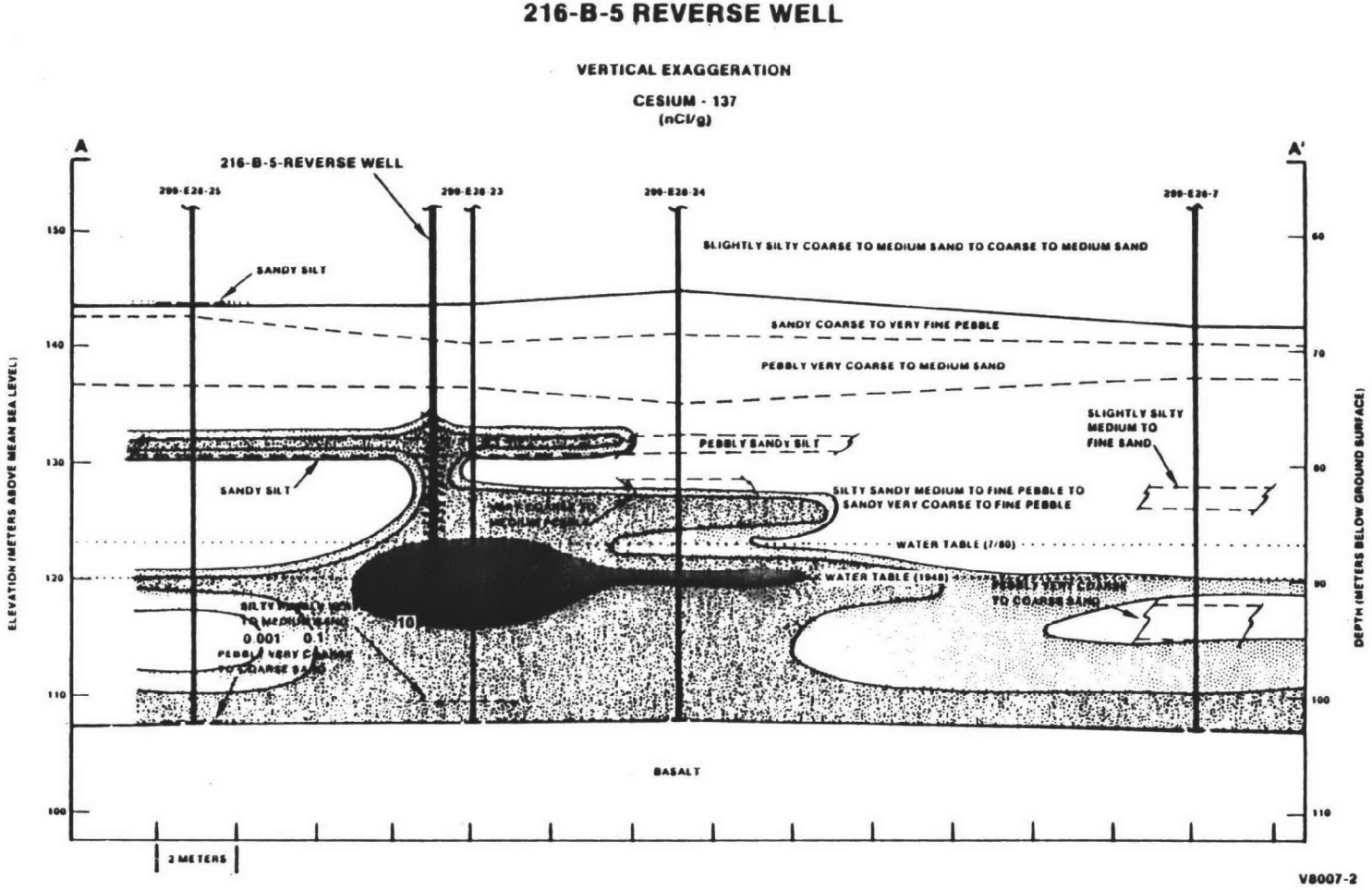

FIGURE V.16. Cesium-137 Distribution (Smith 1981)

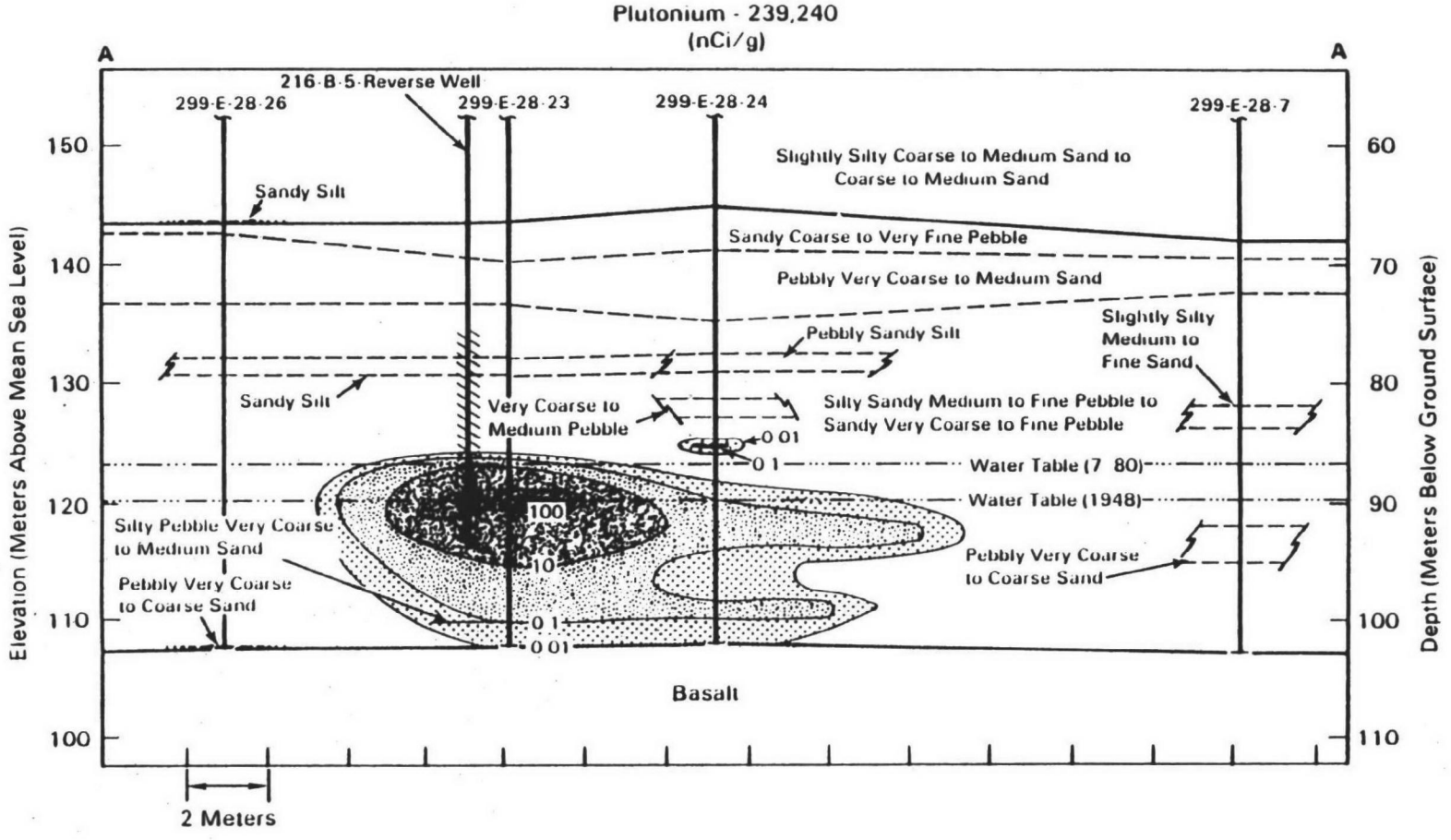

FIGURE V.17. Plutonium-239-240 Distribution (Smith 1981) (216-B-5 Reverse Well)

The major objectives of the study were to determine the spatial distribution of radionuclide contamination in the groundwater and to predict the direction that contamination would migrate if it moved at all. Eleven wells were drilled from November 1947 to May 1948. The wells were drilled 9 m into the saturated zone below the water table. Sediment and groundwater samples were collected at the time of drilling and were analyzed for alpha and total beta-gamma contamination.

Figure V.18 shows the distribution of ^{90}Sr. This distribution is similar to the other distributions in that it also shows the influence of the 1948 water table and direction of groundwater flow. The limited distribution of ^{90}Sr compared to ^{137}Cs was partially attributed to settling of ^{90}Sr in the 241-B-361 settling tank. Therefore, a larger portion of the ^{137}Cs inventory overflowed to the reverse well than the ^{90}Sr inventory.

In summary, although plutonium was introduced directly to the aquifer, little migration has been observed. The ^{90}Sr and ^{137}Cs are more widespread due to their increased mobility. However, the zone of contamination around the 216-B-5 reverse well appears to be stable, with no apparent further migration of radionuclides.

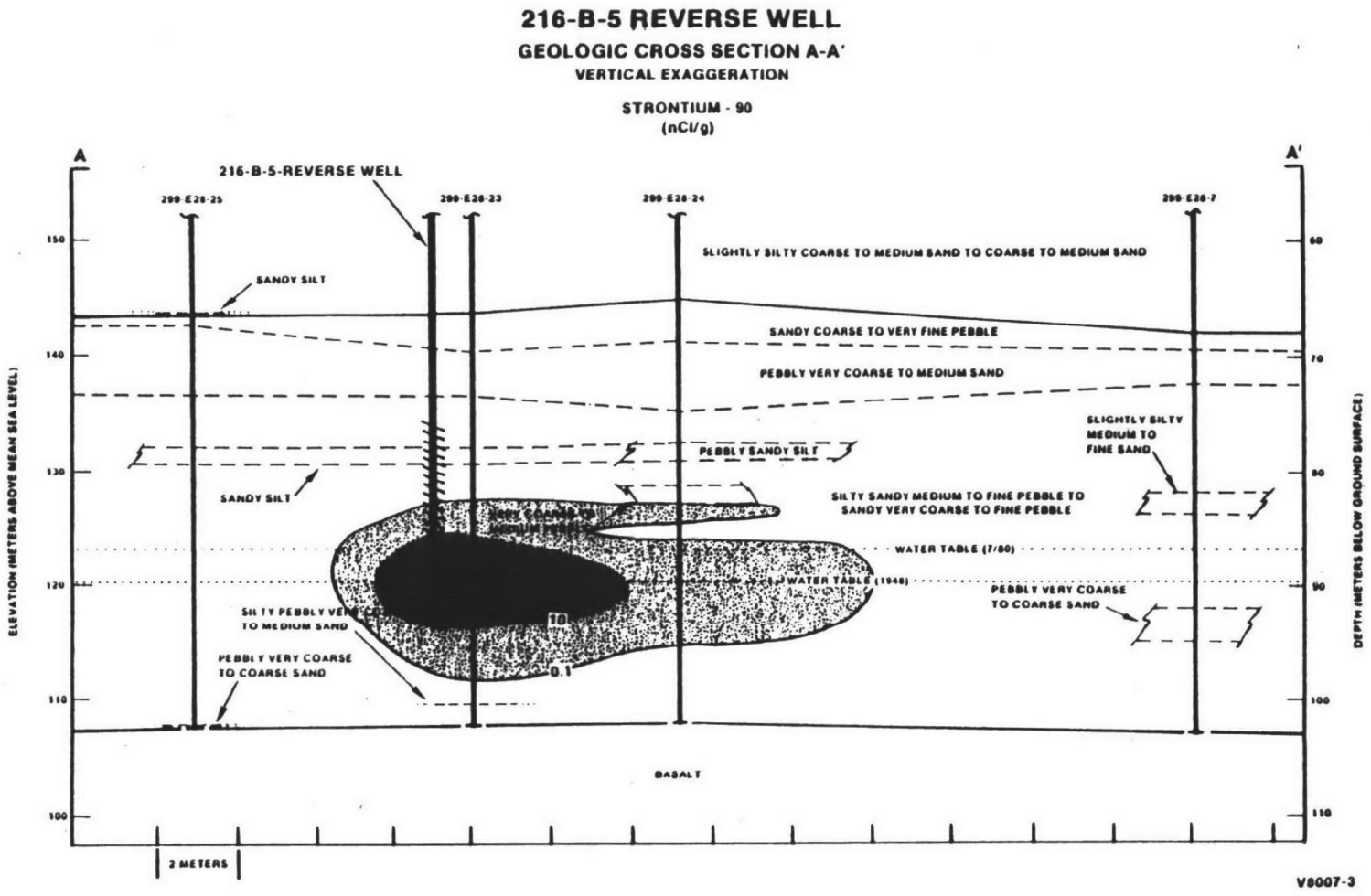

FIGURE V.18. Strontium-90 Distribution (Smith 1981)

Section 8.1.5

TITLE OF STUDY: (or **SOURCE OF INFORMATION**)	Report on Findings of NRC/EPA - Underground Injection Liaison Group; Radioactive Waste Injection and In-Situ Mining of Uranium
AUTHOR: (or **INVESTIGATOR**)	Underground Injection Liaison Group
DATE:	September, 1982
FACILITY NAME AND LOCATION:	Not Applicable
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	Radioactive waste injection and in situ mining of uranium are two areas in which there exist dual regulatory jurisdictions between the Nuclear Regulatory Commission and EPA. The report indicates that coordination between the areas should be done at the State or Regional level.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

file

OCT 2 0 1983

Mr. John Linehan, Section Leader
Operating Facilities Section
Uranium Recovery Licensing Branch
Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, MD 20910

Dear John,

Enclosed you will find a copy of the report of our last meeting as well as the memos that were used to let our Branch Chief and Office Director know about our findings. As you will notice, the final format has been changed for the sake of ease in processing. We hope this will not cause any problems. If, in the process of reporting on the group to your superiors, you see the need to modify the report, please let us know.

Paul Osborne, who is a liaison group member in our Denver office, has requested to be kept up to date on the negotiations with Wyoming. We formally request that you invite him to any and all meetings that take place in the course of negotiations with the State, and that you inform him and/or us of any significant developments in this matter. We would also appreciate if you follow the same pattern in any future negotiations with States. We will provide, at your request, the name of our Regional Representatives. We are sure that both your agency and ours will benefit from this arrangement. Paul's number is FTS 327-3914.

Thank you for your cooperation, and please do not hesitate to contact us if we can be of service.

Sincerely,

Jentai Yang, Chief
State Programs Implementation Section
(WH-550)

Enclosure

cc: Mario Salazar
Paul Osborne, Region VIII
Ron Van Wyck, Region VI

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DATE SEP 10 1982

BJECT Report on the NRC/EPA Underground Injection Liaison Group

FROM Thomas E. Belk, Chief
Ground Water Protection Branch (WH-550)

TO Victor J. Kimm, Director
Office of Drinking Water (WH-550)

Radioactive waste injection and in-situ mining of uranium are two areas in which there exist dual regulatory jurisdictions between the Nuclear Regulatory Commission (NRC) and EPA. In order to minimize the regulatory burden, representatives of this Branch and the Uranium Recovery and High and Low Radioactive Waste Branches of NRC have met. The main thrust of the meetings has been to find ways to coordinate the regulatory efforts.

After our last meeting on July 8, 1982, a consensus was developed. The group recommends the following (see attached report):

- Since there are only two States (Wyoming and Nebraska) that have a problem in the overlapping of authority between EPA and NRC programs, it is recommended that a State specific MOU can be worked out by the two agencies' Regional offices together with local authorities. A national MOU is not justified.

- An interagency agreement on radioactive waste injection is premature, since we do not have any engineering and construction standards for Class IV and V wells and the "President's Report" on radioactive waste is not complete.

- We will assist the States and/or Regional Offices in any coordination effort in the future. Communication channels will be kept open.

Attachment

EPA Form 1320-6 (Rev. 3-76)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

SEP 10 1982

MEMORANDUM

SUBJECT: NRC/EPA - Underground Injection Liaison Group Report

FROM: Mario Salazar, Environmental Engineer
Ground Water Protection Branch (WH-550)

TO: Thomas E. Belk, Chief
Ground Water Protection Branch (WH-550)

THRU: Jentai Yang, Chief
Criteria & Standards Section
Ground Water Protection Branch (WH-550)

Attached find the report narrating the final agreement which was reached with the Nuclear Regulatory Commission (NRC) on common jurisdictional areas.

Summary

Due to the fact that problems are foreseen in only one State, the group feels there is no need for a MOU at the national level. We recommend that any coordination be done at the State or Regional level. It has also been agreed that any coordination needed for Class IV and V wells used for disposal of radioactive waste be delayed until regulations are promulgated and/or the President's Report comes out.

Attachment

Report on Findings of NRC/EPA-Underground Injection Liaison Group; Radioactive Waste Injection and In-Situ Mining of Uranium

The second meeting of the NRC/EPA-Underground Injection Liaison Group took place on July 8, 1982, at the offices of the Nuclear Regulatory Commission (NRC) in Silver Spring, Maryland. Present at the meeting were:

John Linehan	Uranium Recovery, NRC
Jentai Yang	Ground Water Protection, EPA
Cindy Bryck	Uranium Recovery, NRC
Frederick Ross	Uranium Recovery, NRC
Mario Salazar	Ground Water Protection, EPA
Kitty Dragonette	Low Level Waste Licensing, NRC
Dan Fehringer	High Level Waste Licensing, NRC
Georgia Callahan	Permits Division, EPA

The first item on the agenda was to try to assess high and low level radioactive waste responsibilities in the Underground Injection Control (UIC) Program. Ms. Dragonette and Mr. Fehringer were briefed on the UIC requirements for Class IV and V wells, and the fact that there are very few regulations to control these facilities. They were also given the briefing material in Attachments A, B and C. It was assessed that at the present time, due to the lack of regulations by EPA on radioactive waste injection, there was no need for coordination in these areas. It was agreed that as soon as EPA promulgates regulations and/or a general national policy is developed (i.e., President's report on radioactive waste), coordination meetings will take place. John Linehan explained that bleed-off liquid from in-situ processes comes under his jurisdiction. Mr. Fehringer requested that EPA speak with a single voice at that time. Soon thereafter, Mr. Fehringer and Ms. Dragonette left the meeting.

The meeting resumed with Mr. Salazar explaining the distributed paper titled "Considerations for NRC/EPA Coordination." This is an option paper which indicates that significant problem occurs when only one of the programs has been delegated to the State (see Attachment "C"). Mr. Linehan, at the probing of Dr. Yang, indicated that presently this is the case in only two States, Nebraska and Wyoming. These two States will take delegation of the UIC Program only. Nebraska used to be an "agreement" State for uranium recovery, but decided recently that it was cheaper to let NRC implement the program (see Attachment "D"). In any case, Nebraska is in the process of reaching an

understanding with NRC to make sure that a double jurisdictional problem is solved in the State. NRC believes that the State is acting in good faith and does not foresee any problem.

The case of Wyoming is different. Mr. Linehan informed tne group that the State is asking NRC to change its regulatory approach and treat Wyoming differently from the other States. The State wants a tailor-made program before it will agree to any coordination effort. Talks are still taking place.

Mr. Linehan also pointed out that exploration for uranium, in which in-situ leaching may take place, will also be occurring in seven States. These States are Michigan, North Dakota, South Dakota, California, Nevada, Washington and Oregon. The work group agreed that it would be premature at this time to try to coordinate nationwide and establish an understanding for potential States. Instead it appears wise to wait for the resolution of the Nebraska and/or Wyoming impasse and use any agreement as the model for potential States.

Summary

The following points were discussed and resolved as shown:

- Any attempt for EPA to initiate talks with the High and Low Level Waste Divisions of NRC is premature since the UIC Program does not have complete regulations for Class IV and V wells.

- Only two States are at a critical stage right now - Wyoming and Nebraska.

  - Talks are taking place to solve the impasse with Wyoming. No agreement is forthcoming.

  - Nebraska is not seen as a problem. NRC has reached an informal accommodation with State.

- Seven States are engaged in exploration and may use in-situ mining (Michigan, North Dakota, South Dakota, Californa, Nevada, Washington and Oregon).

  - The market of uranium is depressed.

  - It would be premature to try coordination at this time.

- It would be wise to wait for the results of the negotiations between NRC and Wyoming or Nebraska before deciding upon a national policy.

Recommendation

Due to the very limited universe at the present time, the work group does not recommend a national agreement. We do recommend sending this document along with the other working papers (Attachments A, B, C and D) to the EPA and NRC Regions involved. The EPA and NRC Regional Offices can then negotiate agreements to solve the double jurisdictional problems on a case-by-case basis. The group would be available to assist the Regional Offices and will meet as needed.

Attachments

Underground Injection Control(UIC) Requirements
for Radioactive Material Wells

° Two basic areas

1. Injection of radioactive waste:

   ° Class V wells when injecting radioactive waste below an USDW (§146.51(b));
   ° Class IV when injecting above or into an USDW.

2. In-situ mining of Uranium:

   ° Class III wells;
   ° May be done in an USDW, after exemption (§§146.04, 122.35).

° Requirements for Class V radioactive wells:

- Operator has to report within one year (§146.52(a));
- Well assessment in three years (§146.52(b));
- Financial respnsibility;
- Penalties for enforcement;
- Ability of regulatory agencvy to reagulate by rule (§122.37);
- Ability to require a permit when the well may affect health and the environment (§122.37(b)).

° Requirements for Class IV radioactive wells:

- Mainliners --
  ° Prohibition in six months (§122.36(a);
- Non-mainliners--
  ° Authorized by rule until six months after regulations are approved or promulgated (§122.37(a)(3);
  ° Regulations reserved (40 CFR 146 E);
  ° Quarterly non-compliance reports (§122.18(a);
  ° May be permitted after regulations are approved or promulgated (§122.18(a);
  ° Subject to 40 CFR §122.45, requirements for wells injecting hazardous waste;
- Wells also subject to RCRA regulations;

° Requirements for Class III wells (In-situ mining of Uranium)

- Authorized by rule for up to five years (§122.37(a)(1));
- Permits must be issued in the five year period (§122.37(a)(1));
- Construction requirements (§146.32)--
  - Cased and cemented to prevent migration into or between UDWs;
  - Appropriate logs should be conducted during the drilling;
  - Other tests must also be performed to test integrity;
  - Parameters to be determined concerning the injection zone are fluid pressure, fracture pressure and physical and chemical characteristics of formation fluids;
- Demonstration of mechanical integrity at least once in the life of the well--
  - No leaks in the casing (§146.08(b)
  - No movement along the borehole (§146.08(c)
- Area of Review (146.06--
  - Radious of endangerment determination by formula (§146.06(a) or,
  - Fixed radious of endangerment at least 1/4 of a mile (§146.06(b)).
- Corrective action in the area of review (§146.07);
- Financial responsibility, plugging and abandonment (§146.10).

SOME HELPFUL DEFINITIONS

Well means a bored, drilled or driven aft, or a dug hole, whose depth is eater than the largest surface mension.
Well injection means the subsurface placement of fluids through a bored, illed or driven well, or through a dug ell, where the depth of the dug well is eater than the largest surface mension.

Radioactive Waste means any waste uch contains radioactive material in ncentrations which exceed those ted in 10 CFR Part 20, Appendix B, ble II column 2.

Underground source of drinking water SDW) means an aquifer or its portion:
1)(i) Which supplies any public water stem; or
(ii) Which contains a sufficient antity of ground water to supply a blic water system; and
(A) Currently supplies drinking water human consumption; or
(B) Contains fewer than 10,000 mg/l tal dissolved solids; and
(2) Which is not an exempted aquifer.

Classification of injection wells.

Injection wells are classified as lows:
a) *Class I.*

(1) Wells used by generators of azardous waste or owners or operators f hazardous waste management acilities to inject hazardous waste eneath the lowermost formation ontaining, within one quarter (¼) mile f the well bore, an underground source f drinking water.

(2) Other industrial and municipal posal wells which inject fluids eath the lowermost formation ntaining, within one quarter mile of well bore, an underground source of inking water.

(b) *Class II.* Wells which inject fluids:

(1) Which are brought to the surface in connection with conventional oil or natural gas production and may be commingled with waste waters from gas plants which are an integral part of production operations, unless those waters are classified as a hazardous waste at the time of injection.

(c) Class III. Wells which inject for extraction of minerals including:

(1) Mining of sulfur by the Frasch process;

(2) *In situ production of uranium or* other metals. This category includes only in-situ production from ore bodies which have not been conventionally mined. Solution mining of conventional mines such as stopes leaching is included in Class V.

(3) Solution mining of salts or potash.

(d) Class IV

(1) Wells used by generators of hazardous waste or of radioactive waste, by owners or operators of hazardous waste management facilities, or by owners or operators of radioactive waste disposal sites to dispose of hazardous waste or radioactive waste into a formation which within one quarter (¼) mile of the well contains an underground source of drinking water.

(2) Wells used by generators of hazardous waste or of radioactive waste, by owners or operators of hazardous waste management facilities or by owners or operators of radioactive waste disposal sites to . . . dispose of hazardous waste or radioactive waste above a formation which within one quarter (¼) mile of the well contains an underground source of drinking water.

(3) Wells used by generators of hazardous waste or owners or operators of hazardous waste management facilities to dispose of hazardous waste, which cannot be classified under §§ 146.05(a)(1) or 146.05(d) (1) and (2) (e.g. wells used to dispose of hazardous wastes into or above a formation which contains an aquifer which has been exempted pursuant to § 146.04)

(e) Class V—Injection wells not included in Class I, II, III, or IV. Class V wells include:

(1) Air conditioning return flow wells used to return to the supply aquifer the water used for heating or cooling in a heat pump.

(2) Cesspools including multiple dwelling, community or regional cesspools, or other devices that receive wastes which have an open bottom and sometimes have perforated sides. The UIC requirements do not apply to single family residential cesspools nor to non-residential cesspools which receive solely sanitary wastes and have the capacity to serve fewer than 20 persons a day.

(3) Cooling water return flow wells used to inject water previously used for cooling.

(4) Drainage wells used to drain surface fluid, primarily storm runoff, into a subsurface formation.

(5) Dry wells used for the injection of wastes into a subsurface formation.

(6) Recharge wells used to replenish the water in an aquifer.

(7) Salt water intrusion barrier wells used to inject water into a fresh water aquifer to prevent the intrusion of salt water into the fresh water.

(8) Sand backfill and other backfill wells used to inject a mixture of water and sand, mill tailings or other solids into mined out portions of subsurface mines whether what is injected is a radioactive waste or not.

(9) Septic system wells used to inject the waste or effluent from a multiple dwelling, business establishment, community or regional business establishment septic tank. The UIC requirements do not apply to single family residential septic system wells, nor to non-residential septic system wells which are used solely for the disposal of sanitary waste and have the capacity to serve fewer than 20 persons a day.

(10) Subsidence control wells (not used for the purpose of oil or natural gas production) used to inject fluids into a non-oil or gas producing zone to reduce or eliminate subsidence associated with the overdraft of fresh water.

(11) Radioactive waste disposal wells other than Class IV.

(12) Injection wells associated with the recovery of geothermal energy for heating, aquaculture and production of electric power.

(13) Wells used for solution mining of conventional mines such as stopes leaching.

(14) Wells used to inject spent brine into the same formation from which it was withdrawn after extraction of halogens or their salts.

(15) Injection wells used in experimental technologies.

(16) Injection wells used for in situ recovery of lignite, coal, tar sands, and oil shale.

Mainliners are class IV wells that inject into a USDW.

Non-mainliners are class IV wells that inject above a USDW.

EQUIREMENT	UIC PROGRAM (EPA)	URANIUM RECOVERY (NRC)
epermitting in five years	• 40 CFR Sec. 122.37(a)(1)	Regulatory Guide 3.46, Page VI 4th Par.
onstruction Requirements	• 40 CFR §146.32	R.G. 3.46; Information on Geology Ground-Water Quality, Isopachs, well logs, etc., can be compared with our requirements (pp. 3.45-1, 3.46-5, 3.46-6, 3.46-10)
quifer Exemption	• 40 CFR §§ 146.04, 122.35	No equivalent requirement could be made part of the license/permit requirement.
echanical Integrity	• 40 CFR §146.08 • No leaks in casing §146.08(b); • No movement §146.03(c); • Once for new wells §14 6.34(b)(2)	No equivalent requirement. Could be understood with repermitting every 5 years.
rea of Review	• 40 CFR §146.06	R.G. 3.46; Page 3.46-3, Section 2.2(7). It requires information on well of public record in a 1/4 mile radius.
emedial Action	• 40 CFR §146.07	No equivalent requirement; it could be introduced as a condition for permit under ground-water protection.
Financial Responsibility— Plugging and Abandonment	• 40 CFR §122.42(g) • 40 CFR §146.10	On page 3.46-17 (Section 6) Information on Plugging in 6.1.e. No financial responsibilities are specified. Emphasis in restoration.
Monitoring Requirement	• Nature of injected fluids §146.33(b)(1) • Pressure volume/rate §146.33(b)(2) • Fluid level in injection zone 146.33(b)(4)	• Monitoring pressure and rates R.G. 3.46 Sec 3.3 (page 3.46-11) • GW monitoring RG 3.46 Sec 5.7.8a (pp. 3.46-16) • Monitoring wells guidance #WM-8102

REQUIREMENT	UIC PROGRAM (EPA)	URANIUM RECOVERY (NRC)
	• Monitoring wells in injection zone if 10,000 TDS and USDW §146.32(e). • Parameters monitoring wells §146.33(b)(4)-(5)	
Restoration Requirements	• Not specifically required.	Required especially in R.G. 3.46 Section 6.
Reporting Requirements	• Quarterly reporting §146.33 • Results of MIT §146.33(c)(2)	Not specified in R.G. 3.64 probably a condition in license.

JUN 22 1982

Considerations for NRC/EPA Coordination

C

DRAFT

BACKGROUND

NCR and EPA have been mandated to regulate overlapping areas of responsibility. These areas are the In-situ mining of Uranium and the disposal by injection of radioactive waste.

In order to minimize redundant permit/licensing, reporting requirements, etc., coordination efforts must take into consideration the following possible situations:

Case 1: A State has received or will receive delegation of both the EPA and NRC Programs.

Case 2: The State has received or will receive delegation of the EPA/UIC or NRC Programs.

Case 3: The State has not or will not receive delegation for either EPA/UIC nor NRC Programs.

The situation in each of thee cases will be different, and any "fix" may entail different solutions depending on the case. Another consideration is that the delegation of the NRC Program is not the same as of the UIC program. In general, NRC retains partial jurisdiction over some of its program elements more so than the EPA does.

CASES

Case 1

In this case, the State program should, in theory, be in compliance with the requirements for both programs. The operator of the injection facility would be regulated (directly) only by the State.

RECOMMENDATION

Confirm above assumption.

Case 2

This case could be the most difficult to coordinate due to the need to coordinate with three different parties NRC, EPA and the State. The development of the UIC State Programs is complete or almost complete, and the incorporation of the NRC requirements into the process could be rather difficult. The same problem could be present if the situation is reversed and a (UIC) direct implementation State has opted for the NRC program delegation.

Operators of injection wells for In-situ mining of Uramium and radioactive waste disposal could be subject to two distinct regulatory processes. Under the best of circumstances, coordination between the three parties involved may result in the implementation of a program more encompassing than either program.

RECOMMENDATION

An agreement be reached, on a case by case basis, in which the State takes the lead in the regulation of these two injection practices. The agency with the mandate for direct implementation would be authorized concurrence veto power. A drop dead time limit for concurrance could be set to coincide with the State's framework. Key personnel, from States in this category should be incorporated into the coordination work group in order to establish direct communication with the State.

Case 3

Where neither NRC nor EPA have been able to delegate a program, the solution could be a simpler one. Even though the programs are different, the incorporation of some additional requirements should not represent a problem in the implementation of the program in such a limited universe.

RECOMMENDATION

An agreement be reached for either the NRC or EPA to take the lead with the other Agency authorized a concurrance/veto power, and a drop dead deadline established. The State should be encouraged to participate in any such agreement.

409.28/JJL/82/06/11/0

- 1 - JUN 16 1982

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REBrowning
JBMartin
MHaisfield
W Kerr-SP

WMUR:JJL
409.28

MEMORANDUM FOR: Ross A. Scarano, Chief
Uranium Recovery Licensing Branch

FROM: John J. Linehan, Section Leader
Operating Facilities Section I

SUBJECT: JUNE 8, 1982 MEETING BETWEEN NRC AND NEBRASKA DEPARTMENT OF ENVIRONMENTAL CONTROL (NDEC)

Purpose: Develop a mechanism for coordinating reviews of uranium solution mining operations by NRC and Nebraska.

Attendees:

NRC

John Linehan	Uranium Recovery Licensing Branch	301-427-4642
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Background

Earlier this year, the Governor of Nebraska requested that NRC reassert authority over that portion of Nebraska's Agreement with the NRC covering licensing of uranium milling and solution mining operations. However, Nebraska will still be involved in regulating uranium solution mining under

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the Underground Injection Control (UIC) permit program. Nebraska is presently working with EPA to assume UIC permitting authority from EPA. Because of the anticipated submittal of an application for an R&D uranium solution mining operation later this year, Nebraska officials want to set up a mechanism for coordinating their review of uranium solution mining operations with the NRC. Nebraska staff and J. Montgomery, NRC, Region IV, have had discussions on development of a Memorandum of Agreement (MOA) on uranium solution mining operations that led to the subject meeting.

Discussion

The meeting started with D. Drain discussing Nebraska's desire to develop a MOA with the NRC for coordinating licensing/permitting reviews of uranium solution mining operations. It was agreed by NRC and the state that the main purposes of a MOA should be to develop communication between technical staff, coordinate reviews, and avoid duplication of effort by both the regulatory agencies and applicants. It was agreed that for maximum effectiveness the agreement should be signed by the level of management directly responsible for permitting and licensing. This would be the Chief, Uranium Recovery Licensing Branch for NRC and the Director, Department of Environmental Control for Nebraska.

After discussion of the NRC license review process for uranium solution mining operations and applicable regulations, regulatory guides, and branch position papers, the attendees discussed the important points to include in a MOA:

1. Spell out State authority under UIC and NRC authority under Atomic Energy Act and UMTRCA.

2. MOA would not place any additional responsibilities or fiscal burdens on the State and the State may use NRC's technical evaluation to support its permitting actions under UIC.

3. Coordination and communication should be maintained at the staff level to provide for prompt and efficient licensing and permit review and avoid duplication of effort by the applicant and regulatory agencies.

4. Both agencies will share all relevant information from the applicant or other sources, as well as any technical evaluations performed by their staff.

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5. Agencies will coordinate public meetings and hearings and will provide written notice and ample time to the other agency to prepare for such meetings.

6. Both agencies will strive to agree on conditions of any permit or license to be issued and the type and amount of surety to cover groundwater restoration and surface decontamination and reclamation.

7. If either agency concludes that a meeting between the respective staffs of each agency is needed, both agencies will strive to arrange such a meeting.

The State agreed to develop a simple and brief, approximately 1 page, draft of an MOA, addressing the above points and send copies to J. Montgomery and J. Linehan for comment.

In the afternoon; J. Linehan met with C. Haberman and his staff to discuss the important geohydrological aspects of solution mining licensing and the proposed Wyoming Fuels solution mining project.

Original signed by

John J. Linehan, Section Leader
Operating Facilities Section I
Uranium Recovery Licensing Branch

... All attendees

WMUR						
JLinehan						
2/16/14						

Items to be included in a memorandum of agreement with EPA

1. Describe EPA authority under the Safe Drinking Water Act and NRC authority under the Atomic Energy Act and the Uranium Mill Tailings Act emphasizing areas of overlapping authority.

2. NRC & EPA will coordinate license and permit reviews.

3. Communication will be maintained at the staff level to provide for prompt and efficient licensing and permitting and to avoid duplication of effort by applicants and regulatory agencies.

4. The NRC agrees to make available to EPA technical evaluations and other relevant information to support permitting actions under UIC.

5. NRC & EPA will be flexible on the format of an application provided that all necessary information is submitted. This will allow industry to submit the same application to each agency.

6. NRC & EPA will strive to make all applicable licensing/permit conditions and requirements identical or at the least compatible.

7. The EPA and NRC will coordinate any public meetings and hearings.

Section 8.2

Experimental Technology Wells Supporting Data

Section 8.2.1

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Aquifer Thermal Energy Storage Experiments at the University of Minnesota, St. Paul, Minnesota, U.S.A.
AUTHOR: (or INVESTIGATOR)	Marcus C. Hoyer and Matt Walton, Minnesota Geological Survey
DATE:	Not Available
FACILITY NAME AND LOCATION:	University of Minnesota St. Paul, Minnesota USEPA Region V
NATURE OF BUSINESS:	Campus Steam Heating Plant
BRIEF SUMMARY/NOTES:	Four short-term and one long-term aquifer thermal energy storage experiments to examine the feasibility of storing water heated to temperatures from 100° to 150° C in a confined aquifer were conducted. Monitoring wells provided thermal and hydraulic response information about the aquifer and confining beds. Energy recovery from the experimental test cycles was approximately 60 percent, close to that predicted by a model.

AQUIFER THERMAL ENERGY STORAGE EXPERIMENTS AT THE UNIVERSITY OF MINNESOTA, ST. PAUL, MINNESOTA U.S.A.

Marcus C. Hoyer and Matt Walton
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ABSTRACT

Four short-term and one long-term aquifer thermal energy storage (ATES) experiments to examine the feasibility of storing water heated to temperatures from 100° to 150°C in a confined aquifer have been conducted at the University of Minnesota, St. Paul campus Field Test Facility (5 MW thermal). The facility uses a well doublet for supplying, storing, and recovering the heated ground water. Heat was supplied by the campus steam heating plant.

Wells are completed in the Franconia-Ironton-Galesville (FIG) confined aquifer, a highly stratified aquifer, which occurs at a depth of ~180 m, has a thickness of ~60 m and is under a static head of ~125 m. The aquifer consists of sandstone with interbedded shale and dolostone. Monitoring wells have provided thermal and hydraulic response information about the aquifer and confining beds.

Energy recovery during the four short-term cycles was 59, 46, 62, and 58 percent, respectively, of the energy added to the ground water during each cycle. Energy recovery during the long-term cycle was 62 percent of the energy added to the ground water during that cycle.

The ground water is a calcium-magnesium bicarbonate water having a hardness of about 12 grains. For the short-term cycles a precipitator was successfully used to prevent scaling in the storage well. An ion-exchange water softener was used for the long-term cycle. Water recovered from storage had approximately reached equilibrium with respect to calcium carbonate and quartz.

FIELD TEST FACILITY

AQUIFER THERMAL ENERGY STORAGE (ATES) experiments to examine the feasibility of storing water heated to temperatures from 100° to 150°C in a confined aquifer have been conducted at the University of Minnesota, St. Paul campus using heat from the campus steam heating plant. Four short-term experiments and one long-term experiment have been completed. In addition a series of isothermal pumping and injecting tests and related lithologic and water chemistry studies were made. Work was performed at the University of Minnesota as part of the U.S. Department of Energy, Underground Energy Storage Program through Battelle Pacific Northwest Laboratories (DE-AC06-76RLO 1830).

The University of Minnesota ATES Field Test Facility is a 5-MW thermal system using a well doublet for supply, storage, and recovery of the ground water. The system is designed to store heated water at a temperature of as much as 150°C at a rate of 18.9 l sec^{-1}. The facility is near the center of the Twin Cities graphic basin having several major aquifers and confining beds of Paleozoic age.

The facility consists of 1) two pumping/injection (source and storage) wells completed in the Franconia-Ironton-Galesville (FIG) aquifer; 2) nine (eight for short-term cycles) monitoring wells completed in the FIG aquifer, its confining beds, and the Jordan and Mt. Simon aquifers; 3) connecting piping, heat exchangers, and water conditioning (precipitator or softener) between the source and storage wells; and 4) piping to supply steam to heat the aquifer water (Fig. 1). For the short-term test cycles a precipitator was used to prevent scaling in the storage well. For the long-term test cycle an ion-exchange water softener was installed to prevent scaling in the heat exchangers and storage well.

SOURCE AND STORAGE WELLS - The source (B) and storage (A) wells are 255 m apart (Fig. 2) and completed with two screened intervals in the FIG aquifer opposite the more permeable hydrologic zones (Fig. 3). The upper 6-in. (0.15 m) diameter, 13.7-m section of 25-slot stainless-steel screen is opposite the upper portion of the Franconia Formation; the lower 22.9 m section of screen is opposite the entire thickness of the Ironton and Galesville Sandstones, as well as a small thickness of the lowermost Franconia and uppermost Eau Claire Formation. The 6-in. (0.15 m) diameter casing extends approximately 9.5 m into the 13-3/8-in. (0.34 m) K55 well casing where a packer adapts to the casing. The drilled hole below the casing is 12 in. (0.30 m) in diameter; a quartz gravel pack fills the annular space between the wellscreen and the rock face. The wells are constructed to accommodate or restrain the thermal expansion of the well casing during hot water injection. The constant-speed turbine pumps in each well are set at a depth of 154 m.

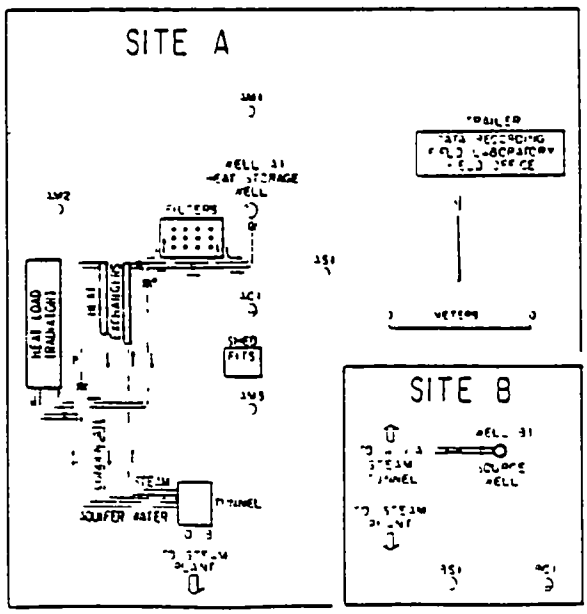

Fig. 1 - University of Minnesota St. Paul ATES field test facility during short-term test cycles

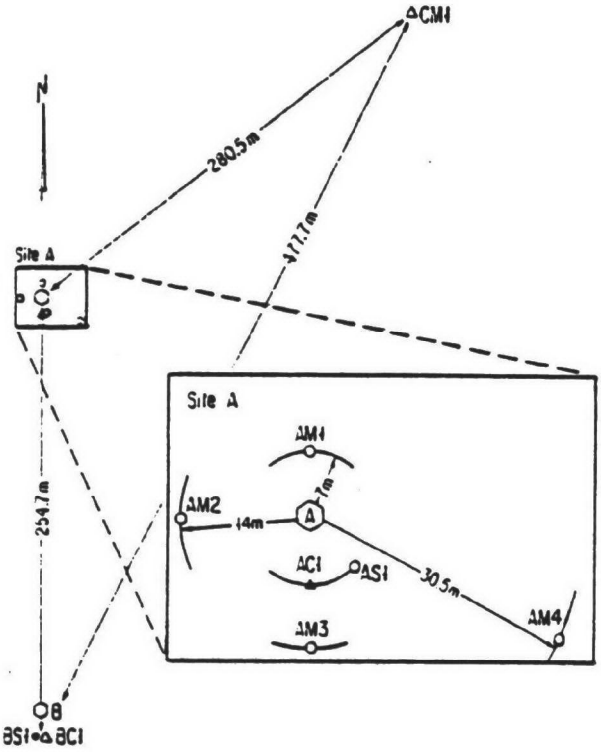

Fig. 2 - Well locations at the University of Minnesota ATES field test facility

MONITORING WELLS - The nine monitoring wells provide instrumentation for the full stratigraphic interval affected by the system. Temperatures and pressures (water levels) are measured at monitoring wells. Ground-water samples are collected for analysis from these wells. The wells are located at the storage site (Site A), the source site (Site B), and at a site beyond any thermal effects of test cycles, site C, which is located 280.5 m northeast of the storage well (Fig. 2).

Monitoring wells at the storage site, with the exception of AC1 which has not been used for monitoring because of problems in completion, all have multiple-pair, type-T thermocouple strings for monitoring temperatures in the FIG aquifer and confining beds immediately above and below (Fig. 4). A 0.9-m screen is installed in conjunction with each pressure transducer for monitoring water levels (pressures). At the source site, the monitoring wells have a thermocouple at the screened interval of the pipe used for observing water levels (pressures).

PIPING, HEAT EXCHANGERS AND WATER CONDITIONING - Piping between the wells, and from the campus steam plant, is routed through the steam tunnel which passes under sites A and B.

Heating of the aquifer water takes place in the two-pass tube and shell subcooler and condenser. The simulated heating load during recovery is a radiator.

After a preliminary attempt to conduct a short-term cycle with no water conditioning (1*), a precipitator was added to the system to protect the storage well (2). This precipitator is a fixed-bed reactor using

*Numbers in parentheses designate References at end of paper.

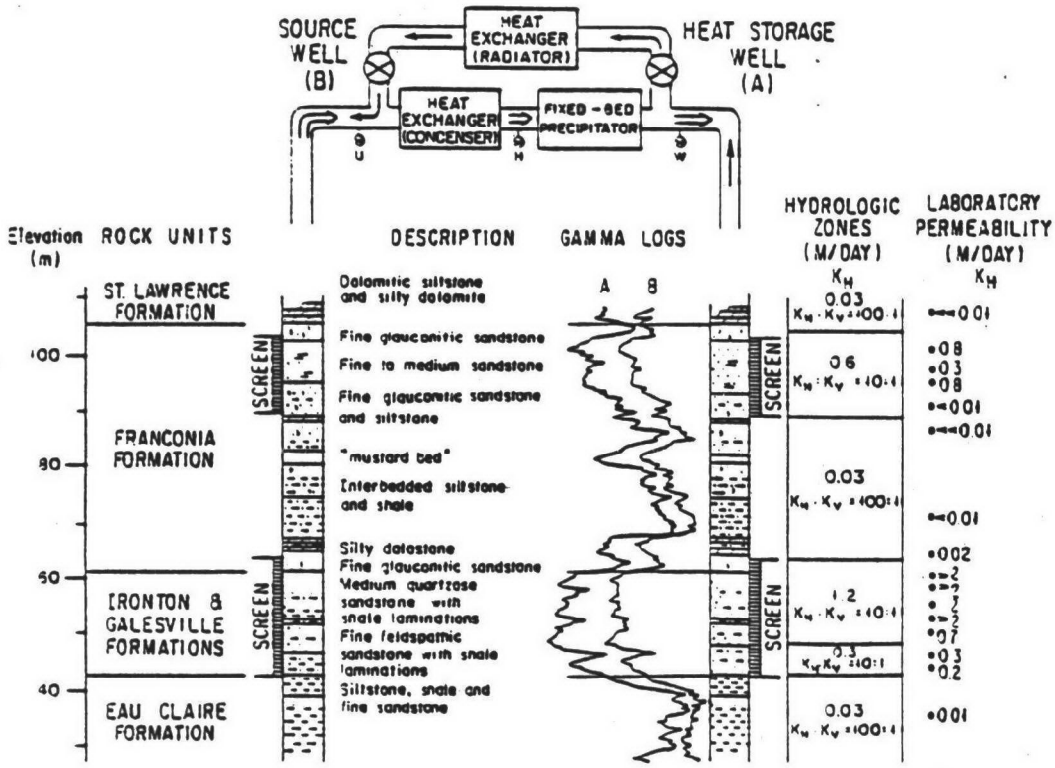

Fig. 3 - Flow diagram of ATES field test facility during short-term test cycles and lithologic and hydrologic units of the Franconia-Ironton-Galesville aquifer and confining beds

PERFORMANCE - The system performed according to its design capacity. During each period of injection, flows and temperatures of injected water decreased as head increased because the precipitator clogged and the condenser scaled (Fig. 6). Temperature of the injected water decreased because of the decreased efficiency of the condenser as scaling progressed. During cycles 2, 3, and 4, when a second precipitator allowing about 2 days of operation was available, an increase in flow took place when the switch to the fresh precipitator was made.

The temperature of the recovered water reached its maximum after about 12 hours of pumping. Because of the siltstone and shale interbeds and the slightly different artesian heads at the separate screened segments, there is a slow down-well flow during storage from the upper Franconia to the Ironton-Galesville part of the aquifer (Fig. 3). This flow draws the water by the relatively cool rock between the two screened intervals and draws some cooler water toward the well at the Franconia level. Following the attainment of peak temperature, the temperature declined nearly linearly with time and cumulative withdrawal until the end of recovery (Fig. 6). The rates of declining temperature for the cycles with approximately 10 days of storage are similar. Cycle 2 with the extended storage period had a lower peak temperature and a slower rate of decline. Peak temperature during recovery was a function of the temperature of the water stored and the period of storage.

The precipitator reduced the supersaturation with respect to calcium carbonate of the heated water significantly during injection. Appreciably more calcium was withdrawn from the storage well during recovery than was injected with the hot water (3, 5).

The chemical composition of the water recovered during the short-term cycles indicated that equilibrium with respect to silica and calcium-magnesium bicarbonate had been attained by the time the water was recovered (5). The trends were for the silica concentration to decrease as the temperature decreased, and for hardness-related constituents, calcium for example, to increase as temperature decreased.

Water returned to the source well was not cooled back to ambient (11°C), in order to conduct each succeeding test cycle at higher temperatures. The water supplied for the second and subsequent cycles was not isothermal. Its major-ion chemistry reflected the temperature of the water.

Thermal responses in the monitor wells at the storage site reflect the layered nature of the PIC aquifer (Fig. 7). Highest temperatures recorded in the wells approximately equaled the mean temperature of the injected water. The thermal front at the wells 7 m from the storage well arrived after about 1.5 days of injection at the more permeable parts of the aquifer.

ENERGY RECOVERY - The four short-term cycles showed that about 50 to 60 percent of the energy added to the water can be recovered in a symmetrical ATES cycle. Results of the field experiments agreed quite closely with the modeled results (6). If energy recovered is compared against ambient conditions, the recovery ratio is as large as 75 percent (Table 1). However, the useful thermal energy that can be recovered in a given operating system is only that above a particular specified minimum temperature, which is usually not the ambient temperature.

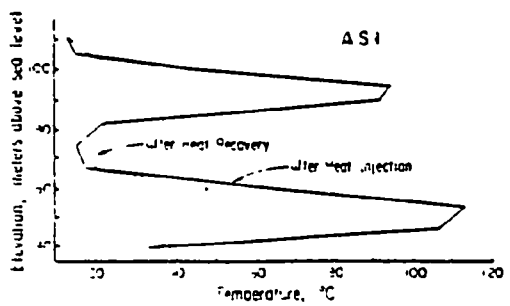

Fig. 7 - Temperature profile of well AS1 during short-term cycle 4

LONG-TERM EXPERIMENTAL TEST CYCLE

A long-term cycle consisting of approximately 59 days of heated water injection, 64 days of storage, and 58 days of recovery was conducted from November 1984 to May 1985 (Table 1 and Fig. 8). For the long-term cycle, an ion-exchange water softener (Fig. 5) and an additional monitoring well, AM4 located 30.5 m from the storage well (Fig. 2), were added to the system. The ion-exchange water softener was made possible by a change in the permit conditions. The softener allowed injection to proceed with few interruptions. The new monitor well allowed monitoring at a point closer to the thermal front than would have been possible with the previous monitoring wells.

OPERATION - Problems with the water softener, weather, monitoring equipment, and flowmeter were encountered at different times during the cycle, but they did not materially impact on the experiment. Some pressure tranducers failed during parts of the cycle so that it was necessary to measure water levels manually in key wells.

Interruptions in injection resulted from: 1) malfunctioning of the water softener; 2) weather-related malfunctioning of automatic safety shutoffs; 3) scheduled shutdowns for system maintenance and repairs; and 4) a holiday period.

The temperature of the stored water fluctuated with the source-water temperature, steam-setting adjustment, weather, and the final-rinse phase of water-softener regeneration. Steamflow was a function of the incoming steam pressure and valve settings. The steam controller was originally set to maintain a temperature of approximately 115°C. This temperature could be maintained only while the source-water temperature was above 20°C because of the capacity of the system. Problems with the water softener affected the temperature capability of the system during the injection phase. The effect of water-softener failure is clear during the first days of injection with the decrease in injected water temperature (while steam pressure increased) as the condenser lost efficiency. Extremely cold weather (<-20°C--normal for January) affected incoming steam pressure because of other campus heating loads. The abrupt decrease in temperature of the injected water beginning at day 63 (Fig. 8) of injection was caused by low steam pressure. The final-rinse phase of water softener regeneration briefly decreased the flow to the storage well and increased the temperature. The spikes on the flow curve (Fig. 8) are the result of these regenerations.

Storage was extended to 64 days to repair leaks in the radiator and to replace the flowmeter. Recovery was interrupted once by a campus power outage.

PERFORMANCE - The injection phase of the long-term test cycle consisted of 59.1 days of injection spread over 74.7 days. Mean flow rate was 18.03 l sec^{-1}, mean source-water temperature was 19.7°C, mean injected water temperature was 108.5°C, and mean delta T was 98.6°C. A total of 9.21×10^4 m^3 of heated water was stored. A total of 9.47 GWh of energy added to the stored water by the steam was stored. A total of 10.40 GWh (above ambient conditions) was stored in the aquifer, the difference being supplied in the source water.

The source waters were not isothermal, but reached a high temperature of 10.5°C about 8 days into the test cycle and then declined slowly to 11.0°C by the end of the injection period (Fig. 8). The highest temperature of the source water occurred approximately when the volume pumped from the source well equaled the volume of the short-term test cycles. Trends of Ca and Mg concentrations, as well as alkalinity in the source water were, however, quite close to what they would have been with entirely ambient water temperatures (200 ppm as $CaCO_3$). The water softener reduced hardness to <20 ppm when it functioned properly. There was an increase in sodium in the softened water to 113 ppm from the ambient level of <20 ppm.

Table 1 - Summary of Test Cycles, University of Minnesota Field Test Facility

Cycle	1	2	3	4	Long
Duration (days)					
Injection - Pumping	5.2	8	7.7	7.7	59.1
Injection - Total	17	10	10.4	12	74.7
Storage	13	90	9.7	10.1	64
Recovery - Pumping	5.2	8	7.7	7.7	58
Recovery - Total	5.2	8	8	7.7	58.8
Temperature (°C)					
Source Water	11.0	20.5	36.1	52.6	19.7
Injected Water	89.4	97.4	106.1	114.8	108.5
Recovered Water	59.2	55.2	81.1	89.1	74.7
Flow Rate (l sec^{-1})					
Injection	18.4	17.6	18.3	17.9	18.0
Recovery	18.1	17.8	17.3	17.8	18.4
Volume (10^4 m^3)					
Injection	0.83	1.22	1.22	1.19	9.21
Recovery	0.81	1.23	1.18	1.19	9.22
Energy (GWh)					
Added	0.770	1.084	0.989	0.867	9.47
Recovered	0.453	0.495	0.617	0.503	5.86
Energy Recovery Factor					
(using source temperature)	0.59	0.46	0.62	0.58	0.62
(using ambient temperature)	0.59	0.52	0.71	0.75	0.65

Recovery continued for 58.0 days until 9.22×10^4 m^3 of stored water was recovered. The temperature of the recovered water reached a high of 93.3°C after about 2 days of pumping. The final water temperature was 45.6°C. Mean temperature of the recovered water was 74.7°C. Flow during recovery averaged 18.4 l sec^{-1}.

Thermal response in the monitor wells was observed in less than 2 days, as during the short-term cycles. Figure 9 plots temperatures at five thermocouples in well AS1 during injection and recovery. Notice that the arrival of heat is not uniform, and that the response to pump shutoff is different at different levels. Temperatures in the upper Ironton-Galesville and lower Franconia change quite dramatically with pump shutoff (Fig. 9), probably because of the interbedded nature of the aquifer. Figure 10 plots temperature in AS1 at six times during the cycle. There is an indication of thermal tilting in the upper Franconia portion of the storage zone during the cycle (Fig. 10).

Temperatures in porous and permeable portions of the aquifer declined during the recovery phase (Figs. 9, 10). The heat which went into the lower Franconia portion of the aquifer and confining beds remained; note the temperature increase throughout recovery in the St. Lawrence Formation (Fig. 9).

The chemistry of the recovered water was close to what was expected; silica, calcium, and magnesium were at equilibrium for the temperature. However, a significant quantity of the sodium added by the water softener was not recovered during recovery, and its concentration decreased with time during recovery. The mass balance of the dissolved ions for the test cycle is being evaluated.

ENERGY RECOVERY - Using the energy which was added to the water as a base, 62 percent of the stored energy was recovered. If the ambient temperature is used, 65 percent was recovered. The temperature curve during recovery is noticeably convex (Fig. 8). Plotting temperature against cumulative flow makes this clearer. The significant amount of energy recovered and the relatively slow falloff in it during the first third of the recovery period suggest that a significant amount of useful thermal energy may be recovered in seasonal operation.

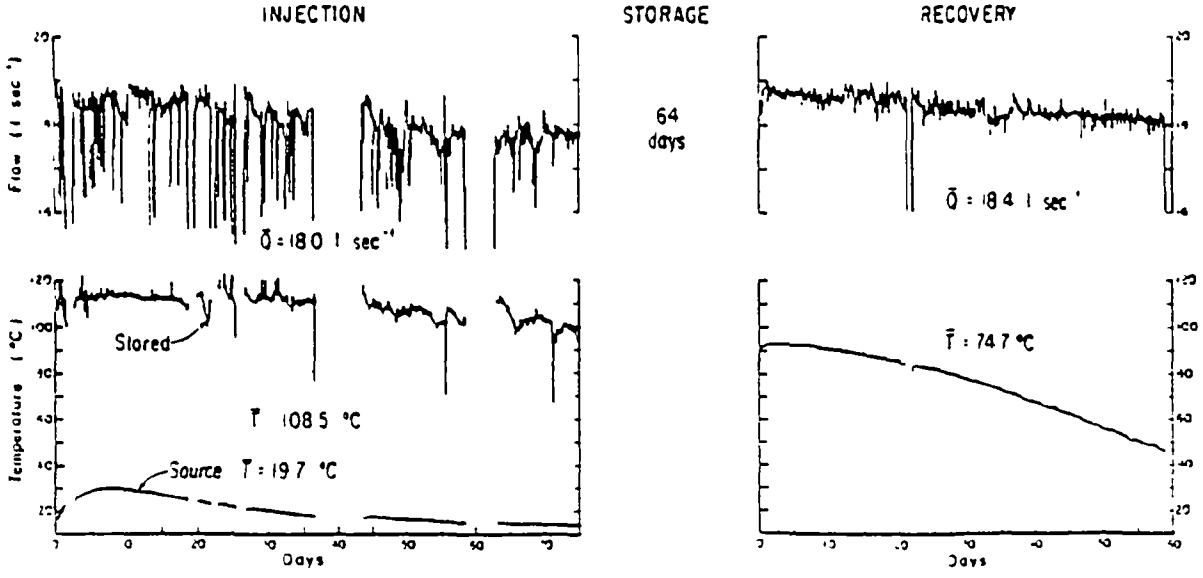

Fig. 8 - Heated water flow and temperature during the long-term test cycle at the University of Minnesota ATES field test facility

CONCLUSIONS

Aquifer thermal energy storage (ATES) in a deep, confined aquifer is a technically feasible method for storing available energy on a periodic basis for use at a later time. Energy recovery from the experimental test cycles at the St. Paul campus of the University of Minnesota using the Franconia-Ironton-Galesville (FIG) confined aquifer for storage was approximately 60 percent. Modeled energy recovery was in close agreement.

Characterization of the aquifer system is done in order to anticipate potential problems, determine the well and well-field designs, plan monitoring, and model energy and mass-flows of the system. The initial characterization work (cores, geophysical logs, pumping tests) revealed the highly stratified nature of the FIG aquifer and provided the basis for dividing the aquifer into four hydrologic zones. The FIG is hydraulically well separated from the overlying and underlying aquifers.

Characterization of the ground water is also of critical importance because the temperature changes affect the chemical equilibria of the ground water. The natural ground water of the FIG aquifer is a calcium-magnesium bicarbonate water, with a hardness of 200 ppm as $CaCO_3$. The potential for scaling had to be addressed. The ground water required some conditioning in order to prevent scaling of piping and the storage well. For the short-term cycles a precipitator served as an effective, but stopgap, method to prevent scaling in the well, but not in the heat exchanger (condenser). For the long-term cycle, an ion-exchange water softener provided a more useful solution, which allowed nearly continuous operation by replacing the calcium and magnesium during injection of heated water with sodium. The change in ground-water chemistry is very local and easily monitored. Stored ground water rapidly reaches equilibrium with the storage conditions of the aquifer. After storage, the recovered water is a sodium-calcium-magnesium bicarbonate water. With repeated cycles, the sodium level would increase by only as much as is necessary to remove the hardness during subsequent cycles.

The highly stratified nature of the aquifer is reflected in the arrival pattern of the thermal front at monitor wells near the storage well. The stratification helped inhibit convection within the heat-storage zone. Heat losses were to the less-permeable rock of the aquifer and to the confining beds.

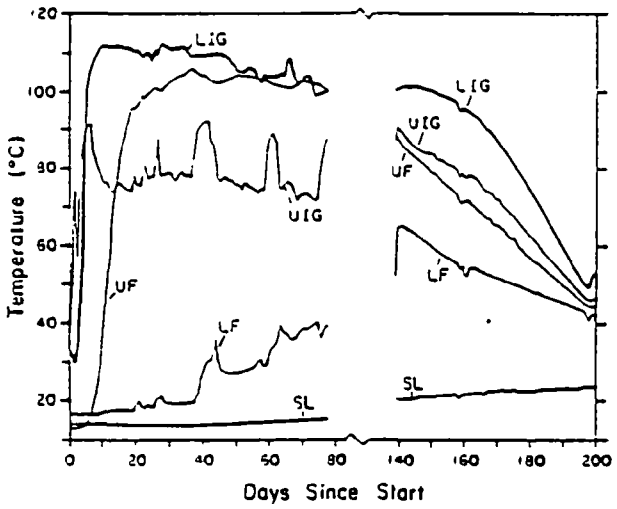

Fig. 9 - Water temperatures in the lower and upper Ironton-Galesville (LIG, UIG), lower and upper Franconia (LF, UF), and St. Lawrence (SL) intervals in well AS1 during the long-term cycle

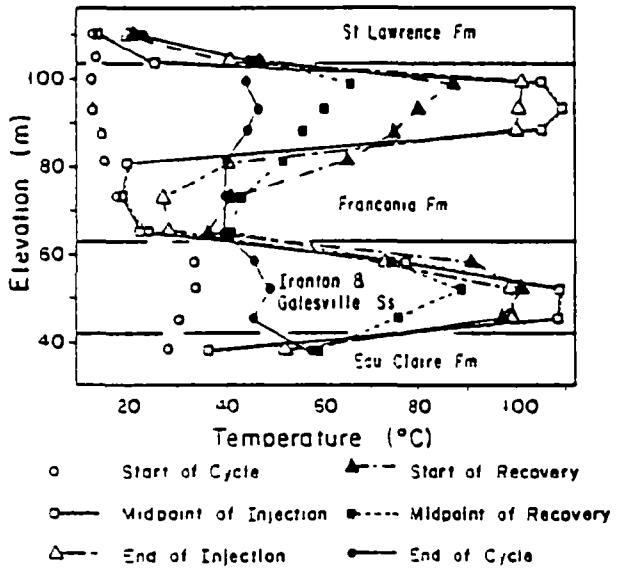

Fig. 10 - Temperature profiles of well AS1 during the long-term cycle

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6. R. T. Miller (this volume).

Section 8.2.2

TITLE OF STUDY: (or SOURCE OF INFORMATION)	"Mound of Water Present Following Air-Injection Test" From The Cross Section, Vol. 31, No. 7.
AUTHOR: (or INVESTIGATOR)	(Published by High Plains Underground Water Conservation District No. 1., Lubbock, Texas)
DATE:	July, 1985
FACILITY NAME AND LOCATION:	City of Wolfforth, Water District, and Texas Department of Water Resources, Texas USEPA Region VI
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	This article describes research concerning the theory that injecting water into the unsaturated sands of the Ogallala Formation induces the release of capillary water. Three tests were conducted in Wolfforth. Among numerous conclusions resulting from research to date include (1) secondary recovery of capillary water can be accomplished, (2) injection of compressed air is the most economical and successful mechanism for secondary recovery, and (3) secondary recovery is economically feasible for municipal/industrial purposes and marginally feasible for agricultural purposes.

THE Cross SECTION

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SECONDARY RECOVERY RESEARCH CONTINUES

Mound Of Water Present Following Air-Injection Test

Continuing research into the theory of injecting air into the unsaturated sands of the Ogallala Formation to induce the release of capillary water has revealed some impressive results, some theories that appear comical on the surface, and an improved economic feasibility for this innovative technique

Continuing Field Studies

In 1984, the City of Wolfforth joined with the Water District and the Texas Department Of Water Resources to conduct an air-injection test in the city's well fields in the hope that this test would increase the city's current water reserves

As Mayor Don Bell explains, the test seems to have been successful "Based on conversations I have had with farmers who have wells around town, they tell me that they had one-third more water to pre-irrigate their beds with this year than they had in previous years Going by that, I know in my mind that the city has more water Because the city wells are pumping under restrictions, it is hard to say that they are pumping more water But I think we've got more water in the aquifer to be used at a later date In those terms, I believe very definitely that the secondary recovery test has been beneficial to the city by prolonging the life of our water reserves"

Mr Lloyd Hopper, a local landowner with land located approximately one and three-quarters miles from the test site, explains, "We had two wells where the water level was raised considerably One well is here at the house, a domestic well, and the other is an irrigation well I don't remember the actual water-level measurement, but seems to me it was raised several feet I do know that these wells had been pumping air I don't know whether they are now pumping any more water than they did before the air-injection test, but they have quit producing air"

The Wolfforth test site was located on land owned by the Frenship Co-op Association Gin Geologic evaluation of this site revealed that there were two separate unsaturated zones which air could be injected into during the test These two zones were separated by a bed of hard rock, which would serve as a confining laye-

This secondary recovery effort was also approached from a different perspective than previous air-injection tests In an effort to improve the economic feasibility of secondary recovery of ground water, this test was designed to inject low volumes of air under low injection pressures to release capillary water Previous laboratory studies indicated that by applying two to three pounds per square inch of air-drive pressure, a 20 percent increase in water yield can be obtained over that available through gravity drainage

Wolfforth Air-Injection Test One

The first test at this site was designed to inject air under low pressure (eight psi) at low air volumes (approximately 300 cubic feet per minute) into the unsaturated zone above the hard rock layer During this test, air was injected over a 61-day period

Several things happened during the first test First, capillary water was released from the upper unsaturated zone Prior to the air-injection test, the moisture content of the formation material in this upper section was 17 percent moisture by volume This indicates a moisture content less than field capacity in the upper section Field capacity for the type of formation material present in this section would range from 23 to 27 percent by volume

Following the test, the moisture content of this zone, within 300 feet of the air-injection well, had been reduced to an average of 13 percent moisture content by volume The air pressure front extended beyond this 300-foot area; however, no before or after soil moisture samples were collected for analysis beyond the 300-foot distance from the air-injection well

Additionally, the capillary water released from this upper section penetrated the hard rock layer and moved into the lower unsaturated zone This increased the moisture content of the lower zone Increased moisture content in the lower zone was evidenced when formation push-core samples were collected and analyzed The moisture content of these samples reveals that the moisture content by volume in this lower zone was increased from about 28 percent before the test to more than 40 percent after the test Additionally, when the air injection well was developed into the sand section below the hard rock layer, the borehole from the top of the rock layer to the bottom of the hole filled with water This indicates that gravity water was abundant in the sand section below the rock after the first test

Wolfforth Air-Injection Test Two

During the 36-day second test period when air was injected at low pressures with low air volumes below the hard rock layer, some interesting observations were made First, the test achieved the release of some of the capillary water which had been made available in the lower sand section as a result of the previous test

Additionally, researchers encountered a gravel lense in this zone which appears to have "short-circuited" the secondary recovery process in terms of actual observed water-level rises Air pressure monitors located at the test site indicated that for several hundred feet away from the air-injection well, significant air flow and pressure occurred in the gravel lense Right above the gravel lense very little formation pressure responses were observed This indicates that air flow from the air-injection well took the path of least resistance, flowing into and through the gravel lense.

Contrary to initial reactions, this occurrence was not all bad The researchers were able to document increased yields in irrigation wells during and after the air-injection test within a two-mile radius of the test site

Researchers have several explanations for this occurrence One is that during the air-injection test water was pushed through the gravel lense, both the water released from the upper and lower unsaturated zones plus the water held in the gravel lense itself Another theory is lovingly referred to

continued on page 2 AIR INJECTION

Rainfall Runoff Furthers Playa Lake Recharge Research

Recent rains around the area have provided the rainfall runoff necessary for researchers at Texas Tech University to continue their investigation into artificially recharging playa lake water through the use of commercially available fabric underdrain materials

Dr Bill Claborn, Associate Professor of Civil Engineering at Texas Tech University, and Dr Lloyd Urban, Assistant Director of the Texas Tech University Water Resources Center and Associate Professor of Civil Engineering, installed fabric underdrain materials in a playa lake located nine miles northwest of Lubbock in early 1984 Prior to the recent rains received in the area, the researchers had received a maximum of only nine inches of runoff water into the playa lake during the previous year

That runoff was received in June of 1984 and provided a "shake-down" of the design of the field test site and monitoring equipment The shake-down went pretty well, with approximately 20 percent of the water in the playa following that June, 1984, runoff event, passing through the filtration/metering system and into the recharge well

At that time, varying flow rates through the filtering materials ranged from insignificant through two lines to over five gallons per minute in four lines

As of this writing, four rainfall runoff events have occurred where runoff water collected in the lake Dr Claborn notes, "The first rainfall event we had this summer provided as much runoff water as we had previously had in the lake"

In this new approach to artificial recharge, the original objectives of the project were

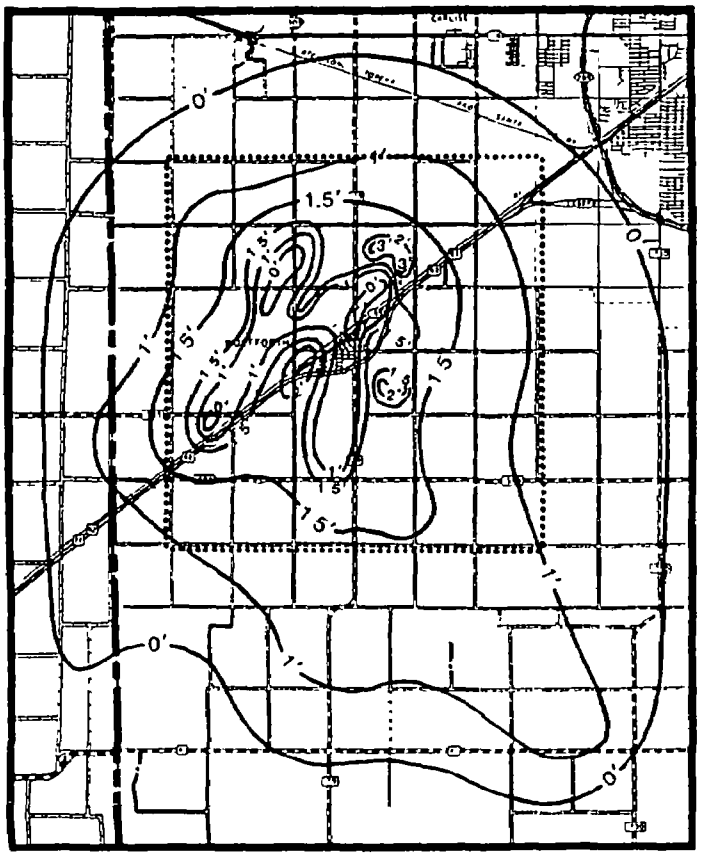
- to further test the concept of using "wick" filters, geotextiles and available drainage materials to attain water suitable for recharge,
- to test a wide range of filter materials and design configurations in order to determine design parameters, and
- to examine water quality parameters associated with the recharge operation

Water Quality

"I believe, with this test, we are now in a position to answer the quality questions regarding the water that drains from the lake through the filtering materials," notes Dr Claborn "When all the data is in, I think we will have a reasonably good handle on the water quality aspect"

continued on page 3 RECHARGE

CHANGE IN WATER LEVELS 143 DAYS AFTER AIR INJECTION AT THE WOLFFORTH TEST SITE



(Uncorrected For Extensive Area Pumpage)

Within the "0" contour line indicated on the map, a mound of water exists following the air injection test which is estimated to contain 8,577 acre feet of water that was *not present prior to this test* Within the dotted line, an area of 36 square miles, three miles in each direction from the air injection site, the mound of water contains an estimated 4 463 acre feet Researchers have looked at the effects of natural recharge, and irrigation recirculation, as well as the effects of the air injection test as contributing factors to the presence of this mound of water

AIR INJECTION . continued from page 1

by those very close to the project as the "gas can theory"

The "Gas Can Theory"

Don Rauschuber, P E , Consultant for the project, explains the "gas can theory" in these terms "As we moved air beneath the hard rock layer through the gravel lense, we provided a pressure relief valve for area irrigation wells.

"The geologic logs in the general area of this site, as well as delayed responses in the formation to atmospheric barometric pressure changes, indicate that the Ogallala Formation below the hard rock layer is semi-confined In a confined or semi-confined situation, the air pressure that exists on the surface of water in the well as the well is being pumped and the water level drops, does not immediately equalize with air pressure at the surface A partial vacuum is created, which may increase pumping levels and/or reduce well yields So you have a pressure differential, sort of like the pressure you have when you try to pour gas from a gas can into your lawn mower or car without opening the air valve The gas pours out very slowly, because air is trying to get inside the can to relieve the vacuum

"Essentially, forcing air through this gravel lense in a secondary recovery test in this semi-confined area provided an air relief valve in the formation, just like the air relief on the gas can This allowed ground water to flow more freely through the aquifer toward the well"

Wolfforth Air-Injection Test Three

A third test was also performed at the Wolfforth test site During this 12-day test period high volumes of air at high air-injection pressures were injected into the lower unsaturated zone A final set of formation core samples were collected following this air-injection phase Only a small change in moisture was found to have occurred

Researchers attributed the small change to the fact that the air-injection process was short-circuited by the presence of the gravel lense Therefore, the lower section was never subjected to an air-pressure front of sufficient pressure to cause the release of large quantities of capillary water Additional drainage is, however, expected to occur over time as a result of the influence of gravity In time, it is expected that the moisture content in this section will decline to about 25 percent from the current 43 percent by volume level

Wolfforth Test Results

One hundred and forty-three days after completion of the air-injection test performed at the City of Wolfforth, a mound of water occurs over an area of approximately 100 square miles with the air-injection well being located near the center of the mound Within the "zero" contour line on the accompanying map on page 2, the mound of water contains approximately 8,677 acre-feet of water, as compared to that quantity of water present prior to the air-injection test.

This mound of water exists despite pumpage by area irrigators and the City of Wolfforth The City of Wolfforth pumped 303 acre-feet of water during 1984, and pumpage by irrigators within the immediate 36-square mile area of the test is estimated at 7,152 acre-feet during 1984 This amount of pumpage should have resulted in a water-level decline of about two feet over the entire area had no natural recharge, irrigation recirculation or release of capillary water occurred

Effects Of Natural Recharge

A review of precipitation data within the area during 1983 and 1984 leads the researchers to believe that some of the mound may have been a result of natural recharge

In 1983, during the months January through September, the area's rainfall was extremely sparse, amounting to only 8 53 inches Then in October of 1983, the area received more than 10 inches of precipitation, some of which was collected in area playa basins Considering the nine-month drought which preceded these large rainfall events, it is unlikely that natural recharge occurred in significant quantities, except within the playa basins

The playas were dry when the October rainfall events occurred, and they were only filled with sufficient quantities of runoff water to bring the water level up to or slightly above the Randall clays Randall clays inhibit the movement of water; therefore, if the playas were not filled above these clays, it is unlikely that a significant amount of natural recharge occurred

The total rainfall for 1984 was 14 62 inches, which is approximately 78 percent of the 18 57 inch norm for the area This below average rainfall, plus the fact that no large rainfall events occurred in 1984, indicates to the researchers that little or no natural recharge could have occurred in 1984 as a result of precipitation

Irrigation Recirculation

Records of fuel use by irrigation wells and well yield tests during 1983 and 1984 for select farms in the study area indicate that the amount of irrigation water applied, plus the precipitation received prior to and during the growing season, did not equal the crop water demands in inches Therefore, little, if any, irrigation recirculation could have occurred to contribute to the mound of water

In December of 1983 and January of 1984, the regional soil moisture survey was conducted In the Wolfforth area a soil moisture deficit of four inches was noted Part of this deficit was a result of heavy vegetative growth, which occurred after the large rainfall events in October and before the first freeze experienced in the area in 1983.

Air Injection

The researchers offer the following explanation as to why such a large area experienced increased water levels after the air-injection test Large quantities of air were injected into a gravel lense during the second and third tests This resulted in the distribution of air and the air pressure front throughout a substantial area, consequently releasing capillary water over a large area

Because the gravel lense occurred only a few feet above the existing water level, the researchers do not know what to expect as far as future drainage in that area below the gravel lense is concerned However, the researchers will continue to monitor the water level within the test area In the area of the city, where water was released from above the rock and drained into the area below the rock filling it to a level above field capacity, the researchers expect drainage to continue for a long period of time

Water Quality Evaluation

During the Wolfforth air-injection test, researchers also evaluated the effects of the air-injection process on the quality of water within the city s wells Through cooperative arrangements with the Texas Department of Health, sixteen water quality constituents were evaluated on a pre and post test comparison basis

There were no significant changes in the area of ground-water quality as a result of the air-injection test An analysis of the data indicates that five of the sixteen constituents had slightly higher values (indicating lower water quality) after the test than before the test The remaining eleven constituents all reflected slightly higher water quality than pre-test conditions, however, all post-test values were well within acceptable limits

Land Subsidence

It has been theorized by project observers throughout the secondary recovery research effort that as capillary water is removed from the clays and/or sands in the formation, possible structural changes could result from air injection, such as the collapsing of the pore spaces, thereby causing land subsidence Consequently, during and after the Wolfforth and Idalou tests elevation data were collected to determine if subsidence occurred

Based on the land surface elevation study, as of May 8, 1985, no subsidence has occurred as a result of secondary recovery tests at either the Idalou or Wolfforth sites

Additional Objectives

As a part of the continued researc into secondary recovery of groun water, projects directed at both mathematical and physical modeling of t theory and concepts of secondary r covery are progressing

With respect to the mathematic modeling effort being conducted b Bill J Claborn, PhD, Water Resourc

continued on page 4 AIR INJECTIO

AIR INJECTION . . continued from page 2

Center, Texas Tech University, Lubbock, Texas, a model has been developed to simulate the secondary recovery process at the Idalou, Slaton and Wolfforth test sites However, the model is too large to operate on mainframe computers available to the project team As of this writing, time on a "super computer" has been requested to verify the model.

The concept of a true physical model of secondary recovery in the Ogallala Formation was considered by Donald Reddell, PhD, Texas A&M University, College Station; however, abandoned due to difficulties involved in scaling. It is extremely difficult, if not impossible, to scale down water. Therefore, in lieu of a true physical model, construction of a sand-tank model was initiated Once completed, this model will be capable of simulating a secondary recovery test in a confined or unconfined aquifer. Measurements of the changes in permeability as the model is dewatered, as well as other parameters, will be available from this sand-tank model

The wedge-shaped sand tank, which is being constructed by Dr Reddell, measures 24 feet in length by 12 feet in height, with a circumference of eight feet Its potential, first of all, is to simulate field responses to air injection. Secondly, data developed from the physical model can be used to test the mathematical model

Idalou Updated Test Results

Updated information from the Idalou secondary recovery project, approximately 1,000 days after the air-injection test ended, reveals that an estimated 787 acre-feet of water were made available within a one-square mile control section as a result of that air-injection test Based on 787 acre-feet of additional water being made available for pumpage by area wells, the cost for the release of capillary water would be about $24 00 per acre-foot within the control section

Researchers documented, however, that the secondary recovery test at this location affected an even broader area than the 640-acre control section Adding the mound of water outside the 640-acre control area, researchers estimate that a total of 1,100 acre-feet of water was made available for pumpage as a result of this test

Water drainage at the Idalou test site has continued for almost three years following the air-injection test This additional water reduces the per acre-foot cost of released water from $50 as originally reported, to about $17 The above estimates do not consider the cost of lifting water to land surface

Research Results To Date

To date, the principal researchers involved in the secondary recovery project believe that several conclusions can be drawn from field programs and laboratory testing, as well as physical and mathematical modeling efforts Among these are the following conclusions

- Secondary recovery of capillary water can be accomplished
- There is an estimated potential of 1 46 billion acre-feet of capillary water underlying the High Plains of Texas
- *Injection of compressed air is the* most economical and successful mechanism for secondary recovery
- Twenty-five to thirty percent of the capillary water in storage can be released under induced pressures of less than eight pounds per square inch at the injection point
- Regional secondary recovery field programs can be constructed to recover capillary water
- At this time, secondary recovery of ground water is economically feasible for municipal/industrial purposes and marginally feasible for agricultural purposes based on current commodity prices
- Secondary recovery is successful even in formational material that has a *moisture content less than field* capacity
- Post capillary water drainage occurs for months/years after short-term injection periods

This final observation comes as no surprise to District Manager A Wayne Wyatt. "A review of monthly water-level measurements made back in the 1940's following abnormally heavy rainfall events in 1941 reveals that water levels in area wells continued to rise for five years after these heavy rains were experienced

"Comparing the drainage that results from secondary recovery tests with the drainage that occurred as a result of this natural recharge, it has not been a surprise to us that drainage has continued over long periods of time after secondary recovery operations have been completed."

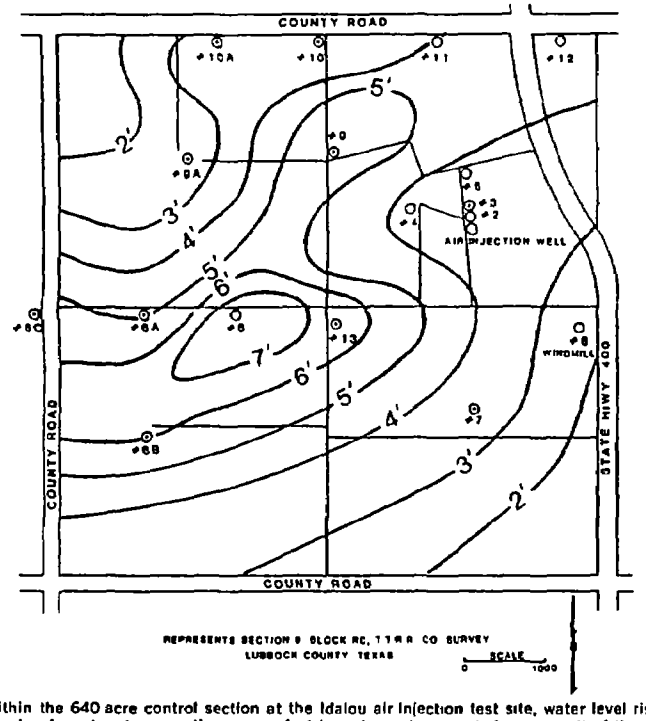
Ronald Schilling, owner of the land where the Slaton air-injection test was conducted, and Clifford Hilbers, owner of the test site in Idalou, both boiled down the benefits of secondary recovery to very meaningful personal terms

Hilbers relates, "I think that the secondary recovery test helped me some My irrigation wells seem to hold their own now, instead of dropping off in yield I can't see that it did anything but help me a little In fact, if I had another place where they wanted to make a test, I'd just tell them to get after it."

Schilling states, "I shut off my irrigation wells the year they performed the test because my water levels had fallen off so much But the big thing about secondary recovery as far as I am concerned is that I don't think we will ever be out of domestic water thanks to this new technology Before the test we were concerned about running out of domestic water for our home Since the test I feel like I'll never run out of water for the house"

The estimated quantity of gravity water in storage in the Texas portion of the Ogallala aquifer as of 1980 is about 375 million acre-feet, according to the U S Geological Survey The current volume of capillary water estimated to be in storage in the unsaturated zone equals 840 million acre-feet This estimate increases by 625 million acre-feet of capillary water which will be held in storage when the Ogallala is ultimately depleted of all gravity water The total of the two, 1 46 billion acre-feet, indicates that almost four times as much water will remain in storage in the unsaturated portion of the Ogallala aquifer than is presently considered recoverable by gravity flow into wells Secondary recovery could potentially double the life of the current ground-water supplies available to the area

CHANGE IN WATER LEVELS 1,000 DAYS AFTER AIR INJECTION ENDED AT THE IDALOU TEST SITE
(Water Level Rises Remain Through Three Seasons of Irrigation)



Within the 640 acre control section at the Idalou air injection test site, water level rises *ranging from two to more than seven feet have been documented as a result of the air* injection test performed at this location These water level rises exist despite three seasons of irrigation pumpage in the area It is estimated that 1,000 days following completion of the air-injection test, there is a mound of water containing 787 acre feet of water within the control section, and 1,100 acre feet taking into consideration the mound of water which exists outside the control area

THE CROSS SECTION (USPS 564-920)
HIGH PLAINS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1
2930 AVENUE Q
LUBBOCK, TEXAS 79405

SECOND CLASS PERMIT

Section 8.3

Aquifer Remediation Related Wells Supporting Data

Section 8.3.1

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	From Oklahoma Class V Well Study and Assessment
AUTHOR: **(or INVESTIGATOR)**	Oklahoma Industrial Waste Division, State Department of Health
DATE:	July, 1985
FACILITY NAME AND LOCATION:	Oklahoma USEPA Region VI
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	The excerpt from Oklahoma's Class V report describes geohydrology, construction features, nature and volume of injected fluids, and jurisdictional considerations associated with known remediation projects in Oklahoma.

Recovery of refined hydrocarbons that have spilled or leaked into the subsurface has become popular in the last decade. Increased interest in hydrocarbon recovery is due mainly to environmental concerns, but in some situations can also be very profitable for companies. Various conditions affect migration and recovery of a hydrocarbon spill such as hydrogeological conditions, the extent and volume of the spill, the type of hydrocarbon to be recovered and the potential or immediate hazard imposed by the spill. As a result, recovery systems must be tailored to each site.

The most popular means of hydrocarbon recovery from water table aquifers is the recovery well. Normally, this system provides for an efficient and fast recovery compared to other methods. The recovery well creates a cone of depression in the water table that establishes a hydraulic gradient towards the well, and hydrocarbons within this cone are directed to the well and can be removed. Often recovery wells utilize recharge wells to direct the water back to the aquifer that was pumped out of the recovery well. The Division considers these recharge wells a type of Class V well. In Oklahoma, approximately 60 hydrocarbon recovery recharge wells are currently known to exist. These wells are being utilized in aquifer rehabilitation programs initiated by various refineries in the state. Since the recovery of refined hydrocarbons that are caught in soils underlying refineries, pipelines, and storage areas are becoming increasingly important both economically and environmentally, we feel the hydrocarbon recovery recharge wells may deserve more indepth review and consideration. We also believe in the future this type of well will be more prevalent in Oklahoma.

It is important to note, that these recharge wells are not confined to large scale refinery use but may be feasible in emergency clean-up operations as well as small scale clean-ups such as leaking gas tanks at service stations.

Since the only wells we know to exist are at the refineries engaged in an operation of larger scale, we will present the typical model well based on material we have received from the various refineries.

Geohydrology

Before drilling a recovery well or associated recharge wells a preliminary evaluation should be done to determine hydrogeologic conditions underlying the facility. Soil type should be determined for drilling feasibility. The depth to the water table is also important. The following is an example of hydrogeologic information that should be collected.

I. Physical Characteristics of the Aquifer
- a) In unconsolidated formations
  - 1) grain size distribution
  - 2) continuity of clay/sand layers
  - 3) position of oil layer relative to clay layer
  - 4) depth of permeable sands underlying the oil layer
- b) In consolidated formations
  - 1) Fracture or venting orientation

2) Stratification
3) Solution cavities - orientation, size, depth

II. Hydraulic Characteristics
a) Depth to water table
b) Presence of perching layers
c) Presence of confining layers
d) Permeability within oil-bearing zone
e) Depth and permeability of the water saturated zone underlying the oil
f) Direction and rate of flow

It is characteristic for hydrocarbons in an aquifer to be retained by the unsaturated soil and sediments above the water table. The free hydrocarbons that eventually reach the saturated zone, accumulate on top of the capillary fringe and migrate to the lowest points in the capillary fringe. These low points may be due to increased grain size of the formation, discharges from the aquifer, or excavations.

The refineries that have started hydrocarbon recovery programs have done so on their own initiative. It is anticipated the more refineries in the state will be interested in hydrocarbon recovery in the future.

Construction Features

In large scale recovery operations, such as the refineries have, a popular recovery well design is a two-pump system utilizing one recovery well. In this system addition of soluble hydrocarbon components to the waste water is minimized, since the water and oil are not mixed when recovered. The intent of this report is not to discuss recovery well design but the associated recharge well design. However, Figure 1, a schematic drawing of a two pump - one recovery well system, is included for clarification purposes. The water discharged from this system is recharged back into the aquifer via the recharge injection well.

Figure 2 is a schematic drawing of a typical recharge well. This 'model' well is a direct recharge well that involves the use of a completely closed system in which the produced water is never exposed to air. It was drilled with a rotary rig using a 9 - 7/8 inch bit. Total depth of the borehole was 36 feet. A 5' sump was drilled into the bedrock to allow for any side wall collapse during the installation of the screen and casing., No drilling fluid additives were used throughout the completion of the recharge well, and following completion the well was disinfected with chlorine.

Depth of the recharge well is 30 feet below ground surface. The well was constructed with 15 feet of .065 slot, 5 inch PVC screen and schedule 40 casing. Pitless adaptors were installed aproximately 3 feet below ground level. A 1¼ inch PVC discharge pipe is connected to the pitless adaptor and extends to the bottom of the well. Centralizers were installed at the bottom and top of the screen to insure even distribution of gravel pack around the screen. At the side of the well is a piezometer, consisting of 20 feet of 1 inch PVC pipe with 2 feet of .030 slot PVC screen at the bottom. The piezometer is to monitor the well

without introducing oxygen to the close system.

The well was gravel packed to a level approximately 3 feet above the top of the screen. In completing the well an annulus seal was installed, comprised of approximately 4 feet of Bentonite and 5 feet of cement grout, preventing any type of surface contamination to the well. The rest of the hole was filled with native material.

Figure 3 is an example of a typical well log format. The data is actually from an existing recharge well at a refinery in Tulsa. Whenever a recharge well is drilled a log of this nature should be submitted to the Division.

In general, any recovery recharge well should:

1. Be placed to enhance the gradients to recovery wells. This can reduce the number of recovery wells and increase recovery rates.

2. Be adequately spaced from other recharge wells, and recharge rates adjusted so that the water level is maintained at an acceptable level below ground surface.

Basic technical considerations for direct recharge wells included:

1. Clay or cement seals above the gravel pack.

2. A pressure relief system to prevent well pressure from rising above desired levels.

3. The recharge line and drop tube in the well should always maintain a positive pressure on the water being recharged.

4. Centrifugal pumps in the recovery wells should be avoided. The pressure drop on the water can cause precipitation problems in the unstable waters.

Nature and Volume of Injected Fluids

Nature of injected fluid will vary from operation to operation. In a directed recharge system, the composition of injected fluids will depend largely on the hydrocarbons that are being recovered. Similarly, volumes of injected fluids will vary depending on the recovery system being utilized.

The 'model' recharge well we have previously described receives water directly from the recovery well via an underground closed system, PVC pipeline. Recharge rates typically range from 50 to 100 GPM of water. It is not used continuously. The 'model' well has a gate valve to control water recharge rates.

Since hydrocarbon recovery was initiated in Oklahoma, the Oklahoma Water Resources Board (OWRB) has showed concern with recharge wells and the nature of injected water. Due to confidential agreements between the

Figure 3

RECHARGE WELL NUMBER _____

Job Recharge Well Location Tulsa, Oklahoma

Date September ,1983 Logged By M. Howar

Drilling Company Winnek Driller Andy Rig Straight Rotar

Hole Size 9-7/8" Casing Details 5" PVC Pipe, 6.5' to +2.2' ;

Screen: 5" PVC, .040"slot, 16.5' to 6.5'

G. L. Elev. _____ M. P. 2.2' Elev. M. P. _____

Remarks _____

LEGEND

Clay
Silt
Sand
Gravel
Native Fill
Bentonite Seal
Casing & Screen
Topsoil
Bedrock

Casing	Log	Description	Remarks
		0' Fill dirt and ash	Native fill, 1' to 0'
			Bentonite Seal, 5'-1'
		5' Sand, fine	
			Gravel pack, #8, 19.5' to 5'
		10'	
		Sand, fine to medium	
		15' Sand, medium to coarse	
		Bedrock at 16.5'	
		20'	

[8-73]

pumped into water recharge lines, it would be intercepted before it ever reached the recharge well.

Disadvantages of treatment.

1. Capital and maintenance cost of treatment center can be high.
2. Complex problems can arise once the water has been altered by treatment.

    a. The water may no longer be compatible with aquifer water causing precipitation in the aquifer.

    b. If aeration is used in high iron waters precipitation of iron hydroxides results, causing severe plugging of recharge wells. It may also enhance aerobic bacteria growth.

    c. Filter systems provide a good medium for bacteria growth which can contaminate a recharge system.

    d. Chemical additives for bacteria control or precipitation problems may not be compatible with each other or with the produced water.

Advantages of direct recharge.

1. Maintenance costs are low compared to water treatment
2. The system is extremely flexible.

Disadvantages of direct recharge.

1. Plugging problems associated with suspended particles and air bubbles.
2. An accidental discharge of hydrocarbons through the recovery system. The emulsion formed can cause severe plugging of the formation and is difficult to remove. Similarly, agitation can occur during recovery. The mixing of the product and water can result in an increase in the amount of soluble hydrocarbons retained in the waste water.

Other alternatives for handling waste water recovery systems that do not use recharge wells include:

1. Treatment and reuse of water, such as cooling tower make up water.
2. Treatment and discharge to surface water system.
3. Discharge to existing water treatment system such as a city sewer system.

It is apparent that the technical approach best suited for a site will depend on the conditions of that site.

Jurisdictional Considerations

Any new regulatory program for this type of Class V well should lend incentive to continue hydrocarbon recovery from aquifers. Registration of recharge wells, as well as a description of construction features and well

locations should be mandatory. The Division should have an opportunity to examine well proposals and set permit conditions as they see fit, including the quality of fluid to be reinjected. However, Federal or state regulatory standards and limitations set for every well to meet, would be extremely difficult to enforce as well as hinder recovery activity. Permit conditions should be defined on a case by case basis. At times direct recharge may be perfectly feasible, while at other times treatment may be required. As technology becomes available and affordable to accomplish total and absolute hydrocarbon recovery, water quality standards may need to be re-evaluated.

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Hall, Robert A., Blake, Steven B. and Champlin Jr., Stephen C.; "Determination Of Hydrocarbon Thickness In Sediments Using Borehole Data" presented at The Fourth National Symposium and Exposition on Aquifer Restoration and Ground Water Monitoring; Columbus, Ohio, May 23-25, 1984.

Section 8.3.2

TITLE OF STUDY: (or SOURCE OF INFORMATION)	From Inventory of Class V Injection Wells in the State of Colorado
AUTHOR: (or INVESTIGATOR)	SMC Martin, Inc.
DATE:	March, 1985
FACILITY NAME AND LOCATION:	Rocky Mountain Arsenal Near Denver, Colorado USEPA Region VIII
NATURE OF BUSINESS:	Manufactured products for use in chemical warfare and as pesticides
BRIEF SUMMARY/NOTES:	The injection wells are designed to introduce purified water, previously pumped out of contaminated areas back into the groundwater system. The injected water is intended to reverse the contamination of the ground water in the Rocky Mountain Arsenal and to contain existing contamination within the site area. Possible problems could arise from air injection, solids carried with water, and contaminants not removed by the filtering processes. The wells serve a secondary purpose of aquifer recharge.

3. Class VR - Wells Used for Aquifer Recharge (Howard type 6 - see Table 1)

In general, aquifer recharge wells pose the threat of ground-water contamination primarily by: air injection, which may change water redox conditions; introduction of solids that can clog aquifer pore spaces; and by chemical or biological contamination from other impurities picked up by injected water. For this reason, well injection is generally viewed as an undesirable means of aquifer recharge by the Water Resources Division of the Colorado Department of Natural Resources.

All 81 verified wells of this type are on the grounds of the Rocky Mountain Arsenal and are relatively similar with respect to construction and size. These are all 10 to 12-inch diameter cased wells with stainless steel screens. Well depths range from 40 to 60 feet and each was drilled by the reverse rotary method. Water injection into the wells is by gravity pressure only. Because all of these wells are concentrated on the grounds of the Rocky Mountain Arsenal and are in use as part of a ground-water clean-up project, a review of the project will serve as background for the assessment of potential environmental impact.

The Rocky Mountain Arsenal, located north-northeast of Denver, manufactured products for use in chemical warfare and as pesticides until 1982. Wastewater from the manufacturing processes has been disposed of in evaporation ponds and through a deep injection well. The latter project, terminated in 1965, is well known because of the occurrence of injection-related earthquakes (Evans, 1966). However, because the deep injection well was abandoned and plugged prior to the passage of the Safe Drinking Water Act, it does not come under the scope of the UIC program. and has therefore not been inventoried. However, the waste disposal in evaporation ponds is directly relevant to this inventory and assessment effort.

In an effort to contain and reverse the ground-water pollution caused by seepage of wastewater from the evaporation ponds, clean-up programs, including the use of injection wells, in some areas of the Arsenal have been put into effect. The wells reinject ground water that has been extracted from contaminated zones and purified by carbon filtering. Presently, there are three series of wells active on the Arsenal ground. The North Boundary (21 wells) and Northwest Boundary wells (38 wells) are operated by the U.S. Army, while the Irondale Containment System wells (22 wells) are operated by Shell Oil Company, which manufactured pesticides at this location.

All of these injection wells are designed to introduce purified water, previously pumped out of contaminated areas, back into the ground-water system. The injected water is intended to reverse the contamination of the ground water in the Rocky Mountain Arsenal and to contain existing contaminants within the site area (prevent off-site migration). Therefore, if the project operates as designed, the injection will have a beneficial effect on the environment. Possible problems could arise from air injection, solids carried with the water, and contaminants not removed by the filtering process.

A report on the North Boundary wells is due from the U.S. Army Environmental Control office in the spring of 1985. This report should quantitatively address the question of the environmental impact of the injection wells. The environmental impact of Class V wells at the Arsenal must be reviewed within the context of the clean-up project as a whole. The technology of the RMA clean-up project necessitates recharge by injection rather than 'natural' recharge through ditches, trenches, etc. Therefore, injection-related problems, as discussed above, may occur. However, viewed on the broad scale, the aquifer recharge wells can only have a beneficial effect on the environment compared to the pre-cleanup/injection contamination levels in ground-water originating from the Arsenal.

Section 8.3.3

TITLE OF STUDY: (or SOURCE OF INFORMATION)	"Cleaning up Chemical Waste" From Engineering News Record
AUTHOR: (or INVESTIGATOR)	Not available
DATE:	March 26, 1981
FACILITY NAME AND LOCATION:	Rocky Mountain Arsenal Denver area, Colorado USEPA Region VIII
NATURE OF BUSINESS:	Manufactured products for use in chemical warfare and as pesticides
BRIEF SUMMARY/NOTES:	This article discusses economics and engineering plans to clean up the contaminated aquifer. Plans included a 5-year construction program to consist of building a slurry wall barrier, handling residue from an asphalt lined chemical waste evaporation basin, and adding water purification and recharge systems (wells) and a secure disposal site for spoil, sludges, or ash.

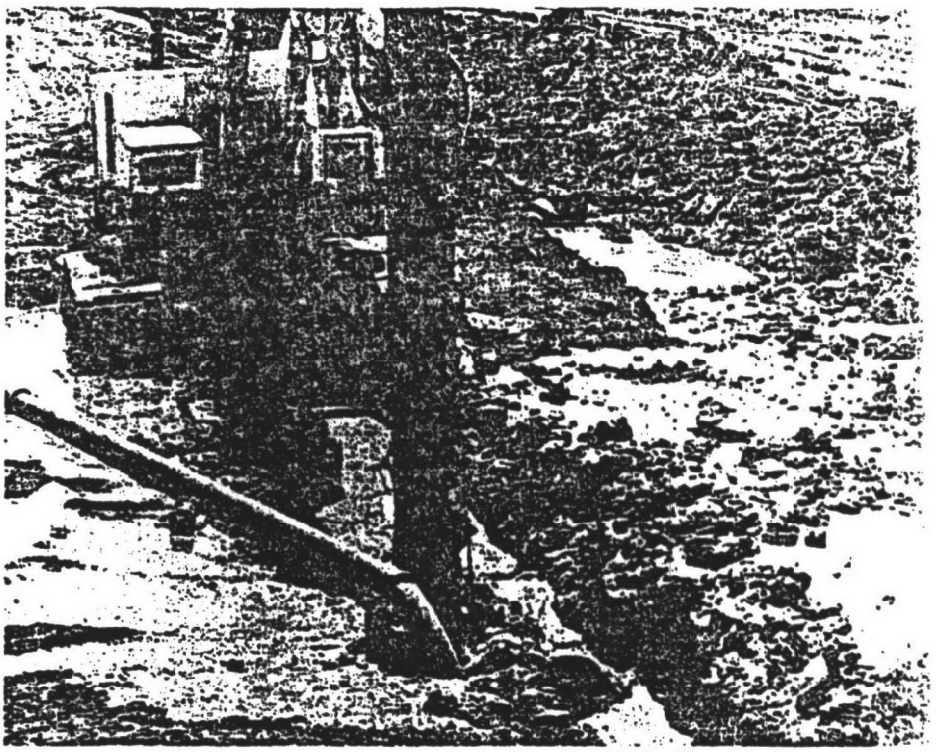
Cleaning up chemical wastes

Army moves to decontaminate Denver aquifer

Groundwater contaminated by military and industrial chemical wastes deposited since World War II at the Rocky Mountain Arsenal near Denver will be intercepted by a slurry wall cutoff, pumped from shallow aquifers, treated with activated carbon beds and recharged in an ambitious $6-million system due on line this August.

By doing what many environmental engineers say needs to be done to reverse the damage done to critical groundwater supplies—and which most claim is too costly to contemplate—the Army will be setting the state of the art and determining the economics of decontaminating aquifers at its Rocky Mountain Arsenal project.

The $6-million system being installed now is the initial phase of a comprehensive solution to the arsenal's chemical waste problem. The grand plan is being pieced together at the Corps of Engineers' Waterways Experiment Station in Vicksburg, Miss., which plans to make its recommendation in October on which of 14 schemes under review should be adopted for what is seen now as a five-year construction program aimed at halting the contamination.



Slurry wall barrier will intercept groundwater for treatment at Rocky Mountain Arsenal.

"We have a long way to go here," says a management coordinator at the arsenal. "We've got to get away from a site-by-site analysis and look at the whole arsenal as a source. That means centralized treatment and disposal of wastes in accordance with RCRA [the Resource Conservation and Recovery Act]."

Building a barrier. In the initial phase, groundwater flows of about 440 gpm along the arsenal's northern boundary will be intercepted by a minimum 30-in.-wide soil-bentonite slurry wall extending 6,740 ft between high bedrock formations. The new barrier will be an extension of a 1,500-ft section installed as part of a pilot test of the purification system being built now. The cutoff is being excavated from 25 to 50 ft deep through saturated alluvium and a drier underlying formation of clay shale and claystone interbedded with sand lenses. Its base will be keyed 3 to 5 ft into bedrock.

Fifty-four dewatering wells, six of them from the pilot test, will be used to selectively intercept and permit separate treatment of three identified plumes of contamination along the length of the groundwater barrier. Collection lines will feed each of the three groundwater streams via a wet well to dual-media filters coupled to one of three counter-current, activated carbon adsorption columns for removal of organic chemicals. Total capacity of the three columns will be about 1 mgd. Treated effluent will be combined into a single stream and injected through 38 recharge wells into the aquifer on the north side of the barrier.

Alvarado Construction Co., Denver, was awarded a $4.2-million contract by the Corps in January for the slurry wall and pumping system under a small business set-aside. Most of the work has been subcontracted, the major portion to Engineered Construction, Inc., a subsidiary of D'Appolonia Consulting Engineers, Inc., Pittsburgh. Black & Veatch, Kansas City, designed the barrier and pumping system for the Corps with geotechnical work done by Earth Sciences Associates, Fort Collins, Colo.

The adsorption columns, projected to use 100,000 to 200,000 lb of carbon a year with 9 to 12 months of service before replacement, are being supplied by the Covington, Va., division of Westvaco Corp., using a treatment system design done for the arsenal by Rubel and Hager, Inc., Tucson, Ariz.

Getting at the source. At least 10 separate sites spread out over the arsenal where chemical wastes were stored, transported or disposed of are being investigated as possible sources of groundwater pollution. In addition to the cutoff and purification

[8-81]

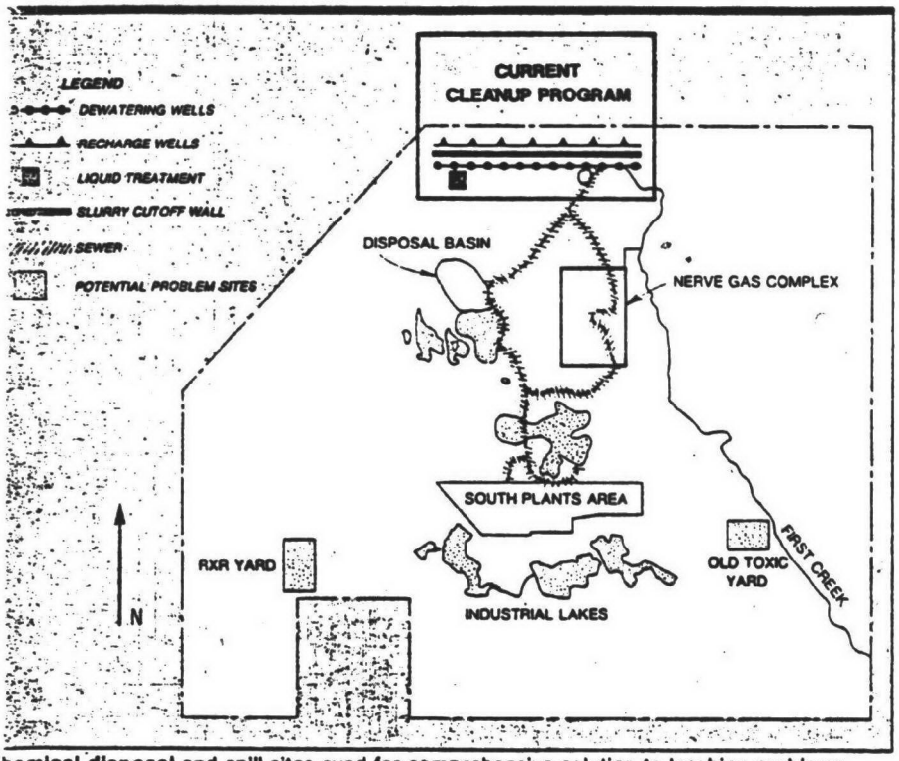
system being built along the northern boundary, plans are being considered for handling residue from an asphalt-lined chemical waste evaporation basin, for a new groundwater barrier along the northwest boundary, additional water purification and recharge systems and a secure disposal site for spoil, sludges or ash.

Groundwater contamination at the arsenal is believed to date from 1942 when the 25-sq-mile facility in Commerce City was built up to produce chemical and incendiary munitions. In 1946, after the war, most of the manufacturing facilities at the arsenal were leased to private companies, Shell Chemical Co. being the largest, for use in production of herbicides and insecticides. Waste effluents from the military and private manufacturing plants were discharged into an unlined basin next to the manufacturing area (see map).

The start of nerve gas production in 1953 meant a huge increase in salt-laden wastes due to repeated scrubbing of effluents to remove any trace of the deadly gas compounds. For that reason, three additional basins to the northwest of the original disposal area were used to handle overflows.

In 1954, a wet year, several farmers northwest of the arsenal boundary complained of damage to crops irrigated with water pumped from shallow alluvial aquifers. Those complaints, coupled with minor crop damage observed in 1951, led to studies that indicated the unlined ponds on the arsenal were the source of the problem. To halt leaching, the 90-acre asphalt-lined disposal basin was completed in 1957 north of the natural waste effluent ponds. These were breached and emptied into the new evaporation basin. Over the years, however, as the basin filled to its 250-million-gal capacity, the asphalt liner corroded and eventually failed.

Marching orders. Trace concentrations of organic chemicals from nerve gas and Shell's pesticide production were discovered leaching from a bog on the northern boundary of the arsenal and in a well 8 miles north of the arsenal in 1974. A year later the Colorado Department of Health stepped in and ordered the Army to halt discharges of the chemicals, develop a cleanup plan and monitor groundwater to assure compliance.



hemical disposal and spill sites eyed for comprehensive solution to leaching problems.

Subsequent water analyses have shown that chemicals not covered under the original order are present in trace concentrations in wells to the north and northwest of the arsenal. Among the most worrisome is a pesticide manufactured at the arsenal by Shell under the trade name Nemagon from 1955 to 1976. A male sterilent and suspected carcinogen, minute concentrations of the pesticide were discovered two months ago in 25 shallow wells west of the arsenal.

Groundwater in the vicinity of the arsenal flows mostly through shallow deposits of alluvium in channels between high areas of bedrock. A slight gradient dipping to the north and northwest carries the slow-moving groundwater to a branch of the South Platte River, as close as 5 miles away on the western boundary. Land between the arsenal and the river is used primarily for irrigated agriculture. Even before the contaminants were discovered, however, the diminishing quantity and quality of the groundwater in the alluvial aquifers meant that most farmers and homeowners had drilled deep wells.

The Denver office of the Environmental Protection Agency, while leaving most of the standards-setting to the state, is working with the Army, Shell and the Colorado Health Department to develop a schedule for the cleanup via a letter to be signed by each of the parties. Although state fish and wildlife officials are pushing for quick action, EPA's Paul Osborne says, "Our dates may be a few months ahead of the Army's, but it's not going to mean big problems."

Duck soup. Among the most immediate concerns of the state and EPA is the rate at which the remaining disposal basin is emptied. It originally held 250 million gal of chemical wastes. That was reduced to 160 million gal by 1978 and is now down to about 50 million gal. In addition to leaching, one of the problems is that few of the unsuspecting ducks that land on the basin survive, although warning systems and the basin's smaller size have reduced kills from over 1,000 per year to between 300 and 400.

Once the basin is dry, the residue will be removed and treated, incinerated or moved to a secure disposal area. The question at that time will be how much of the contaminated soil will have to be treated or disposed of. Once other areas in the arsenal are analyzed, the same question could apply at those sites as well. Says EPA's Osborne, "If they have to scrape 5 or 6 ft of earth off those areas, I've heard estimates that the disposal cost could range up to a billion dollars."

One purpose of the Corps' painstaking analysis of alternative solutions is preventing costs from snowballing into those kinds of figures. Holding costs in check while solving the groundwater contamination problems will be difficult, however. For example, the Corps recently estimated it would cost $89 million to dredge and seal a section of river at its Redstone Arsenal, near Huntsville, Ala., where Olin Corp., Stamford, Conn., discharged 835 tons of DDT over 20 years from a plant leased from the Army (ENR 3/19 p. 56).

In any case, while most public agencies and private companies responsible for chemical waste dumps spend their time and money in courtrooms, the Corps and Army officials are moving to find a fix for the effects of past disposal practices. As a result, says one technical specialist, "There are a lot of lessons being learned by the Corps that could be applied at other sites across the country. It could be the action agency in a national effort to get uncontrolled chemical wastes sites straightened out." □

opening at the flow line of the half-ring stations helps dry-weather-flow clean the conduit between half-ring stations (photo). The flow area at the half-ring station is large enough to pass any debris entering the 114-inch pipe. The 30° bevel of the leading face of a ring segment provides a radial force component to hold the segment and facilitates debris passage.

The whole design procedure began with the use of FHWA Hydraulics Engineering Circular 13. The outlet pipe, size of ring segments, and spacing of the ring stations are determined from these documents. This initial design, however, has five 5-ring stations each, of which has four 4-ring segments. The first model flow tests indicated this initial design provided too much choking when model flow simultated the 100 year frequency storm. The excessive choking forced the model 120-inch pipe into pressure flow. Two ring stations plus the top two 2-ring segments were removed to obtain the desired choking level. The greatest turbulence with maximum energy change occurred within the 156-inch pipe, but did not project back into the simulated 120-inch pipe. Maximum energy loss with no backwater was the final design criteria for the outlet pipe. □ □

AMSA makes marketing and distribution recommendations

The EPA should require less stringent groundwater monitoring and sludge analysis standards. This is one of several recommendations contained in the Association of Metropolitan Sewage Agencies (AMSA) recent review of the EPA's Preproposal Draft Regulations on the distribution and marketing of sewage sludge products.

The AMSA also recommended:

- Reliance on finished product limitations on chemical constituents present in the sludge to ensure protection of the public health.
- Modification of the sludge fertilizer product definition by providing what they call more reasonable moisture and nitrogen requirements.
- Adoption of a 60 ppm cadmium limitation for distribution and marketing of sludges.
- Elimination of all other limitations on cadmium from the regulations.
- Adoption of a level of 30 ppm for PCB's. The AMSA views this as a satisfactory limit to ensure protection of the public health. They feel it will allow POTW's to beneficially use their sludge.
- Authorization for the states to adopt sale and give-away standards consistent with local soil conditions. This would include the deletion of the 10% lime requirements for soils with a greater than 6.0.
- Adoption of a lead level of 1000 ppm for sludge products. The AMSA stated that this would be sufficient to protect pica children even if they ingested sludge directly. They cited available scientific information.
- Deletion of the requirements for metal and PCB content for sludges applied to government owned lands.
- Adoption of, what they termed, a more reasonable and scientifically justified approach to Processes to Significantly Reduce Pathogens as well as Processes to Further Reduce Pathogens. (The AMSA feels these should be eliminated.)

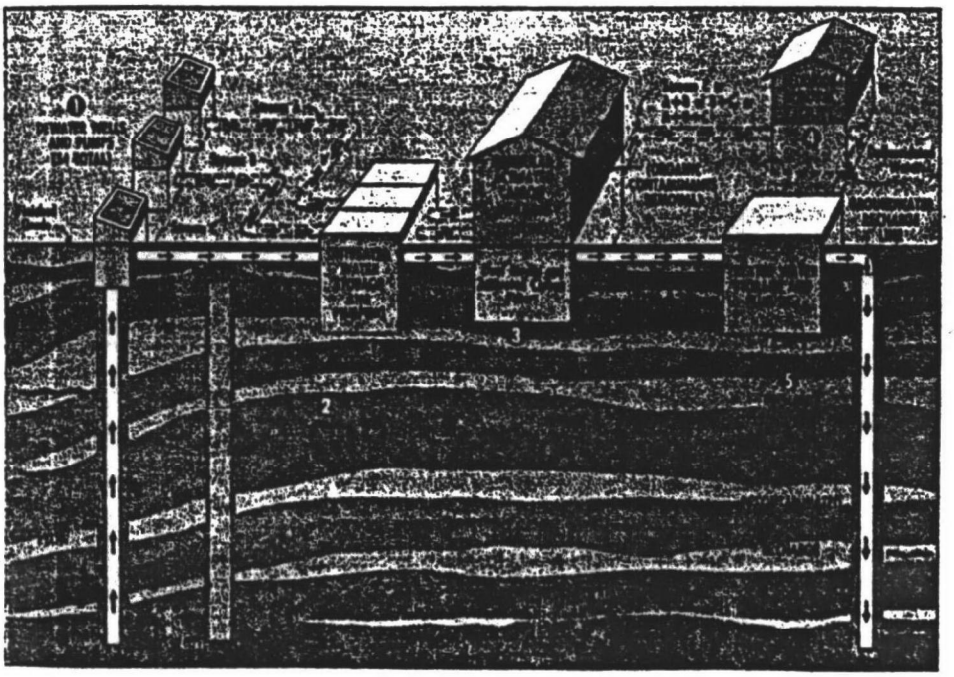
According to the AMSA, the EPA's marketing and distribution regulations scheduled for proposal this December, and promulgation in December 1981, could have a severe economic impact on municipal agencies with sludge give-away and sale programs.

In addition, they feel the regulations may make it more difficult for POTW's to dispose of their sludge and to meet federally mandated pretreatment requirements.

The AMSA stated that the EPA's initial response to their recent comments was favorable. However, they stressed that the extent to which the Agency is amenable to their suggestions will not be evident until the Agency proposes the marketing and distribution regulation in the Federal Register. This is planned for December.

The AMSA plans to review this proposal and make recommendations to ensure that "yet another municipal sludge management option is not foreclosed by the EPA".

System to treat contaminated groundwater developed



A system to contain contaminated groundwater, remove it from the aquifer, treat it, and return it to the aquifer has been designed for use at the Rocky Mountain Arsenal in Colorado.

Major components of the system include:

(1) 54 dewater wells valved and manifolded to selectively intercept and permit separate treatment of three zones of contamination (2) a 6,740 ft. long groundwater barrier extending into bedrock (3) granular activated carbon filters for organic contaminant removal (4) activated alumina columns for fluoride removal (5) 38 groundwater recharge wells downgradient of the barrier to reinject treated water into the aquifer (6) monitoring wells located throughout the system, which will provide water quality and water level information to permit fine tuning of the system to its maximum effectiveness.

The system was developed by the Black & Veatch Special Projects and Civil Environmental Divisions for the U.S. Army Corps of Engineers.

Section 8.4

Abandoned Drinking Water/Waste Disposal Wells
Supporting Data

Section 8.4.1

TITLE OF STUDY: (or SOURCE OF INFORMATION)	"Abandoned Wells" From Inventory and Assessment of Class V Injection Wells in Minnesota
AUTHOR: (or INVESTIGATOR)	Geraghty and Miller
DATE:	December, 1986
FACILITY NAME AND LOCATION:	Minnesota USEPA Region V
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	This excerpt discusses the following topics concerning abandoned wells: magnitude of the problem, adverse effects of abandoned wells, reasons for sealing abandoned wells, priorities for sealing abandoned wells, sealing procedures, inspection, sampling, remedial action-clearing the well, casing removal, sealing, zones of lost circulation, types of grout, grout pump and grouting procedures, and abandoned well reports.

ABANDONED WELLS

Water Wells

- 2/3 of Minnesota's population (2.6 million people) consume ground water
- 800,000 residents use private wells
- Approximately 200,000-400,000 private wells exist in the State
- Approximately 10,000 new wells are drilled annually

Abandoned Water Wells

- Definition - "Abandoned water well" means a well whose use has been permanently discontinued, or which is in such disrepair that its continued use for the purpose of obtaining ground water is impractical or may be a health hazard.
- Regulatory Control - Minnesota Statutes, Chapter 156A.05
  Minnesota Water Well Construction Code, 7 MCAR § 1.218C.

Number of Abandoned Wells

- Low Estimate - Houston, Wabasha, Winona, Fillmore survey, estimates 1500 to 2150 abandoned wells in the four counties; 375 to 535 per county.
- High Estimate - Using one abandoned well per active well equals approximately 3000 abandoned wells per county.

Priorities

1. Wells located in areas of major pollutant discharge or intercepting ground water contamination plumes. Wells near spills of chemicals or petroleum products, waste sites, processing facilities, landfills.
2. Developments with private wells annexed by, and connected to, municipal water systems. Cross-connection hazards.
3. Demolition, rehabilitation or construction areas. Problems of scheduling proper sealing while access is available.
4. Wells improperly constructed, located, or maintained. Wells with faulty seals or casings, multi-aquifer wells, "recharge" or disposal wells, wells near contamination sources such as septic systems.
5. Wells in geologically sensitive areas, wells completed in or through carbonates.
6. All other abandoned wells.

Proper Well Abandonment

1. Inspection, surface and subsurface

2. Sampling

3. Remedial action, if necessary. Redrilling, clean out, perforation

4. Complete sealing when clear and clean

5. Evaluation if ground water contaminated

   - Costs vary from nominal to $100,000+
     Average domestic 4-inch wells is $500-$1500

   - Most cost effective abandonment at time of new well construction or as part of large program

Abandonment Program

1. Status Quo - State program

2. Surveillance - Informal liaison with State

3. Inspection - Onsite, in conjunction with new well, septic, building or other programs

4. County Survey - Door to door, well records, remote sensing

5. Ordinance - With or without new well inspection

6. Permits - With or without new well permits

7. Enforcement - Local ordinance, State Well Code, Minnesota Statutes, injunction, imminent health hazard

Problems

- Location - Where are the wells?

- Inspection - What is magnitude of problem?
  Time, personnel, sampling and equipment costs

- Enforcement - Inevitable

ABANDONED WELLS

Magnitude of the Problem

Abandoned wells are water wells whose use has been discontinued or which are in such disrepair that continued use is impractical or may be a health hazard. Abandoned unsealed wells can act as conduits or channels for contamination to reach the groundwater. The threat of open holes serving as passageways for surface or near-surface contamination poses a major problem to the groundwater, particularly in contaminated areas.

The magnitude of the problem was demonstrated by a pilot study conducted by the Minnesota Department of Health in 1973. The pilot study located abandoned wells in five southeastern Minnesota townships in Winona, Fillmore, Wabasha and Houston Counties. The study revealed a surprisingly large number of abandoned wells with estimates ranging from 1,200 to 2,050 abandoned wells for the five townships or about one abandoned well for every five active wells in operation. Later information from the University of Minnesota, School of Public Health's abandoned well survey indicated that there may be as many as one to four abandoned wells for every active well.

The total number of abandoned wells can be visualized when it is realized that approximately 100,000-400,000 active wells are estimated to exist in the state. Based on the abandoned well survey, this means that approximately 100,000-1,600,000 abandoned wells are present throughout the state threatening the quality of the groundwater.

Adverse Effects of Abandoned Wells

Properly constructed water wells are not normally sources of groundwater contamination. But when the wells are in a state of disuse or disrepair, or if they are buried or casings are damaged and begin to deteriorate, then the wells can become conduits through which contamination can travel vertically through boreholes.

Since 1974, when the Minnesota Water Well Construction Code came into effect, water wells have been drilled so that they do not pose a threat to the groundwater if properly maintained. In some instances today, an aquifer must be sealed off and special well construction employed, for example, in geologically sensitive areas underlain by limestone. The Code may require casing and grouting of the limestone.

An abandoned well's potential for adversely affecting groundwater quality will depend on its original use, the local geology, land use, the hydraulic characteristics of the subsurface fluids, and the type of well construction. When a well is improperly sealed, it is often simply covered by a board or a sheet of metal in an unsuccessful attempt to insure that the well does not become a hazard. Unfortunately, such procedures fail to take into account the fact that the mere existence of an unsealed, abandoned well represents a great hazard to groundwater quality either as a direct conduit for surface contamination to enter the groundwater or for inter-aquifer exchange, that is, flow between two aquifers having different heads.

The natural quality of groundwater tends to be degraded by the activities of man. Wastes, which are not discharged into lakes and streams are deposited on or below the land and from there may migrate downward to contaminate the groundwater. The problem is compounded because groundwater contamination and the effects of contamination are not usually recognized until groundwater quality is seriously impaired.

Reasons for Sealing Abandoned Wells

Unsealed abandoned wells constitute a hazard to public health and a danger to groundwater supplies. In Minnesota approximately two-thirds of the state's population (2.6 million people) consume groundwater. Such a valuable resource must be protected from unwarranted neglect in allowing degradation from abandoned wells.

The principal dangers of an abandoned well are that it may transfer surface or near-surface contamination through the well bore or through the unsealed annular space between the casing and hole or between two casings or from a contaminated aquifer to an uncontaminated aquifer. Many abandoned wells are buried below the ground surface and may transfer contamination directly into the groundwater. Groundwater normally moves very slowly, from a few feet to tens of feet per year, and in the process is filtered and cleaned up or attenuated before it moves into the lower water-bearing zones. An abandoned well will cause the natural clean-up process to be circumvented and transfers large amounts of contaminated water to be concentrated at one point.

The ability of a well to transfer large amounts of water back into the groundwater system has been documented on many occasions. Such an example occurred a number of years ago when a recharge well in the Twin Cities was used to dispose of storm water before the practice was halted by the state. The well drained a storm sewer holding pond into the underlying groundwater at the rate of 2,000 gallons per minute. The well was reported to be completed in the highly fractured Shakopee limestone, a formation known to yield and accept large volumes of water.

A summary of the types of abandoned or unsafe wells that may transfer contamination into the groundwater may be classified as follows: (1) buried wells in which contamination may enter the well through the buried top of the casing; (2) wells in which the casing has been corroded and surface or near-surface water may run into the well; (3) improperly constructed wells in which the annular space around the outside of the casing is not sealed and acts as a channel; (4) improperly constructed wells in which an unsealed inner casing allows the transfer of water between formations; (5) open hole wells in which the borehole interconnects aquifers.

Priorities for Sealing Abandoned Wells

The abandoned well program has been one of the target projects for extra effort by the Minnesota Department of Health because of the recognition of the importance in protecting groundwater. Recognizing that a large number of abandoned wells exist with varing hazards, an abandonment priority has been developed:

1. Major well abandonment efforts have been the target for abandoned wells located in areas of major pollutant discharge or where wells intercept contamination plumes. This includes wells located near spills of industrial chemicals or petroleum products, waste sites, processing facilities and landfills.

2. Developments with private wells annexed by and connected to municipal water systems. A cross-connection hazard exists between the water systems.

3. Demolition, rehabilitation or construction areas or where there are problems of scheduling proper sealing while access is available.

4. Wells improperly constructed, located or maintained. Wells with faulty seals or casings, multi-aquifer wells, "recharge" or disposal wells, wells near contamination sources such as septic systems.

5. Wells in geologically sensitive areas, wells completed in or through carbonates (limestone).

6. All other abandoned wells.

Sealing Procedures

Sealing of abandoned wells may be classified as temporary or permanent. A temporary seal or temporary removal of a well from service requires written approval from the Minnesota Department of Health. In addition to placing a watertight cap or cover on the casing, the well must be maintained so that it is not a source or channel of contamination when not in service. A permanently abandoned well requires that it be disconnected from the system and the hole completely filled.

The statutory authorization for the sealing of abandoned wells is vested in Minnesota Statutes, Chapter 156A. Under this statute the Minnesota Department of Health, through the Commissioner of Health, has been granted strong regulatory power. The Commissioner may order the owner of a well to take remedial measures including making repairs, reconstruction or sealing of a well. The order may be issued if the Commissioner determines, based upon inspection of the well and site or analysis of the water from the well, that any of the following conditions exist:

1. The well is contaminated.

2. The well has not been sealed and abandoned properly.

3. The well is in such a state of disrepair that its continued existence endangers the quality of the ground water.

4. The well is located in such a place or constructed in such a manner that its continued use or existence endangers the quality of the groundwater.

The law (Chapter 156A) specifies that no contractor shall drill, construct, repair or seal and abandon a water well unless in the possession of a valid license issued by the State Commissioner of Health.

Inspection

Inspection of abandoned wells is the first step in proper sealing. While some wells are easily located, others may be buried or otherwise concealed. Location of abandoned wells may be through contact with the present or past owners, neighbors, or water well contractors. Regulatory officials may have information. Historic documents may be used such as aerial photo and plat maps, insurance company maps or photographs. Metal detectors may be of value in locating buried casings.

The procedure for sealing abandoned wells starts with obtaining information on the well's construction and condition. This information is best obtained from water well drilling records. Historical well records are filed with the Minnesota Geological Survey. Water well records for wells drilled after 1974 may be obtained from the Minnesota Department of Health. When written water well record information is lacking, interviews with the owners or well driller may provide information. A downhole TV camera survey can provide valuable information and can also verify the current well depth, condition and construction. In specific circumstances, the Minnesota Department of Health may conduct a camera survey.

After information is obtained about the well's construction, a site inspection will be necessary to ascertain the condition of the well and to note if the well is accessible, located in a pit, or buried, if the pump has been removed or if the well is currently operating. Inspection should also note if the well has been damaged or obstructed. When the well has been damaged, it is usually very expensive and time consuming to seal it.

Sampling

The policy of the Minnesota Department of Health is to require water samples from abandoned wells in industrial or commercial areas or where contamination is present or suspected. The water analysis is usually tailored to the specific constituents suspected, but a complete analysis may be run where a broad range of chemicals are suspected.

The owner is responsible for the cost of sealing an abandoned well including sampling costs. A complete laboratory analysis can consist of the following parameters:

1. 20 inorganic chemicals - sodium chloride, nitrate, etc.
2. 10 metals - lead, mercury, etc.
3. 12 volatile non-halogenated organic chemicals, such as benzene, toluene, etc.
4. 42 volatile halogenated organic chemicals - trichloroethylene, etc.

The sampling protocol is to pump the well until a water sample is obtained that is clear of debris, and sediment. Once the water is "clear" the usual procedure is to pump the well three to five times the calculated volume of water in the well bore to obtain a representative sample. The object is to purge the well of water that has been "standing" in the casing. Water samples taken for anlaysis at the Minnesota Department of Health are only taken in clean, specialized sample bottles provided by the Minnesota Department of Health laboratory.

Remedial Action - Clearing the Well

Sealing of abandoned wells starts with removing the pumping equipment and clearing any obstacles or debris that may have entered into the well.

When the well is obstructed and pumps or other equipment have been dropped down the well, the debris will have to be removed or "fished" out before the well can be sealed. A variety of fishing tools are used to remove obstructions. Threaded taps on the end of a drill rod may be run into the hole in an attempt to screw into the top of a pump or drop pipe. Other types of equipment used are over shots (a casing with inner teeth that is run over the obstacle to be removed), corkscrews, and spears used to hook the obstacle for removal.

In some instances the driller may chop or grind up the obstacle in an attempt to clear the well. Debris or other materials such as rock, sand, clay, stones, wood, etc., is usually drilled out or washed out of the hole. Fishing material out of a borehole is very difficult and the success of the operation is dependent on the experience and ability of the driller, but also somewhat subject to luck.

Casing Removal

Multiple strings of casing in a well increase the difficulty of sealing the well. To properly seal a well a non-grouted inner casing must be: (1) removed, or (2) perforated or ripped to insure that the annular space is sealed throughout its length, or (3) in rare instances a tremie line may be installed between the casings to grout up the annular space. In older wells the annular space is often too small to grout by use of a tremie line between the casings.

Whenever possible, the Minnesota Department of Health recommends that the casings be removed. On shallower wells, particularly sand point wells, the casing can usually be removed. Often the cost of casing removal and negligible salvage value will lead to leaving the casing in place.

Sealing

Upon clearing of the well bore, the well is ready for sealing. The preferred method of sealing is to pump neat cement through a tremie pipe from the bottom of the well to within two feet of the surface in one continuous operation. The casing should be cut off two feet below the surface and the hole backfilled with native material.

Permanent sealing of an active unobstructed well will usually require the simple process of removing the pumping equipment, inserting the tremie line and pumping grout into the well. Care must be taken at this time that the grout line does not become buried too deeply in the cement so that it cannot be pulled out. Usually the driller will use "feel" to determine if the grout level is rising on the tremie line, and remove one or more sections at a time, keeping the lowest section of the tremie pipe submerged in grout.

Usually a tremie line of 1- or 1½-inch diameter galvanized steel or plastic pipe is used to install the grout to the bottom of the well. Larger diameter pipes may be used for larger diameter wells.

Grout and sealing materials other than neat cement may be used to seal a well in some instances, but the filling material should be selected so as to restore natural conditions as nearly as possible.

1. Unconsolidated deposits such as glacial drift may be sealed with a mixture of clean sand and puddled clay or neat cement grout or concrete grout (above the static water level) to provide a permeability no greater than the natural condition.

2. Cavernous or creviced rock such as cavernous limestone, basalt, creviced granite, etc., may be sealed with alternate layers of neat cement or concrete with gravel or stone aggregrate. When alternative materials are placed in the well they shall be installed so that consideration is taken to seal the hole. For example, a large diameter well constructed through several aquifers separated by confining beds must have cement grout placed so that the confining beds are isolated or sealed off from the aquifers. Thus when large diameter wells are sealed, the filling material will be selected so that the water-bearing zones are isolated.

3. A blasted and bailed hole in which a large cavern was created may be filled with clean sand equivalent in permeability to the aquifer.

The Well Code requires that concrete grout, cement grout, and bentonite must be installed through a tremie line to insure the proper placement of the grout from the bottom to the top of the well.

It should be noted that a tremie line is used because it (1) insures that grout is placed in the bottom of the hole, (2) insures a proper cement/water ratio, which affects the strength and permeability of the grout, (3) insures that the sand and cement in a concrete mix do not segregate.

Zones of Lost Circulation

Zones of lost circulation are commonly encountered when sealing wells completed through cavernous rock. Such zones may be badly fractured rock that has large caverns or solution channels in which large volumes of grout may be lost.

The Minnesota Department of Health recommends that whenever lost circulation zones are encountered, the grout should be pumped until it is certain that

cement is being lost. Grouting should then stop and the cement be allowed to set up. Generally three hours is sufficient time for the grout to set, after which grouting can be resumed. If upon resuming the grouting operation the grout continues to be lost, 3/8- to 1/2-inch diameter "pea rock" may be inserted very judiciously from the surface in an attempt to plug the zones of lost circulation while simultaneously inserting grout through the tremie pipe.

The "pea rock" is used to plug the cracks and crevices as it floats on the top of the cement and acts as a plug or restriction to the cement flow through fractures or broken rock in the zones of lost circulation.

In all well abandonment operations, no matter what types of filling material are used, the top 10 feet must be sealed with cement or concrete grout.

Types of Grout

Grout used to seal wells may be classified as follows:

1. **Neat Cement Grout** - A mixture of one bag (94 pounds of Portland cement (ASTM C150-69A)) to not more than 6 gallons of clean water. Bentonite up to 2% by weight of cement may be added to reduce shrinkage or other admixtures (ASTM C457-69) to reduce permeability and/or control set time below the water level in the well. It should be noted that one bag of cement to 6 gallons of water is a very fluid mixture, but the mixture will set up like concrete after it hardens. Cement grout may be used as grout for wells constructed in all geologic formations.

2. **Concrete Grout** - A mixture of cement, sand and water in the proportion of one bag of Portland cement (94 pounds) (ASTM C150-69a) and an equal volume of dry sand to not more than 6 gallons of clear water. Where large volumes are required to fill openings, gravel not larger than ½-inch diameter may be added. Concrete grout shall not be used below the water level.

   Concrete grout may be used in all geologic formations such as drift, sandstone, metamorphic rock, and igneous rock but must not be placed below the water level.

3. **Heavy Drilling Fluid or Heavy Bentonite** - Heavy bentonite is a mixture containing a minimum of 10% bentonite by weight added to clean water or approximately 5% bentonite added to drilling mud. The fluid must be of sufficient viscosity to require a time of at least 70 seconds to discharge one quart of grout through an API (American Petroleum Institute) Marsh funnel viscometer.

   Heavy drilling fluid or heavy bentonite may be used as grout for glacial drift formations comprised of sands, clays, tills, etc.

Grout Pump and Grouting Procedures

Grout is inserted under pressure by means of a grout pump. These pumps are typically screw, rotor, piston, or diaphram-type pumps usually run by a gas engine or an air compressor. A Moyno pump is typical of the screw-type pump. Other common types are the Wilden diaphram and piston pumps typically called "contractor's" pumps. The pumps are usually capable of developing 100-125 psi or greater pressure. All pumps will clog with aggregate or bad cement. To avoid this problem contractors will usually screen the cement before it is run through the pump. Pumps will not allow large-sized aggregate to pass through. A diaphram pump will usually allow aggregate not larger than one-third the throat size to pass. The throats are usually 1/4- to 3/8-inch in diameter. Particles larger than sand size will often clog typical pumps.

Licensed water well contractors seldom use the drilling equipment mud pump for grouting with cement because of the difficulty in cleaning and fear of clogging the mud pump. A separate pump is generally dedicated for grouting use.

Abandoned Well Report

The final step in sealing an abandoned well is the submission of an abandoned well report by the licensed water well contractor. The report is the official documentation that the well has been sealed and no longer constitutes a real or potential pathway for contamination to enter the groundwater.

The abandoned well report should be reported to the Minnesota Department of Health on a water well Work Copy (the water well form that does not have a Unique Well Number printed on the upper righthand corner). The information given should include all data that is known about the well including such information as depth, diameter, static water level, casing schedule, geology, method of sealing, volume and type of grout used.

TABLE 1
CAPACITIES OF WELL CASING

Diameter of Holes - Inches	Gallons Per Linear Foot	Sacks of Cement Per Linear Foot	Linear Feet Per Sack of Cement	Cubic Yard of Grout To Fill 100' of Hole
1¼"	0.064	0.007	137.8	.03
2"	0.163	0.020	50.2	.08
3"	0.367	0.031	32.1	.18
4"	0.653	0.079	12.6	.32
5"	1.020	0.124	8.0	.50
6"	1.468	0.178	5.6	.73
8"	2.611	0.337	3.2	1.3
10"	4.080	0.496	2.0	2.0
12"	5.875	0.714	1.4	2.9
14"	7.996	.972	1.03	4.0
16"	10.448	1.270	0.78	5.2
18"	13.219	1.606	0.62	6.5
20"	16.320	1.983	0.50	8.1
24"	23.501	2.856	0.36	11.6
30	36.720	4.462	0.22	18.2
36	52.877	6.426	0.15	26.2

*One sack cement = 1.1 foot^3

TABLE 2
Typical Quantity of Grout Found Necessary
to Fill Wells in the Seven County
Metropolitan Area

Wells Completed in Geologic Formation	Volume (Does not include blasted and bailed sections of wells.)
Drift	1 x Calculated Borehole Volume x Depth
Platteville Limestone	3 x Calculated Borehole Volume x Depth
St. Peter Sandstone	1.2 to 1.3 x Calculated Borehole Volume x Depth
Shakopee Dolomite	2.5 x Calculated Borehole Volume x Depth
Jordan Sandstone	1.2 x Calculated Borehole Volume x Depth

Useful Formula:

- Gallons per 100' = 4.08 x (Inside Hole or Casing Diameter)^2
- Cubic feet of grout per 100 feet = .55 x (Inside Hole or Casing Diameter)^2
- 7.48 gallons = 1 cubic foot
- 202.0 gallons = 1 cubic yard

Anoka | Abandoned

Township Name: Oaktree | Township Number: 120 N | Range Number: 22 W | Section No.: 16 | Fractions: NW¼ SE¼ SE¼

Distance and Direction from Road Intersection or Section Address and City or Well Location: 100' East of Co Rd 9, 200' South of Co Rd 2

Show direction of well location

Address of Well: Red Oaks | Block Number: 2 | Lot Number: 1

Co Rd 2 | Co Rd 9 | Well

FORMATION LOG	COLOR	HARDNESS OR FINENESS	FROM	TO
*Sand	brown	soft	0	10
Clay	green	med	10	50
Clay and sand	grey	med	50	98
clay	blue	med	98	115
sand	brown	med	115	126
†formation log	estimated from			
well nearby	(#101057)			

Use a second sheet if needed

REMARKS ELEVATION SOURCE OF DATA etc

Pump removed from well. 1¼ yds neat cement installed thru remie pipe. Casing cut off 2 feet below grade. Top 2' filled with native soil.

WORK COPY

3 PROPERTY OWNER'S NAME: John Jones
Address: RR1 Box 23, Gilman, Mn 56297

4 WELL DEPTH (completed): 126' | Date of Completion: drilled 1948

5 [X] Cable tool [ ] Rotary [ ] Driven [ ] Dug [ ] Hydraulic rotary [ ] Air [ ] Jetted [ ] Bored [ ] [ ] Reverse rotary [ ] Directional [ ] Other (specify)

6 USE: [X] Domestic [ ] Public supply [ ] Industrial [ ] Irrigation [ ] Monitoring [ ] Commercial [ ] Test Well [ ] Air conditioning [ ]

7 CASING: [X] Black [X] Threaded [ ] Galv. [ ] Welded [ ] Plastic [ ] | Height Above/Below: Surface 1 ft. | Open Hole? Yes ___ No ___
4 in. to 122 ft. | Weight ___ lbs./ft. | Hole Diam ___ in. to ___ ft.

8 SCREEN: Make ___ | Type Brass mesh | Dia. 4 inch | Slot/Gauge 15 | Length 4 feet | Set between 122 ft. and 126 ft. | Fittings ___ | Or open hole from ___ ft. to ___ ft.

9 STATIC WATER LEVEL: 52 ft. [X] below land surface [ ] above | Date Measured 2/2/85

10 PUMPING LEVEL (below land surface): ___ ft. after ___ hrs. pumping ___ GPM

11 WELL HEAD COMPLETION: [ ] Pitless adapter manufacturer ___ model ___ [ ] Basement offset [X] At least 12" above grade

12 WELL GROUTED? [ ] Yes [ ] No
[X] Neat cement [ ] Bentonite [ ] ___
Grout material: cement | From 2 ft. | To 126 ft. | Cu. Yds. 1¼

13 NEAREST SOURCES OF POSSIBLE CONTAMINATION: ___ feet ___ direction ___ type
Well disinfected upon completion? [ ] Yes [ ] No

14 PUMP: Date installed Removed 2/2/85 | Not installed
Manufacturer's name: Dooks
Model number: B-12 | HP 1/2 | Volts 110
Length of drop pipe: 72 ft. | Capacity ___ GPM
Material of drop pipe: ___
Type: [X] Submersible [ ] L.S. Turbine [ ] Reciprocating [ ] Jet [ ] Centrifugal [ ] ___

15 WATER WELL CONTRACTOR'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Gopher State Well Co 74999
Licensee Business Name | License No.
Box 382, Rt 1 Gilman, Mn
Henry Ramsey | Date 2/2/85
Authorized Representative
Ralph Sibley | Date 2/2/85
Name of Driller

HE-01218-01

[8-97]

Section 8.4.2

TITLE OF STUDY: (or SOURCE OF INFORMATION)	Permanent Well and Test Hole Abandonment
AUTHOR: (or INVESTIGATOR)	U.S. Environmental Protection Agency, Office of Water Supply
DATE;	1975
FACILITY NAME AND LOCATION:	Not Applicable
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	This excerpt from the Manual of Water Well Construction Practices discusses preparation for abandonment, abandonment of several types of wells, aquifer sealing criteria, permanent bridges, placement of grout, placement of fill, special conditions, and well abandonment records.

PERMANENT WELL AND TEST HOLE ABANDONMENT

From: Manual of Water Well Construction Practices, U. S. Environmental Protection Agency, Office of Water Supply, EPA-570/9-75-001

PREAMBLE

Unsealed abandoned wells constitute a hazard to public health, safety, welfare, and to the preservation of the ground water resource. The sealing of such wells presents a number of problems, the character of which depends upon the construction of the well, the geological formations encountered, and the hydrologic conditions. To seal an abandoned water well properly, several things must be accomplished: 1) elimination of a physical hazard; 2) prevention of ground water contamination; 3) conservation of yield and maintenance of hydrostatic head of aquifers; and 4) prevention of the intermingling of desirable and undesirable waters.

The basic concept governing the proper sealing of abandoned wells is the restoration, as far as feasible, of the hydrogeologic conditions that existed before the well was drilled and constructed, for an improperly abandoned well might serve as an uncontrolled invasion point for contaminated and polluted water. Any well that is to be permanently abandoned should be completely filled in such a manner that vertical movement of water within the well bore, including vertical movement of water within the annular space surrounding the well casing, is effectively and permanently prevented and the water is permanently confined to the specific zone in which it originally occurred. If all these objectives can be accomplished, all the rules for sealing wells heretofore presented will be fulfilled.

To seal an abandoned well properly, the character of the ground water must be considered. If the ground water occurs under unconfined or water-table conditions, the chief problem is that of sealing the well with impermeable material so as to prevent the percolation of surface water through the original well opening, or along the outside of the casing, to the water table. If the ground water occurs under confined or artesian conditions, the sealing operation must confine the water to the aquifer in which it occurs -- thereby preventing loss of artesian pressure by circulation of water to the surface, to a formation containing no water, or to one containing water under a lower head than that in the aquifer which is to be sealed.

Preparation for Abandonment

Strong efforts should be made to remove all materials from a well which may hinder its proper abandonment. This is especially important where specified zones must be sealed.

If a screen has been installed in the well by telescoping, its recovery is usually possible by installing a string or fishing casing from the top of the well to a sand hitch placed close to the bottom of the screen. Following the setting of the sand hitch, a lifting force, applied either by mechanical or hydraulic jacks, or multiple pulling lines from the casing reel of the drilling machine, will usually withdraw the screen from the well.

In recovering steel casings extending to the surface, the least expensive and least hazardous method is to apply a lifting force to the casing by the use of jacks, or with the drilling machine, or with the two in combination. Still more effective is the use of a jarring head applied at the top of the casing string and used in combination with lifting devices.

Maximum recovery is usually obtained by using a trip-type casing spear actuated by a fishing cable tool string and used in combination with lifting devices. The trip spear is usually limited in its use to recently drilled wells or to those in which the casing is known to be in sound condition. The risk of failure associated with the use of a casing spear increases with the age of the well and the depth at which it is to be used.

It is always good practice to probe the well with a swage of the same diameter as the spear prior to inserting the latter.

The order of descent into the casing for a trip spear string of tools is: 1) trip spear; 2) fishing jars; 3) sinker bar of drill stem; 4) rope socket, which is attached to the drilling line. The swage would replace the spear in the above string of tools.

Abandonment

Borehole Bridging --

To reduce cost of unnecessary backfilling of long sections of borehole, it is often desirable to establish a temporary bridge in the borehole upon which a permanent cement-based bridge can be placed. No organic materials should be used in either the temporary or permanent bridge--except that specially manufactured devices such as cement plugging tools in which neoprene rubber or plastics are used, are acceptable and those greatly facilitate the work. Some of these devices permit establishing the permanent bridge without first having to set a temporary one.

Abandonment of Flowing Artesian Wells --

The flowing artesian well with improperly sealed casing and with water escaping around the outside of the casing either to the surface or to another formation presents a special problem. A necessary first step in bringing the

flow under control is to establish a permanent cement seal between the casing and the point or points from which the water is escaping.

In order to place this seal effectively, the flow must be stopped and the water level lowered in the well. This can be accomplished by several methods. Some of these are: 1) pumping the problem well, thereby producing the necessary drawdown; 2) pumping nearby wells, producing the same effect; and 3) introducing high specific gravity fluids at the bottom of the borehole and filling the hole with the fluid until all flow ceases. The method or methods used will depend in part on the shut-in pressure of the well and the depth to which the water level must be lowered.

The sealing of abandoned wells that have a large movement of water between aquifers or to the surface requires special attention. The movement of water may be sufficient to make the sealing with ordinary metarials and by the usual methods impractical. In such wells, large stone aggregates (not more than 1/3 of the diameter of the hole), lead wool, steel shaving, a well packer, or cast lead plug or bridge should be used to restrict the flow thereby permitting the placement of appropriate sealing material. If preshaped or precast plugs are used, they should be several times larger than the diameter of the well to prevent tilting. The flow of artesian wells to be abandoned can best be stopped with neat cement or sand-and-cement grout piped under pressure or, in some instances, by the use of a suitable well packer or cast lead plug placed at the bottom of the confining formation immediately overlying the artesian water-bearing zone.

In wells in which the hydrostatic head producing the flow is low and in which there is no escape of water below ground, the movement of water can be arrested by extending the well casing to an elevation above the artesian pressure surface. This permits the placement of sealants and fill materials, after which the casing may be cut off at or below ground level.

Abandonment of Other Borings and Holes --

Mineral exploration holes, solution or "in situ" mining wells, dewatering wells, temporary service wells, construction water wells, process wells, and/or other structures that affect the withdrawal from or quality of water in the ground water reservoir, regardless of location or intended life of the structure or hole, should be abandoned as described herein for water supply wells.

Functions of Seals --

Three basic types of seals -- distinguished by their functions -- may be used in a properly abandoned well. They are:

A. Permanent Bridge-Seal: The deepest cement seal to be placed in the well, this seal serves two purposes: it forms a permanent bridge below which a considerable volume of unfilled hole may remain and upon which fill material may be safely deposited; and it seals upper aquifers from any aquifer(s) which may exist below the point of sealing (See Fig. 1).

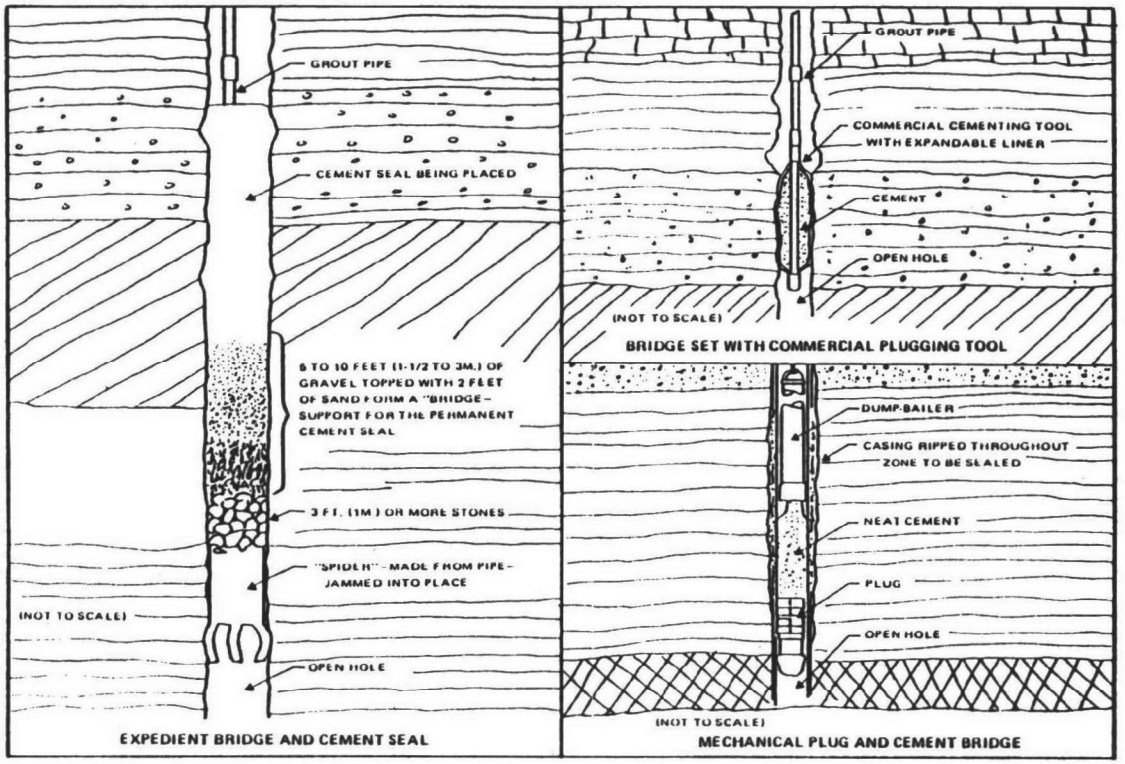


Figure 1. Permanent Bridge Seals.

B. Intermediate Seal: This seal is placed between water-bearing formations which have, or are believed to have, different static heads. Its function is to prevent the inter-aquifer transfer of water (See Fig. 2).

C. Seal at Uppermost Aquifer: This seal is placed immediately above the uppermost aquifer penetrated by the bore hole. Its function is to seal out water from the surface and from shallower formations. In flowing artesian wells, it is designed to prevent the escape of water to the surface, or to shallower formations (See Fig. 3).

Each abandonment effort should be considered an individual problem, and methods and materials should be selected only after detailed study of both construction and hydrogeology. Whenever there is doubt about either the construction or the hydrogeology involved, the choices of materials and procedures should be those affording the greatest probability for successful sealing.

AQUIFER SEALING CRITERIA

56.100-000-000 Aquifer Sealing Criteria: Aquifers shall be filled with disinfected, dimensionally stable materials, compacted mechanically if necessary to avoid later settlement. (Cement, cement-and-sand, and concrete do not require disinfection.)

Disinfection of aquifer fill materials shall be accomplished by using chlorine compounds such as sodium hypochlorite or calcium hypochlorite. Aquifer fill materials shall be clean (relatively free of clays and organic materials) before placement in the well. Disinfection shall be accomplished by dissolving sufficient chlorine compound to produce a calculated concentration of at least 100 mg/l available chlorine in double the volume of water in the well. The fill material shall be placed in the well after the water in the well has been so treated.

PERMANENT BRIDGES

56.010-000-000 Permanent Bridges: Permanent bridges may be used to avoid having to fill very deep holes below the deepest point at which a permanent seal is required. Permanent bridges shall be composed only of cement or cement-bearing minerals. The cement shall be allowed to harden for at least 24 hours, if Type I cement is used, or for at least 12 hours if Type III (highly early strength) cement is used, before backfilling is continued. Temporary bridges used to provide a base for the permanent bridge shall consist only of inorganic materials--except those patented devices containing expandable neoprene, plastic, and other elastomers, which are specifically designed and accepted for use in well construction.

PLACEMENT OF GROUT

56.001-000-000 Placement Operations: Concrete, sand-and-cement grout, or cement grout used as a sealing material in abandonment operations shall be introduced at the bottom of the well or interval to be sealed (or filled) and

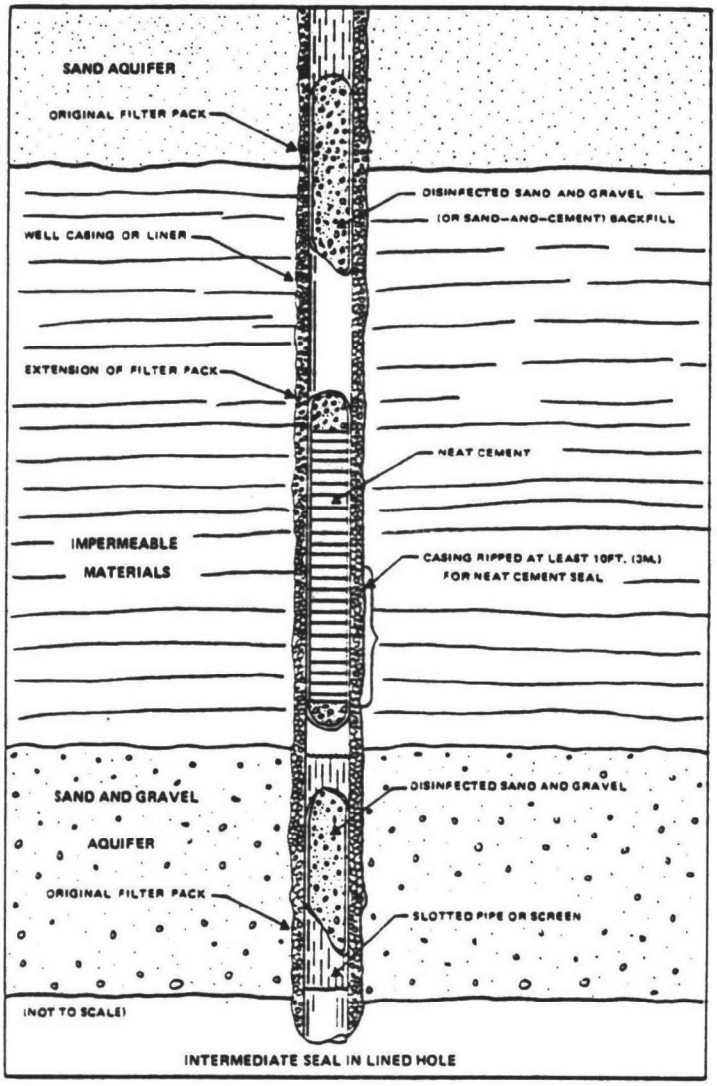
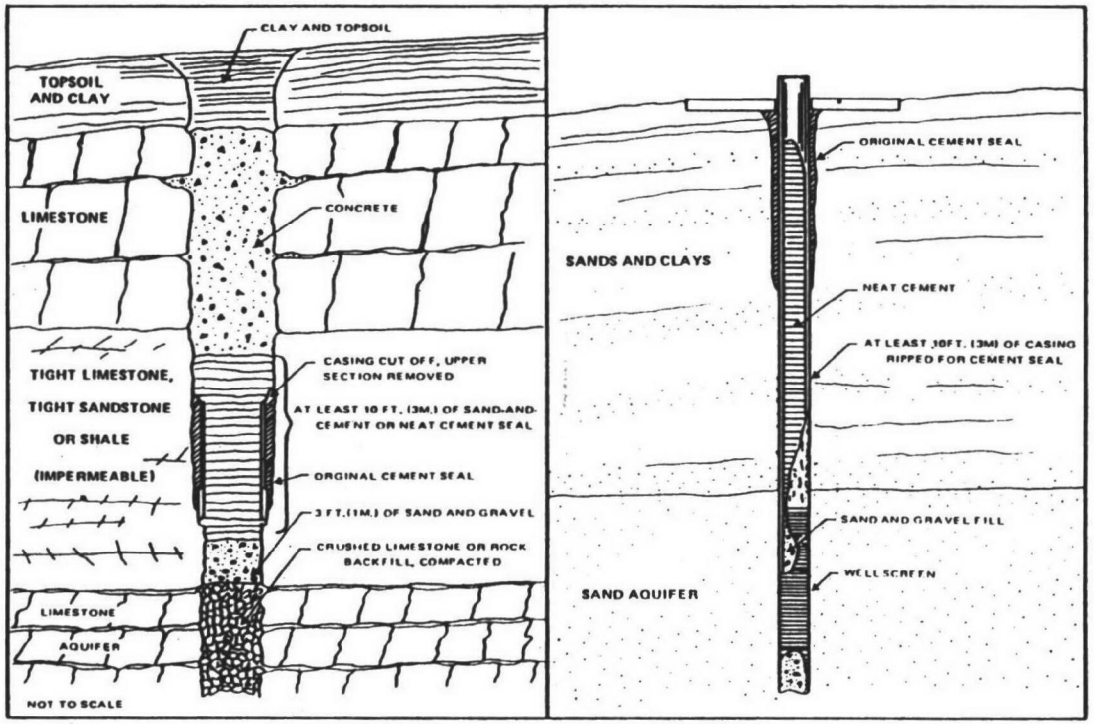


Figure 2. Intermediate Seals.



UPPERMOST AQUIFER SEALS IN WELL ABANDONMENT

Figure 3. Uppermost Aquifer.

placed progressively upward to the top of the well. All such sealing materials shall be placed by the use of grout pipe, tremie, cement bucket or dump bailer, in such a way as to avoid segregation or dilution of the sealing materials. Dumping grout material from the top shall not be permitted.

Seals intended to prevent vertical movement of water in the well or bore hole shall be composed of cement, sand-and-cement, or concrete -- except that where such seals must be placed within casings or liners, only neat cement or grout may be used. The cement-water ratio shall be that specified in Article 48.100-000-000. Cement seals shall be placed by means of pumping through drop-pipe or by use of a dump-bailer, with placement beginning at the bottom and continuing upward. The minimum cement seal length, wherever dimensions permit, shall be 3 meters (10 feet).

56.002-000-000 Intermediate Seals: Intermediate seals of cement, sand-and-cement, or concrete shall be placed in impermeable strata between aquifers which are identifiable as, or are suspected of being, hydraulically separated under natural, undisturbed conditions. Once the required cement seal has been installed, the remainder of the impermeable zone or non-producing zone between aquifers shall be filled with sand, sand and gravel, or cement-bearing mineral material.

56.003-000-000 Seal at Uppermost Aquifer: A cement, sand-and-cement, or concrete seal shall be installed in the least permeable zone immediately above the uppermost water-producing zone. Such seals shall be placed only in quiescent (non-flowing) water. [See Preamble (56.) for instructions on how to seal flowing wells.]

56.004-000-000 Seals Placed Within Casing, Liners, Filters, etc.: Seals which must be placed in casing, liners, or filters require special attention. The material between the well and the face of the bore hole shall be thoroughly perforated, ripped, or otherwise disintegrated as the necessary first step. Neat cement only, or neat cement with a maximum of 5 percent by weight of commercially processed bentonite clay, shall be used as the seal. Either of two methods may be used.

1) The calculated amount of grout required to fill the well interval plus the annular space outside the lining shall be placed within the space to be cemented, running the cement through a special cementing packer manufactured for this purpose and installed immediately above the perforated or ripped zone. The cement shall be injected at a pressure calculated to be at least 3.5 Kg/cm^2 (50 psi) greater than the normal hydrostatic pressure within the well at the point of injection.

2) The calculated amount of cement grout required to fill the casing interval plus the annular space outside the lining, plus sufficient cement grout to fill an additional 3 meters (10 feet) of the lining, shall be introduced at the bottom of the interval to be cemented.

PLACEMENT OF FILL

56.000-100-000 Non-Producing Zones: Non-producing zones below the top of the uppermost aquifer shall be filled with dimensionally stable materials such as sand, sand-and-gravel, cement, cement-and-sand, or concrete. Non-producing zones above the uppermost aquifer seal shall be filled with materials less permeable than the surrounding undisturbed formations. The uppermost 1.5 meers (5 feet) of the bore hole (at land surface) shall be filled with a material appropriate to the intended use of the land.

SPECIAL CONDITIONS

56.000-010-000 Pre-Existing Contamination: An abandoned well which has already been affected by salt water intrusion or any other contaminants shall be considered a special case, and the method of filling and sealing such wells shall be subject to individual review and written approval by the regulatory agency involved.

In the sealing of a double or multiple cased well, the CONTRACTOR shall submit a drawing thereof with a description of the proposed procedure and materials to be used, for prior approval by the regulatory agency involved.

Mineral exploration holes, solution or "in situ" mining wells, dewatering wells, temporary service wells, construction water wells, process wells, and/or other structures which affect the withdrawal or quality of ground water, or the elevation of the water table, regardless of location or intended length of life of the structure, shall be abandoned according to standards and minimums as described herein for water supply wells.

WELL ABANDONMENT RECORDS

56.000-001-000 Recording Location of Abandoned Well or Bore Hole: Before equipment is removed from the site, the exact location of the abandoned well or hole shall be determined and recorded, "tying in" the location with permanent reference points, or as prescribed by the state or local regulatory agency. All information relative to the abandonment procedures and the location of the abandoned well shall be prepared and assembled as prescribed by the state or local regulatory agency, with copies supplied to the respective agency and the owner of the land.

Section 8.4.3

TITLE OF STUDY: **(or SOURCE OF INFORMATION)**	From American Water Works Association Standard for Deep Wells, Section A1-13: Sealing Abandoned Wells
AUTHOR: **(or INVESTIGATOR)**	American Water Works Association
DATE:	Not Available
FACILITY NAME AND LOCATION:	Not Applicable
NATURE OF BUSINESS:	Not Applicable
BRIEF SUMMARY/NOTES:	The following excerpt discusses abandonment procedures for general conditions, wells in unconsolidated formations, wells extending in creviced rock formations, wells extending into noncreviced rock formations, wells extending into more than one aquifer, wells with artesian flow, and sealing methods.

From: American Water Works Association Standard for Deep Wells
American Water Works Association Standard No. A100-66
Section A1-13: Sealing Abandoned Wells

Section A1-13.1 - General: Unsealed abandoned wells constitute a hazard to public health and welfare. The sealing of such wells presents a number of problems, the character of which depends upon the construction of the well, the geologic formations encountered, and the hydrologic conditions. To seal an abandoned water well properly, several factors must be considered: 1) eliminating physical hazard; 2) preventing contamination of ground water; 3) conserving yield and hydrostatic head of aquifers; and 4) preventing intermingling of desirable and undesirable waters.

The guiding principle to be followed in the sealing of abandoned wells is the restoration, as far as feasible, of the controlling geological conditions that existed before the well was drilled or constructed. If this restoration can be accomplished, all the objectives of sealing wells heretofore presented will be adequately fulfilled.

To seal an abandoned well properly, the ground water conditions at the particular well to be sealed must be recognized and evaluated. Thus, if the ground water occurs under water table conditions, the well must be sealed with impermeable material to prevent the percolation of surface water through the original well opening or along the outside of the casing to the water table. If the ground water occurs under artesian conditions, the driller should be equipped to remove obstructions interfering with sealing operations and to provide for placing the sealing materials in the most effective manner. The sealing operations must confine the water to the aquifer in which it occurs--thereby preventing loss of artesian pressure by circulation of water to the surface--to a formation containing no water, or to one containing water under a lower head than that of the aquifer being sealed.

Usually a well should be checked before it is sealed, to insure freedom from obstructions that may interfere with effective sealing operations. This check is especially important in wells that may conduct contaminated or otherwise objectionable water into aquifers yielding potable waters. Removal of liner pipe from some wells may be necessary to assure placement of an effective seal. If liners or casings opposite water-bearing zones cannot be readily removed, they should be split with a casing ripper to assure the proper sealing of water-bearing zones with the sealing material. At least the upper portion of the casing should be removed to prevent surface water from entering the water-bearing strata by following down the casing. This operation is not always essential if the annular space around the outside of the casing was cemented when the well was drilled.

Concrete, cement grout, or neat cement, when used as a sealing material below the water level in the well, should be placed from the bottom up by methods that will avoid segregation or dilution of material. Piping cementing materials directly to the point of application or placement by means of a dump bailer or tremie is recommended. Other sealing materials referred to hereafter, except mud-laden or special clay fluids, can, as a rule, be gradually introduced into the top of the well.

Employment of a competent well driller to accomplish sealing of a deep or flowing well or one in a creviced formation is usually advisable. His knowledge of well construction and the geologic conditions of the region will be valuable in the proper abandonment of a well, just as it is in the construction of a new well. It may be advantageous to call in a consulting engineer or a representative of the state health department or other department having jurisdiction.

The recommendations contained herein pertain to wells in consolidated and unconsolidated formations, to those of small or large diameter, to test wells, and to so-called "stovepipe wells." Each sealing job should be considered as an individual problem, and methods and materials should be determined only after carefully considering the objectives outlined in the first paragraph of this section.

Section A1-13.2 - Wells in Unconsolidated Formations: Normally, abandoned wells extending only into unconsolidated formations near the surface and containing water under water table conditions can be adequately sealed by filling with concrete, grout, neat cement, clay, or clay and sand. In the event that the water-bearing formation consists of coarse gravel, and producing wells are located nearby, care must be taken to select sealing materials that will not affect the producing wells. Concrete may be used if the producing wells can be shut down for a sufficient time to allow the concrete to set. Clean, disinfected sand or gravel may also be used as fill material opposite the water-bearing formation. The remainder of the well, especially the upper portion, should be filled with clay, concrete, grout, or neat cement to exclude surface water. The latter method, using clay as the upper sealing material, is especially applicable to large-diameter abandoned wells.

In gravel-packed, gravel envelope, or other wells in which coarse material has been added around the inner casing to within 6-9 meters (20-30 feet) of the surface, sealing outside the casing is very important. Sometimes this sealing may require removal of the gravel or perforation of the casing.

Section A1-13.3 - Wells Extending Into Creviced Rock Formations: Abandoned wells that penetrate limestone or other creviced or channelized rock formations lying immediately below the surface deposit should preferably be filled with concrete, grout, or neat cement to assure permanence of the seal. The use of clay or sand in such wells is not desirable because fine-grained fill material may be displaced by flow of water through crevices of channels. Alternate layers of coarse stone and concrete may be used for fill material through the water-producing horizon if limited vertical movement of water in the formation will not affect the quality or quantity of water in the producing wells. Only concrete, neat cement, or grout should be used in this type

of well. The portion of the well between a point 3-6 meters (10-20 feet) below and a point above the bottom of the casing should be sealed and a plug formed of sealing material above the creviced formation. Clay or sand may be used to fill the upper part of the well.

Section A1-13.4 - Wells Extending Into Noncreviced Rock Formations: Abandoned wells encountering noncreviced sandstone or other water-bearing consolidated formations below the surface deposits may be satisfactorily sealed by filling the entire depth with clay, provided there is no movement of water in the well. Clean sand, disinfected if other producing wells are nearby, may also be used through the sandstone up to a point 3-6 meters (10-20 feet) below the bottom of the casing. The upper portion of this type of well should be filled with concrete, neat cement, grout, or clay to provide an effective seal against entrance of surface water. If there is an appreciable amount of upward flow, pressure cementing or mudding may be advisable.

Section A1-13.5 - Wells Extending Into More Than One Aquifer: Some special problems may develop in sealing wells extending into more than one aquifer. These wells should be filled and sealed in such a way that exchange of water from one aquifer to another is prevented. If no appreciable movement of water is encountered, filling with concrete, neat cement, grout, or alternate layers of these materials and sand will prove satisfactory. When velocities are high, the procedures outlined in Sec. A1-13.6 are recommended. If alternate concrete plugs or bridges are used, they should be placed in known non-producing horizons, or, if location of the non-producing horizons is not known, at frequent intervals. Sometimes, when the casing is not grouted or the formation is noncaving, it may be necessary to break or slit the casing to fill any annular space on the outside.

Section A1-13.6 - Wells With Artesian Flow: The sealing of abandoned wells that have a large movement of water between aquifers or to the surface requires special attention. Frequently the movement of water may be sufficient to make sealing by gravity placement of concrete, cement grout, neat cement, clay or sand impractical. In such wells, large stone aggregate (not more than one-third of the diameter of the hole), lead wool, steel shavings, a well packer, or a wood or cast-lead plug or bridge will be needed to restrict the flow and thereby permit the gravity placement of sealing material above the formation producing the flow. If preshaped or precast plugs are used, they should be several times longer than the diameter of the well. This will prevent tilting.

Inasmuch as it is very important in wells of this type to prevent circulation between formations or loss of water to the surface or to the annular space outside the casing, it is recommended that pressure cementing with neat cement using the minimum quantity of water that will permit handling be employed. The use of pressure mudding instead of this process is sometimes permissible.

In wells in which the hydrostatic head-producing flow to the surface is low, the movement of water may be arrested by extending the well casing to an elevation above the artesian pressure surface. Previously described sealing methods suitable to the geologic conditions can then be used.

Section A1-13.7 - Sealing Methods: A number of materials for sealing wells satisfactorily, including concrete, cement grout, neat cement, clay, sand, or combinations of these materials, are mentioned herein. Each material has certain characteristics and distinctive properties; accordingly, one material may be especially suited for doing a particular job. The selection of the material must therefore be based on the construction of the well, the nature of the formations penetrated, the material and equipment available, the location of the well with respect to possible sources of contamination, and the cost of doing the work.

Concrete is generally used for filling the upper part of the well or water-bearing formation, for plugging short sections of casings, or for filling large-diameter wells. Its use is cheaper than neat cement or grout, and it makes a stronger plug or seal. But concrete will not penetrate seams, crevices, or interstices. Furthermore, if not properly placed, the aggregate is apt to separate from the cement.

Cement grout or neat cement and water are far superior for sealing small openings, for penetrating any annular space outside of casings, and for filling voids in the surrounding formation. When applied under pressure, it is strongly favored for sealing wells under artesian pressure or those encountering more than one aquifer. Neat cement is generally prefereed to grout as it avoids the danger of separation.

Clay, as a heavy mud-laden or special clay fluid applied under pressure, particularly for sealing artesian wells, is considered adequate by many competent authorities, although others feel that it may, under some conditions, eventually be carried away into the surrounding formations.

Clay in a relatively dry state, clay and sand, or sand alone may be used advantageously, particularly under water table conditions where diameters are large, depths are great, formations are caving, and there is no need of achieving penetration of openings in casings, liners, or formations, or of obtaining a watertight seal at any given spot.

Frequently combinations of these materials are necessary. The more expensive materials are used where strength, penetration, or watertightness are needed. The less expensive materials are used for the remainder of the well. Cement grout or neat cement is now being mixed with specially processed clays and with various aggregates. Superior results and economies are claimed for such mixtures.