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Site Characterization Reports prepared
for Unocal
1980 through 1938
Subsurface Fuel-Related Contamination
Unocal Station 5353
Westlake Avenue and Mercer Streets
Seattle, Washington

GeoEngineers

2405 - 140th Avenue NE, Suite 105
Bellevue, Washington 98005
Telephone: (206) 746-5200
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LETTER OF TRANSMITTAL

To: Washington Department of Ecology
Northwest Regional Office
4350 - 150th Avenue NE
Redmond, Washington 98052

Date: January 16, 1991

File: 0161-013-B69

Attention: Annette Petri

Regarding: Unocal Station 5353 - Westlake and Mercer

We are sending: ☒ Attached ☐ Under Separate Cover

Copies	Date	Description
1	VARIOUS	Historical Site Evaluation Reports

These are transmitted as checked below:

☒ For Your Use ☒ As Requested ☐ Returned
☐ For Review and Comment ☐ Other (see remarks)

Remarks:

This should complete your files for all reports issued to characterize conditions at this site.

Reports are indexed on the following page.

Copy To:

Signed: [signature]

Stephen C. Perrigo

Site Characterization Reports prepared for Unocal
1980 through 1988
Subsurface Fuel-Related Contamination
Unocal Station 5353
Westlake Avenue and Mercer Streets
Seattle, Washington

Appendix A: Geotechnical Recommendations and Considerations; Monitoring and Recovery Operations for Gasoline Spills; prepared for Unocal by Roger Lowe Associates; August 12, 1980.

Appendix B: Progress Reports 1-45 prepared for Unocal.

Progress Reports 1 through 16 prepared by Roger Lowe Associates, Inc.; December 23, 1980 through July 23, 1981.

Progress Reports 17 through 45 prepared by Harding Lawson Associates; August 7, 1981 through October 27, 1982.

Appendix C: Progress Report No. 1, Remedial Action Consultation Services, Subsurface Fuel Vapor Extraction Program; prepared for Unocal by GeoEngineers, Inc.; July 23, 1988.

Appendix D: Interim Status Report, Subsurface Vapor Extraction Program; prepared for Unocal by GeoEngineers, Inc.; October 3, 1988.

APPENDIX A

ROGER LOWE ASSOCIATES INC.
EARTH SCIENCES

August 12, 1980

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. A. L. Barone

Geotechnical Recommendations & Considerations
Monitoring & Recovery Operations for
Gasoline Spills
RLAI Project No. 197-06

Gentlemen:

This letter transmits three copies of our "Geotechnical Recommendations and Considerations, Monitoring and Recovery Operations for Oil Spills." Union Oil originally requested this information during a meeting on June 24, 1980. This report was included as a portion of our professional services as described in our "Confirmation of Agreement and Recommendations for Monitoring" dated June 26, 1980.

The recommendations provided herein are based on our review of available literature and on our experience gained following the gasoline spill at Westlake Avenue and Mercer Street in Seattle, Washington. Our recommendations are intended to be applicable to any gasoline spill in porous soil where the gasoline migrates downward to the water table. However, each site where a spill occurs will have its own unique problems, and modifications of some of our suggestions will undoubtedly be necessary on a case by case basis.

It is our understanding that the discussions provided herein will be used by Union Oil to prepare a general procedures manual regarding gasoline spill prevention and mitigation. We have not included discussion of problems or procedures related to safety or vapor detection, which we understand will be addressed by Union Oil.

MAIL: P.O. BOX 3885, BELLEVUE, WA. 98009 - TELEPHONE (206) 453-8383
LOCATION: BENAROYA BUSINESS PARK, BLDG. 4, SUITE 219 - 300 120th AVE. N.E., BELLEVUE, WA.

It has been a pleasure to serve you on this project. Please call us if you have any questions regarding our report or if we may be of additional service.

Yours very truly,
ROGER LOWE ASSOCIATES INC.

James A. Miller

James A. Miller, P.E.
Senior Geologist

JAM/cp

GEOTECHNICAL RECOMMENDATIONS AND CONSIDERATIONS
MONITORING AND RECOVERY OPERATIONS FOR GASOLINE SPILLS

INTRODUCTION

Gasoline spills can occur in a great variety of geological environments, and the size and rate of spills can vary widely. Consequently, precise instructions for monitoring and recovering gasoline following a spill is not possible. The information contained herein is intended to apply to most gasoline spills where gasoline has entered porous subsurface soils and reached the water table.

We developed the information presented in this report from our experience gained following the gasoline spill at Westlake Avenue and Mercer Street in Seattle, Washington, and on a review of several technical publications. Two of the more pertinent publications are cited at the end of this report.

A general discussion regarding the fate of hydrocarbons in the subsurface, including recovery operations where the hydrocarbon is absorbed by the soil before it reaches the water table, is presented in API Publication No. 4149 (American Petroleum Institute, 1972). This report is intended to augment Publication No. 4149.

GENERAL BACKGROUND

When gasoline is spilled on the surface of the ground or underground, two primary forces act on the fluid. Gravity acts to draw the fluid downward from higher elevation to lower elevation along the path of least resistance. Simultaneously, capillary (pellicular) forces tend to hold a portion of the gasoline on the surfaces and along contact points between the solid particles which comprise the subsurface soil or rock material. When liquid gasoline migrates through porous materials, a portion of the gasoline is retained in the soil mass by capillarity.

Downward gravity flow of gasoline within porous materials will continue until the fluid encounters layers or lenses of relatively impervious material, until the gasoline reaches the water table, or until all of the available fluid is held by capillarity within intergranular spaces in the subsurface material. When a relatively impervious surface is encountered by downward migrating gasoline, most of the gasoline will be directed laterally in the downslope direction along the impermeable interface (depending on the permeability ratio of the two materials, a portion of the gasoline will enter the relatively impervious material and flow through it). When the gasoline encounters the water table, the gasoline will float on top of water interface and flow downslope parallel to the direction of groundwater flow and the slope of the water table. A relatively small amount of the gasoline will dissolve in the water, but most will remain separated due to the immiscibility and density differences of the two fluids.

The migrating gasoline will follow the path of least resistance along natural or artificial avenues of higher permeability. The rate of gasoline migration as well as the path is related to soil permeability.

In general, fine-grained soils such as silt or clay would be expected to retain a relatively large percentage of gasoline by capillarity, and gasoline would migrate slowly within these soils. Coarse-grained sand or gravel soils, however, are capable of rapid intergranular fluid movement and will hold a relatively small fraction of gasoline permanently.

In urban areas, the most convenient path of travel for the gasoline is frequently a trench which is backfilled with imported sand and gravel or loosely compacted native soil. It is quite possible, for instance, that gasoline may travel only a few feet into silt or clay native soils, while at the same time, the gasoline may migrate several hundred feet within the sand and gravel backfill in a utility trench.

INITIAL DATA COLLECTION AND ANALYSIS

When a spill occurs, a leak is detected, or gasoline is found in groundwater, the immediate problem is to determine the boundary of the spill in the subsurface. It is also important that the source of the spill be located, and, if possible, an estimate of the volume of spill should be developed from available records.

Once a spill occurs or is detected, speed is important in determining the extent of the spill in the subsurface, particularly if sand or gravel soils occur in the vicinity of the spill or if a groundwater aquifer is threatened with contamination. A geotechnical consultant should be retained for expert advice for all large spills or spills in environmentally sensitive areas.

The boundary of the gasoline in the subsurface can be determined by drilling monitor wells in the vicinity of the spill. The monitor wells should extend at least 5 feet to 10 feet below the water table. A small diameter (2") slotted plastic pipe should be set to the bottom of each well, and the lower portion of the drill hole should be backfilled with coarse sand or pea gravel so that subsurface fluids have easy access to the well casing.

After completion of each monitor well, the elevation of the top of each well casing should be determined to an accuracy of 0.01 feet using an established, stable datum or local benchmark. The plan locations of each well also should be surveyed to an accuracy of 0.5 feet and a site map should be prepared showing pertinent physical features, the location of each well, and the site of the spill. Accuracy is very important in correctly establishing the water table conditions and evaluating the direction of fluid movement.

When the well casing has had one or more hours to equilibrate after installation, the casing should be "stuck" for the presence of liquid gasoline using water finding paste (or other appropriate water level recording devices), and the upper portion of the well casing should be tested for hydrocarbon vapors with an explosimeter. If liquid gasoline is detected in a monitor well, an additional monitor well should be drilled a greater distance from the spill site.

Sufficient wells should be drilled to plot the limits of the spill in the subsurface with reasonable accuracy. In general, a minimum of 10 monitor wells will be necessary to establish the subsurface boundary of a spill. The number and location of the wells should be related to the local geology or construction history in the area. Expert advice from a geotechnical consultant should be obtained in planning the locations of monitor wells.

When several wells have been drilled and the water levels have equilibrated in each, the "effective" water table elevations should be determined and plotted on the site map. The "stick" data from the monitor wells will include the depth to the water level from the top of the casing and the thickness of gasoline which is floating on top of the water. The "effective" water table elevation can be calculated using the following equation:

$W_e = E - D + (T)(G)$, where

W_e = Effective water table elevation

E = Elevation of top of well casing

D = Depth from top of well casing to water level, as indicated by water-finding paste

T = Thickness of gasoline above the water/gas interface

G = Specific gravity of gasoline (usually about 0.6)

The calculations are facilitated if all measurements are in feet and decimal fractions of a foot.

Once the effective elevation of the water table is plotted for all monitor wells, the data can be contoured to determine the slope of the water table. Gasoline floating on the water table will generally travel downslope perpendicular to the orientation of the water table contour lines. The contour map therefore can be used to predict the direction of gasoline migration.

If the water table is fairly shallow, or if there are relatively impermeable soils in the spill area, utility trenches in the spill area should be tested for the presence of gasoline. The trenches can be tested by excavating test pits at selected locations, or monitor wells can be drilled within the utility trench backfill adjacent to the conduit. (The latter method would require very accurate information on conduit location, which often is not available).

Relatively undisturbed core samples of the subsurface soil or rock should be obtained for most, or all, of the monitor wells. The core samples will allow visual examination and classification of subsurface materials, and some of the samples can be tested to determine their moisture content, density, void ratio, particle size distribution, organic content, or permeability (as appropriate).

GASOLINE RECOVERY

Once the base line data on the extent of the spill and water table slope have been developed, one or more gasoline recovery wells should be constructed. If possible, the recovery wells should consist of large diameter (24" to 36") casing which is slotted or perforated. The base of the recovery wells should extend at least 6 feet below the water table, and the backfill outside the well casing should consist of washed gravel or pea gravel.

For areas of shallow water table, the recovery wells can be constructed by excavating a trench, installing the well casing, and backfilling the trench with gravel. The larger the trench, the more effective the well will be in recovering gasoline. Recovery wells in areas with a deeper water table may have to be constructed using a bucket auger or traditional well drilling equipment. As for the monitor wells, the rim elevation and location of the recovery wells should be surveyed and plotted on the site plan.

Where shallow water table conditions apply and a large diameter well casing is used, it is possible to pump water and gasoline separately and simultaneously from the well. Water can be withdrawn from the well using a submersible pump with the drawdown controlled manually or by automatic detectors. The gasoline can be removed by separate skimming units which float on the fluid surface inside the well casing. If the skimming units are operated by a vacuum lift, it may not be possible to use the units where the depth to the water table is great. In this case, a single pump may have to be used to pump gasoline and water, and the liquids would have to be separated later.

When fluid is withdrawn from a well, the liquid level in the well drops in rough proportion to the rate of pumping. As a result of pumping, a "cone of depression" is formed on the surrounding water table, and the slope of the water table outside the well becomes directed toward the well. It is desirable to generate a cone of depression for two reasons:

1. Since floating gasoline travels in the direction of the slope of the water table, the cone of depression will cause the gasoline to flow toward the recovery well and thereby increase the rate of hydrocarbon recovery.

2. Once the cone of depression spreads beyond the boundary of the spill, the migration of gasoline should be contained and further movement by gravity away from the spill site should not occur.

It may be necessary to construct two or more recovery wells to develop cones of depression which extend beyond the limits of the spill.

Once pumping operations have begun, it is important that accurate records be maintained to evaluate the effectiveness and completeness of the recovery operation. At a minimum, the following should be recorded:

1. "Stick" readings of water and gasoline levels in the monitor wells and pumping wells should be recorded once every four hours at the start of the pumping cycle. This data is used to monitor the spread of the cone of depression. After about two days the time interval between readings can be increased to once every 12 hours. Reading intervals can be gradually increased during the recovery program, and eventually readings once a week may be sufficient.

2. It is very important that a daily and running total of gasoline recovery be maintained on a time chart. Normally the daily rate of gasoline recovery will decline as a logarithmic function of time. Therefore, it is possible to plot the recovery/time data on a semi-log plot and project the length of time which will be required for the recovery program as well as the total volume of gasoline recoverable by pumping.

3. A daily site log should be maintained which documents site activities, times of pumping, equipment malfunctions or calibrations, and other occurrences which may affect the recovery operation.

Using laboratory testing techniques on soil samples collected from the spill area, it is possible to estimate the total quantity of gasoline which will be recoverable by pumping. However, the necessary calculations often are seriously in error. The best method of predicting the volume of gasoline recoverable and the time of the required recovery period is to use the gasoline recovery/time chart discussed above (with total gasoline recovery plotted on an arithmetic scale and time in days since start of pumping plotted on a logarithmic scale). Generally, a full log cycle of data (10 days) should be obtained before attempting extrapolation of the data. Pumping during the initial period of data collection should be relatively constant. Obviously, accurate and timely data is extremely important to successful use and extrapolation of the recovery/time curve.

As discussed previously, only a fraction of the volume of gasoline spilled will be recovered by pumping. In most cases 20 to 80 percent of the spill volume will be retained in the soil by capillary forces, depending on soil type and the depth to the water table. Eventually, the gasoline left in the soil will dissipate by evaporation and consumption by aerobic bacteria. Two years or more probably will be required for complete dissipation (McKee, et al, 1972).

In some cases additional liquid gasoline can be recovered by allowing the water table to rise and flush gasoline out of soil pore spaces. However, laboratory studies (McKee, et al, 1972) indicated that once gasoline is held in capillarity by soil, water flushing has little effect in freeing the gasoline. If flushing is attempted the water table can rise naturally due to seasonal variations in precipitation, by periodically shutting off the water level drawdown pumps, or by injecting water into the ground. If water injection is done, the point(s) of injection should be outside the boundary of the spill so that the change in water table slope caused by injection does not force some of the gasoline to migrate farther away from the recovery well.

Yours very truly,
ROGER LOWE ASSOCIATES INC.

James A. Miller

James A. Miller, P.E.
Senior Geologist

JAM/cp

REFERENCES CITED

American Petroleum Institute, 1972, The Migration of Petroleum Products in Soil and Ground Water: API Publication No. 4149, 36 p.

McKee, J.E., Laverty, F.B., and Hertel, R.M., 1972, Gasoline in Groundwater: Journal Water Pollution Control Federation, Vol. 44, No. 2, p. 293-302.

APPENDIX B

ROGER LOWE ASSOCIATES INC.
EARTH SCIENCES

December 23, 1980

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Jeff Benoit

Progress Report
Monitoring & Recovery Operations
Westlake & Mercer Gasoline Spill
Project No. 14,196,006.07

Gentlemen:

This letter transmits three copies of our Progress Report, "Monitoring and Recovery Operations, Westlake and Mercer Gasoline Spill." This progress report is the first semimonthly status report of our services regarding the monitoring and recovery program for the Westlake and Mercer gasoline spill in Seattle, Washington. The semimonthly reports are being sent in accordance with and in partial fulfillment of our "Proposal, Monitoring Program for Westlake and Mercer Gasoline Spill," dated November 7, 1980.

Due to the recovery program's recent activity, we have been somewhat delayed in preparing this first progress report. It summarizes our experience on this project from the beginning; subsequent progress reports will be less involved and more timely.

Yours very truly,

ROGER LOWE ASSOCIATES INC.,
A Division of Harding-Lawson Associates

Roger A. Lowe

Roger A. Lowe
Principal-in-Charge

RAL/ju

3 copies enclosed

MAIL: P.O. BOX 3885, BELLEVUE, WA. 98009 - TELEPHONE (206) 453-8383
LOCATION: BENAROYA BUSINESS PARK, BLDG. 4, SUITE 219 - 300 120th AVE. N.E., BELLEVUE, WA.

TABLE OF CONTENTS

PROGRESS REPORT
MONITORING & RECOVERY OPERATIONS
WESTLAKE & MERCER GASOLINE SPILL

Project No. 14,197,006.07

Prepared for

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

by

James T. Cameron by RAL

James T. Cameron
Project Manager

ROGER A. LOWE
STATE OF WASHINGTON
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December 23, 1980

PROGRESS REPORT
MONITORING AND RECOVERY OPERATIONS
WESTLAKE AND MERCER GASOLINE SPILL
SEATTLE, WASHINGTON

I. INTRODUCTION

A. Background

In early June, 1980, it was discovered that a large gasoline spill had occurred at the Union Oil Station located, as shown on Plate 1, at the intersection of Mercer Street and Westlake Avenue in Seattle, Washington. The gasoline contaminated subsurface soils around the station and collected on the underlying ground water surface. As a result, gasoline recovery operations were initiated and an extensive monitoring system established. Gasoline recovery is being accomplished through two drawdown wells and numerous scavenger pumps and is monitored periodically through observation wells.

B. Recent Events and Proposed Project Direction

On November 17, 1980, Jeff Benoit of Union Oil Company and Ed Ingham of Ryan Haworth met with the author to discuss the current status and direction of the program. Upon scrutiny of existing data it was decided that there is some question whether the leaked gasoline is being contained within the site block area, especially to the east along Terry Avenue. It also appeared that the northern half of the block north of the Union Oil property line was relatively unaffected by the pumping efforts of the existing well in that portion of the site (Well No. 8). This inference was substantiated by the fact that there appeared to be a major gasoline pool in the vicinity of the Brace Lumber Yard. In addition, pumping efforts through November had very little affect on the gasoline thickness in Well No. 6. The gasoline thickness in this well had, in fact, increased 9 inches in the last month. A further factor of note is that old building plans of the block area indicated that there may be a remnant building wall along the northern property line. The plans indicate that the wall was broken off approximately 18 inches beneath the existing ground surface and extends approximately 14 feet deep. If this wall does indeed exist, then it may be serving as a cutoff wall for gasoline and ground water flow to the northern half of the block area.

Due to the dwindling recovery of gasoline and the known existing pools of gasoline still existent at the site, it was decided to attempt to increase the recovery rates by either deepening existing wells or by installing additional deep wells to increase the drawdown cone at the site. The intent of the new deeper wells will be to depress the water table in the area of the site below the invert elevations of the existing utilities to steepen the cone of depression in an attempt to increase gasoline recovery rates.

The increase in drawdown should result in a proportionate increase in the required pumping rates and thereby the volume of gasoline and water to store or dispel. To reduce the amount of required liquid storage for the recovery operations, an effort will be made to keep the clean and contaminated portions of the extracted fluids (i.e. gasoline and water) separated in order to allow the uncontaminated portions to be discharged directly into the sewer system. This would be implemented by locating the drawdown pumps a sufficient depth below the gasoline-water interface to preclude contamination of the water relative to minimum standards defined by pertinent city, county and environmental agencies. In this manner, the drawdown pumps would discharge water directly into the sewer system and storage would only be necessary for gasoline recovered by sumps placed at the piezometric surface.

Based on research performed by Ryan Haworth, the estimated minimum distance between the drawdown pumps and the gasoline-water interface would be on the order of 25 feet for the minimum hydrocarbon contamination level not to exceed the maximum allowed 15 parts per million.

In a meeting on November 19, 1980 with Jeff Benoit of Union Oil Company, Ed Ingham of Ryan Haworth, Frank Pinney of Pacific Testing Laboratories and addtional PTL staff, the new monitor wells were located and the drilling schedule was set.

On November 25 and November 26, 1980, the four additional wells were installed; three along Terry Avenue (Wells No. 29, 30, 31) and one in the Brace Lumber Yard (Well No. 32). These new monitor well locations are shown on the attached Plot Plan, Plate 1. No gasoline was detected in the borings along Terry Avenue nor was any measured in subsequent readings. Gasoline was encountered in the Brace Lumber Yard monitor well during drilling. However, for approximately the first week after its installation, no gasoline was measured in the well. During this time, the well had been flushed and checked to assure that it was not clogged. Approximately one week after its installation, gasoline was detected in this well and has been present to this date.

C. <u>Gasoline Recovery</u>

The total gasoline recovery information has been logged and plotted in our office since the beginning of the recovery effort. The total volume plotted against a logorithmic plot of time has been approximately linear throughout the job until the installation of the Brace Lumber Yard sump, on October 31, 1980. The graph then takes a sharp bend which reflects the increased recovery rate due to the newly installed sump. As of November 30, 1980, an estimated total of 33,158 gallons of gasoline has been recovered at the site. The semi-logqrithmic plot of the recovery volumes to date is included on Plate 2.

On October 30, 1980, a scavenger pump was installed in the Brace Lumber Yard in order to extract a known gasoline pool in this area. The gasoline recovered by the Brace Lumber pump is being discharged into a 300 gallon tank. As of December 12, 1980, there have been a total of 11 tanks of gasoline extracted by the Brace pump or approximately 3,300 gallons of gasoline. The tank has been filling approximately every two to three days.

II. GENERAL TRENDS

A. Piezometric Elevations

There have generally been two drawdown pumps operating at the site; one at the Monitor Well Location 4a, and the other at Monitor Well Location 8. Some pumping was also performed at Well 5a earlier in the recovery effort. Plate 3 depicts the piezometer water-gasoline surface level elevations prior to pumping in June of 1980. In general, the piezometric contours indicate a gentle slope downward from the south to the north end of the site from approximately Elevation 10.5 to about Elevation 9.5 at the lake. Plate 4 shows the piezometric contours estimated from well data taken on December 7, 1980. Again there is a general decrease in the piezometric surface towards Lake Union to the north. However, now the elevations decrease from approximately 9.5 to 8.5 despite an increase in rainfall from June to December. We feel that this overall lowering of the water table is due mainly to Lake Union being lowered approximately 2 feet in the months of October and November, 1980, and partially to the drawdown effects of pumping.

U.S. Army Corps officials have advised us that the lake was lowered to its minimum level in the beginning of December. Plate 1 also indicates the general effect of the existing wells pumping at the site; there is a general depression at each well location. However, based on our data points, it appears that the northernmost depression may be opened out toward the lake to the north, indicating that Well No. 8 may not be attaining sufficient drawdown to contain the existent gasoline pool. We expect that the general piezometric level at the site area will rise in the future with the rainy season ahead.

B. Gasoline Thicknesses

Plates 5, 6, and 7, depict the gasoline thickness in inches at various phases of the recovery effort history. Plate 5 shows the gasoline thickness at the beginning of the recovery effort in June, 1980. This plate shows the major concentration of gasoline immediately beneath the gas station site. Plate 6, showing the gasoline thicknesses on November 18, 1980, shows two pools of gasoline near the drawdown wells with the area directly beneath the gas station essentially devoid of gasoline. Plate 7, showing the gasoline thickness on December 7, 1980, essentially shows a similar gasoline distribution with somewhat lesser thicknesses. In addition, this plate also includes the gasoline thickness measured at Monitor Well No. 32, which was recently installed. This plate indicates that the northern pool of gasoline may be somewhat more extensive than previously estimated. The lack of detection of gasoline in Wells No. 22, 23, 29, 30, and 31, indicates that the gasoline has been contained within the site.

The existing pumping program has had a variety of influences on gasoline thicknesses in individual wells over the life of the project. Some wells show a definite decrease in gasoline thickness, some show a definite increasing trend, others show a scatter of values varying within a range of thicknesses and still others show an essentially constant thickness. Decreasing trends appear to be prominent in wells located 50 to 100 feet from the drawdown wells, but this is not always the case. In addition, the trend, or mode, of a particular well may change with time. The most recent readings indicate that the majority of the wells have either a scatter or a constant mode of variation in the last month. This may be a result of the decrease in the general water levels at the site due to the lowering of Lake Union. Lowering the lake would tend to reduce the effective drawdown of the two existing pumping wells. The following tabulation depicts the variation in gasoline thickness for each well for the month of November, 1980.

WELL NO.	GASOLINE THICKNESS (Range in Inches)	MODE OF VARIATION
1	7 - 9.5	Constant
2	4 - 14.25	Scattered
3	1.25 - 4.75	Constant
4	12 - 14	Constant
5	2 - 4.25	Constant
6	11.25 - 20	Increasing
7	0	Constant
8	3.5 - 13	Scattered
9	2.5 - 5	Constant
10	3	Decreasing
11	0	Constant
12	0	Constant
13	0 - 2.5	Constant
14	0	Constant
15	0	Constant
16	0	Constant
17	4.5 - 10.75	Scattered
18	0 - 9.5	Scattered
19	8.25 - 15	Scattered
22	0	Constant
23	0	Constant
25	0	Constant
26	2 - 3.5	Constant
28	0	Constant

Nov. '80

C. Explosimeter Readings

Explosimeter vapor readings have been taken at 4 and 8 foot depths in each well on a weekly basis. Our tabulated data of these readings indicates no defined patterns or trends. Vapor readings appear very sporadic and inconsistent at times. Daily readings have varied from 0 percent at 4 feet to 100 percent at 8 feet in the same well. Consecutive readings for a given depth have varied as much as 100 percent in some wells.

In general, explosimeter readings at 8 feet have measured consistently above 50 percent throughout the recovery program for Monitor Wells No. 1 through 10, 17, 18, and 19. Currently all wells, except for Well No. 22, have measurable gasoline vapor in them. Up until recently, Wells No. 11 and 23, at the north end of the block, have had no detectable gasoline vapor in them. The recent high vapor readings in these wells may indicate a northward movement of the gasoline pool due to the general lowering of the ground water table and the subsequent decreased effectiveness of the existing drawdown pumps.

III. SOIL AND HYDROLOGIC CONDITIONS

A. Soil Conditions

Deep subsurface soil conditions were evaluted by drilling Wells No. 29 and 31 to depths of 65 and 70 feet respectively (see Plate 1), and by reviewing existing deep soil data in the vicinity of the site. Based on this data, we estimate that the site contains approximately 35 to 40 feet of relatively impermeable silt, sand, and woody fill material underlain by very dense, highly permeable sand. The upper surface of the dense sand appears to slope to the north approximately from Elevation -15 to Elevation -20 (City of Seattle Datum). The drilling crew experienced 2 to 3 feet of heave in the auger when the surface of this dense sand was encountered. Based on drilling data performed by others to the north of the site along Valley Street, we expect that the dense sand layer extends greater than 90 to 100 feet beneath the existing ground surface. ?

B. Hydrologic Conditions

Based on a pumping test which was performed by our firm at another site on sandy soils very similar to those encountered at depth at this site, we estimate that the permeability of this sandy unit may be on the order of 200 gallons per day per foot. In comparison, our empirical estimate of permeability through the upper fill soils, based on data taken at the site, is on the order of 4.0 gallons per day per foot. As a result, we expect that drawdown pumping rates will be greatly increased for wells extending into the sandy unit. At present, we estimate that the two existing drawdown pumps are operating at a volume rate of approximately 0.15 gallons per minute. This corresponds to a drawdown of approximately 1 foot at each pump location. If an equivalent well (i.e., same diameter, depth and water table) was installed in a permeable sandy unit such as that occurring at depth at the site, we estimate that the pumping rate would have to be increased to approximately 7 gallons per minute. The following table summarizes our estimates for requiring pumping rates to attain a given drawdown at the pump location for wells extending to a 60-foot depth at the site:

Drawdown (Feet)	Required Pumping Rate (Gallons per Minute)
5	15
10	30
15	45

It should be noted that these estimates are based on limited available data. The actual values may vary erratically in the field.

The extent of the cone of influence in a particular well is an important factor in the gasoline recovery effort. The draw-down cone is defined as the depression in the ground water surface caused by a well. In general, the depressed surface is cone shaped, the sides of which are very steep at the well and flatten to essentially horizontal at some distance from the center of the well. The horizontal distance between the well and the point at which no drawdown occurs is defined as the radius of influence. Under a given set of soil conditions, the effective radius of influence of a well is increased as the drawdown for the well is increased. Based on measurements taken in the field, we estimate that the existing radius of influence at the two existing wells at the site are each approximately 50 feet, for approximately 1 foot of total drawdown at each well. Data procured from another site with sandy soils such as those occurring at depth beneath the subject site, indicate a radius of influence over approximately 580 feet with 9 feet of drawdown at the pump. The discrepancy between the above radii of influence is due to the relative difference in permeabilities between the soils at the two sites. The less permeable soils, such as those encountered in the upper soils at the subject site, will tend to increase the steepness of the drawdown cone and thereby decrease the effective radius of the well. It will therefore require a correspondingly deeper drawdown in order to obtain the effective radius of influence which would result if the well was embedded entirely in one soil type or the other.

IV. RECOMMENDATIONS

A. New Wells

We recommend that four new wells be installed at or near the locations indicated on Plate 3 (designated as A through D). The new wells may be located at existing well locations or at new locations. This should be determined in the field and will depend on any physical restrictions or public concerns. It may be possible to delete the well at location "D", if pumping tests and monitoring from the other wells indicate sufficient influence in the vicinity of the proposed location for Well No. D. We therefore recommend that the wells be installed in the order A through D.

Each well should be installed to a depth of approximately 60 feet beneath the existing ground surface. Wells should be drilled to a diameter of approximately 3 feet with an interior casing 2 feet in diameter and backfilled in between with gravel. The bottom of the well casing should be covered or cemented to exclude loose bottom soils which could plug the drawdown pumps. The casings should be vertically slotted for the total length of the well. We expect that temporary outer casing will be required during the excavation for each well. In addition, during our subsurface explorations at the site the dense lower sands heaved up into the auger as its upper surface was breached. We suspect that heave may also occur at this interface during well drilling operations. This can be offset by keeping the casing filled with water or a bentonite slurry during drilling.

Prior to pumping, each well should be surged and bailed for approximately 2 hours to assure that the well is sufficiently clean and operating properly.

B. Potential Problems

Substantial drawdown in the vicinity of the site may cause excessive soil settlement. Removing the water increases intergranular soil pressure just as would the weight of a heavy fill or building. This could affect structures and utilities within the influence of the wells. Each foot that the ground water is lowered is equivalent to placing a uniform surcharge of 60 psf over the area. However, the subsurface soils will not begin to feel this overburden until the ground water is lowered below its previous lowest level in recent history, which we feel is on the order of Elevation 8 in the site vicinity. The block area generally has approximately 20 feet of loose fill and debris overlying more compact native soils. There are many signs of past excessive settlement to pavement and building structures in the block area, especially in the Brace Lumber Yard. We therefore recommend that the ground surface and structures in the vicinity of each well be surveyed to detect any signs of potentially hazardous settlement. This will be expanded on in a subsequent section of this report.

Due to the relatively high permeability of the lower sandy soils, we suspect that the proposed deep wells may experience large inflow of water from these lower soils. This will tend to dilute any hydrocarbons entering from the upper waters.

Also, the pumping rates will have to be large to handle the influx. Based on pumping tests in similar clean sandy soils, we expect that up to 15 feet of drawdown may be experienced with pumping rates on the order of 35 gallons per minute. Greater pumping rates may be required for the subject site. Actual pumping rates will have to be verified in the field. Some means of varying or adjusting pumping rates will be necessary. If possible, equipment with a range of pumping rates between 20 and 80 gallons per minute should be installed.

C. Survey Program

Prior to pumping in any of the new wells, a survey datum should be established a minimum of 500 feet away from the nearest pumping well or on a pile supported structure for monitoring potential settlement due to drawdown. A minimum of five survey points should be established at various distances from each well. We suggest that survey points be established approximately 0, 10, 30, 50, and 80 feet from each well. We recommend that the survey points be read twice daily during drawdown and daily for one week after static conditions have been obtained. After that, surveys should be made on a weekly basis for approximately one month or on a schedule based on monitoring of the trends.

Based on the behavior of the earlier drilled wells, the settlement survey monitoring program may later be revised or exluded for subsequent wells except Well C, which should be monitored regardless of the settlement behavior of previously surveyed walls.

D. Pumping and Monitoring Program

Based on discussions with Jeff Benoit of Union Oil Company and Ed Ingham of Ryan Haworth, we estimate that the likely chain of events which will occur for each well will be as follows:

1. Install well,

2. Install drawdown pump at base of well,

3. Pump well for short period of time into a storage tank,

4. Take a water sample and send to laboratory for testing,

5. Continue to pump until the storage tank is filled (monitor settlement during this time),

6. Shut off pumps, obtain a water sample and send to laboratory for testing,

7. Evaluate testing results,

8. If the hydrocarbon content is sufficiently low in the water samples, turn pump back on and begin developing the drawdown cone for the well while surveying settlement points around the well and taking water level readings in nearby wells to evaluate the rates and shape of the drawdown cone. The water may be disposed of in the storm drain system.

9. If the hydrocarbon content in the water samples is not sufficiently diluted, then storage, filtering or chemical treatment of the water will be required before it is discharged.

Intermittent surveying and water level monitoring should also be performed during step 5, while filling the initial storage tank. We estimate that a 10,000 gallon storage tank will take approximately 4 to 5 hours to fill with a pumping rate of 35 gallons per minute. The results of our pumping tests performed in sandy soils similar to those at depth at the site indicate that for such soils, static conditions are approached in approximately 48 hours.

After the initial evaluation of hydrocarbon concentration is completed and the results approved , full scale pumping of the first well should begin. During the initial pumping, drawdown in the pumped well and several observation wells should be carefully monitored so that the rate of the spread and extent of the drawdown cone can be evaluated. Because we are uncertain of the actual rates of pumping which will be required for a given drawdown, we recommend the following monitoring schedule. We also recommend that one of our staff be present during this initial phase, so that monitoring results can be evaluated on site and pump rates modified if necessary.

We recommend the following monitoring schedule:

1. Prior to turning on the pumps, a depth reading should be taken at the well and in all surrounding wells to be used in the monitoring program.

2. Start pump and take consecutive readings in the pumping well for 5 minutes.

3. From 5 to 10 minutes, take readings of pump well and all monitoring wells within 50 feet of the pump well.

4. From 10 to 30 minutes take readings of pump well and all wells within 100 feet of the pump well.

5. From 30 to 60 minutes, take readings of pump well and all wells within 200 feet of the pump well.

6. Continue to take readings of all pump and monitoring wells every 15 minutes for 4 hours.

7. Continue to take readings at 4-hour intervals until static conditions are attained.

V. USE OF THIS REPORT AND WARRANTY

We have prepared this report for use by Union Oil Company of California or by your design representatives for this project. The data and report should not be considered as a warranty of the subsurface conditions.

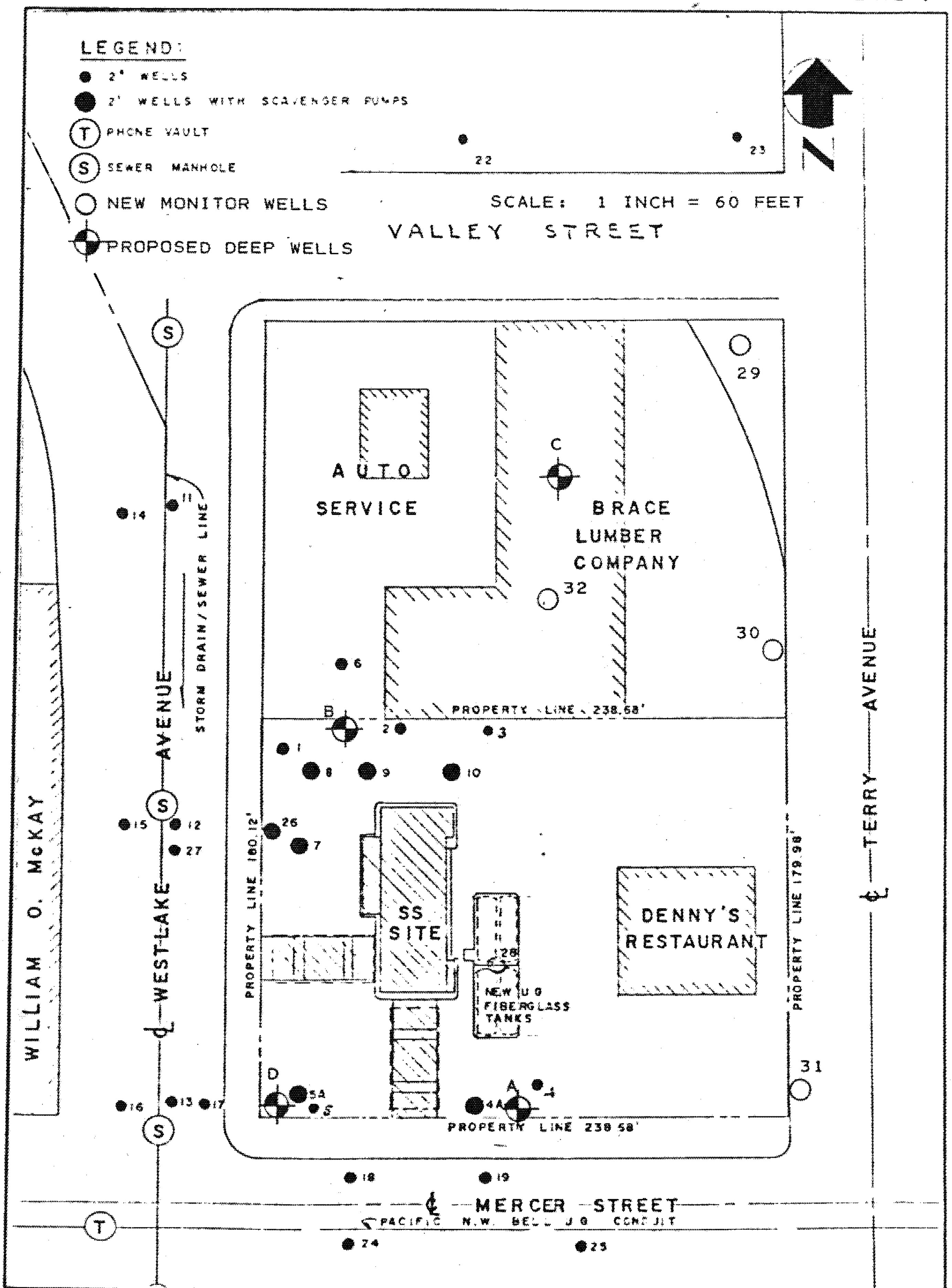
Within the limitations of the schedule and budget for our work, we warrant that our work has been done in accordance with generally accepted practice in this area. No other warranty, express or implied, is made.

The scope of our work did not include services related to construction safety precautions and is not intended to recommend or direct construction means, methods, techniques, sequences or procedures, except as specifically described, and then only for consideration in design, not for construction guidance.

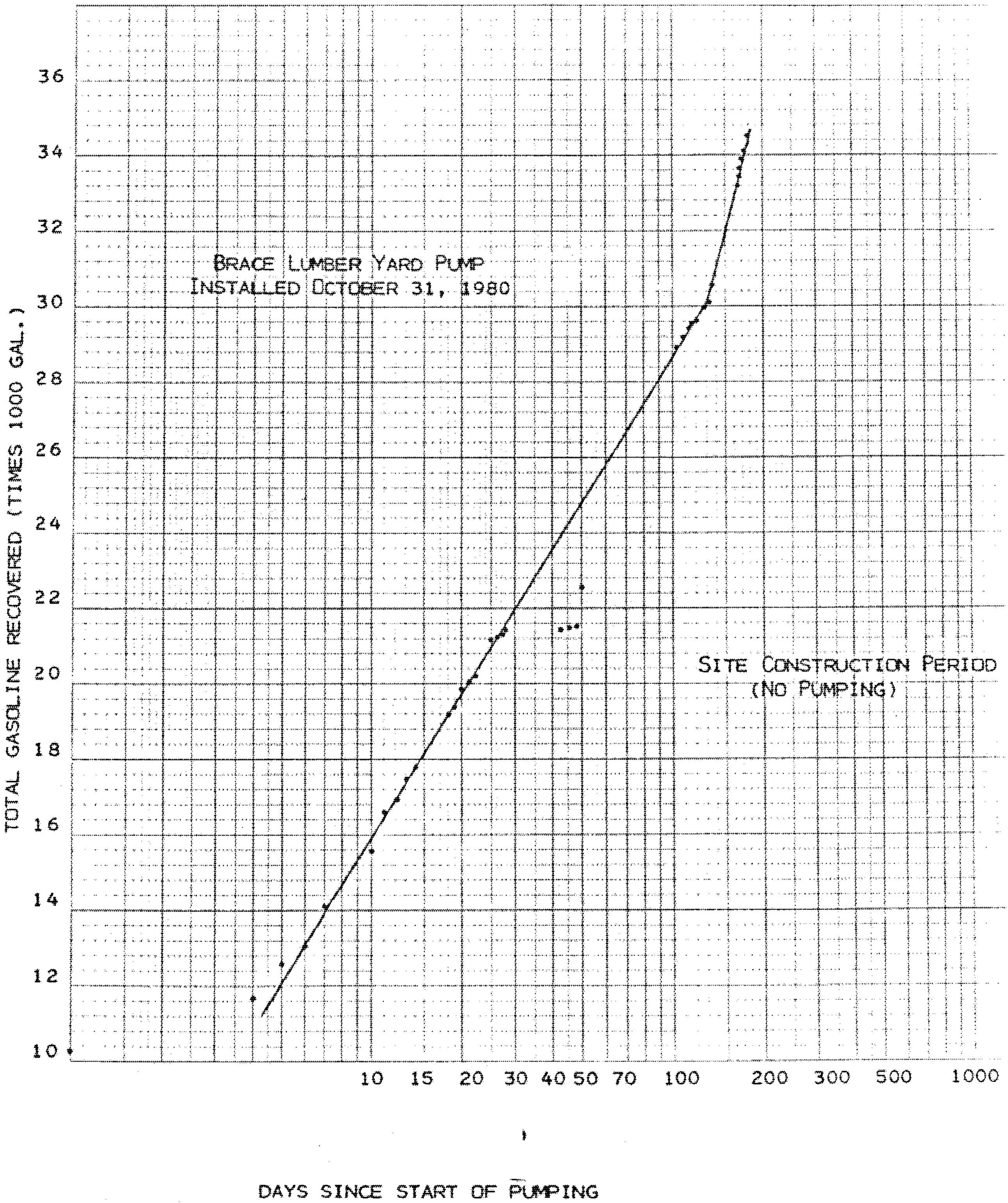
There are possible variations in subsurface conditions between the explorations and also with time. A contingency for unanticipated conditions should be considered.

We understand that we will be working closely with you and your design representatives to develop a corrective program and to see that our recommendations are properly interpreted. If there are any questions concerning this report or if we can provide additional services, please call.

UNION OIL COMPANY   DECEMBER 23, 1980   PLATE 1



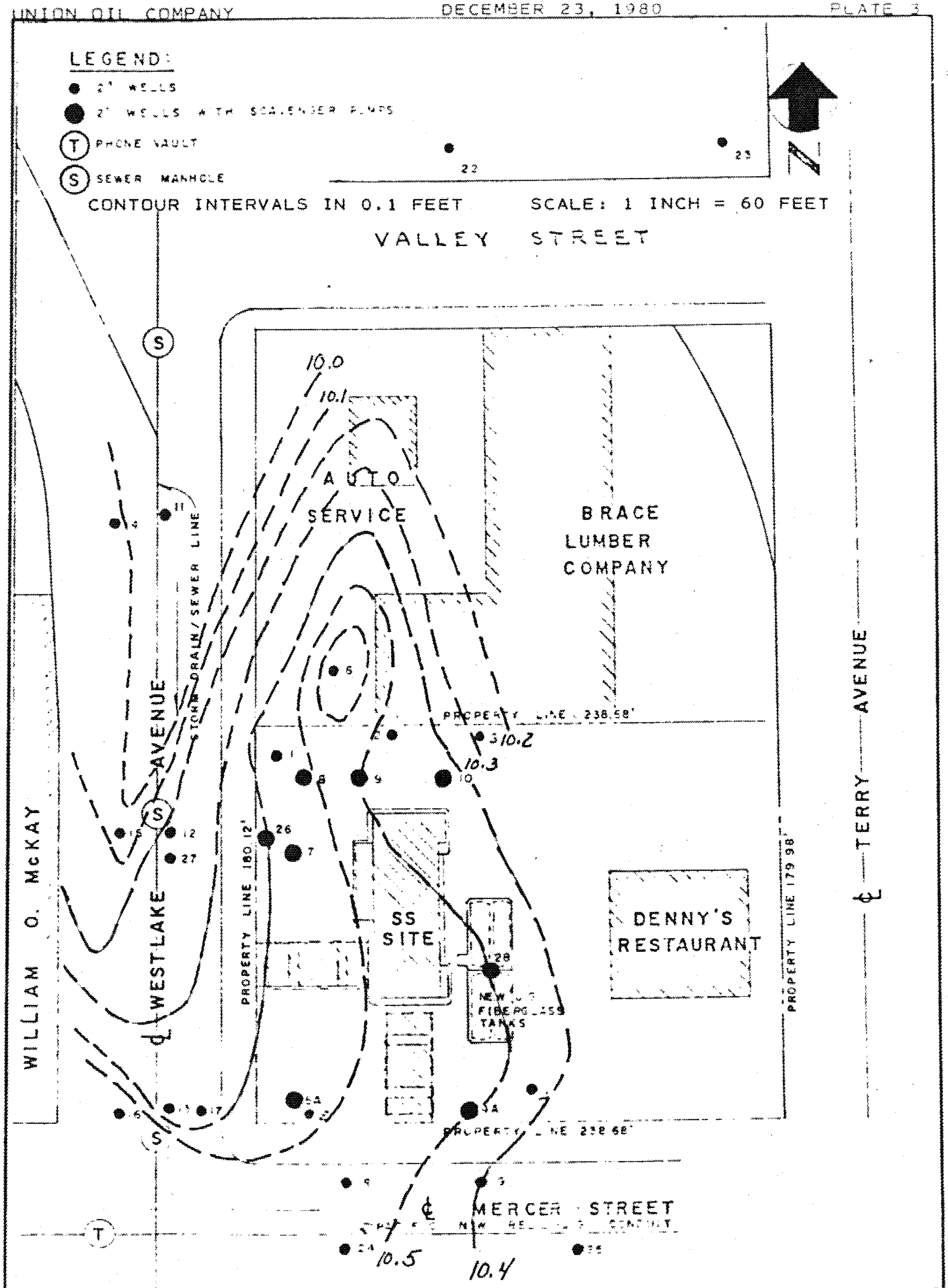
ROGER LOWE ASSOCIATES INC.   PLOT PLAN



NOTE: START OF PUMPING ON JUNE 19, 1980

ROGER LOWE ASSOCIATES | TOTAL GASOLINE RECOVERY

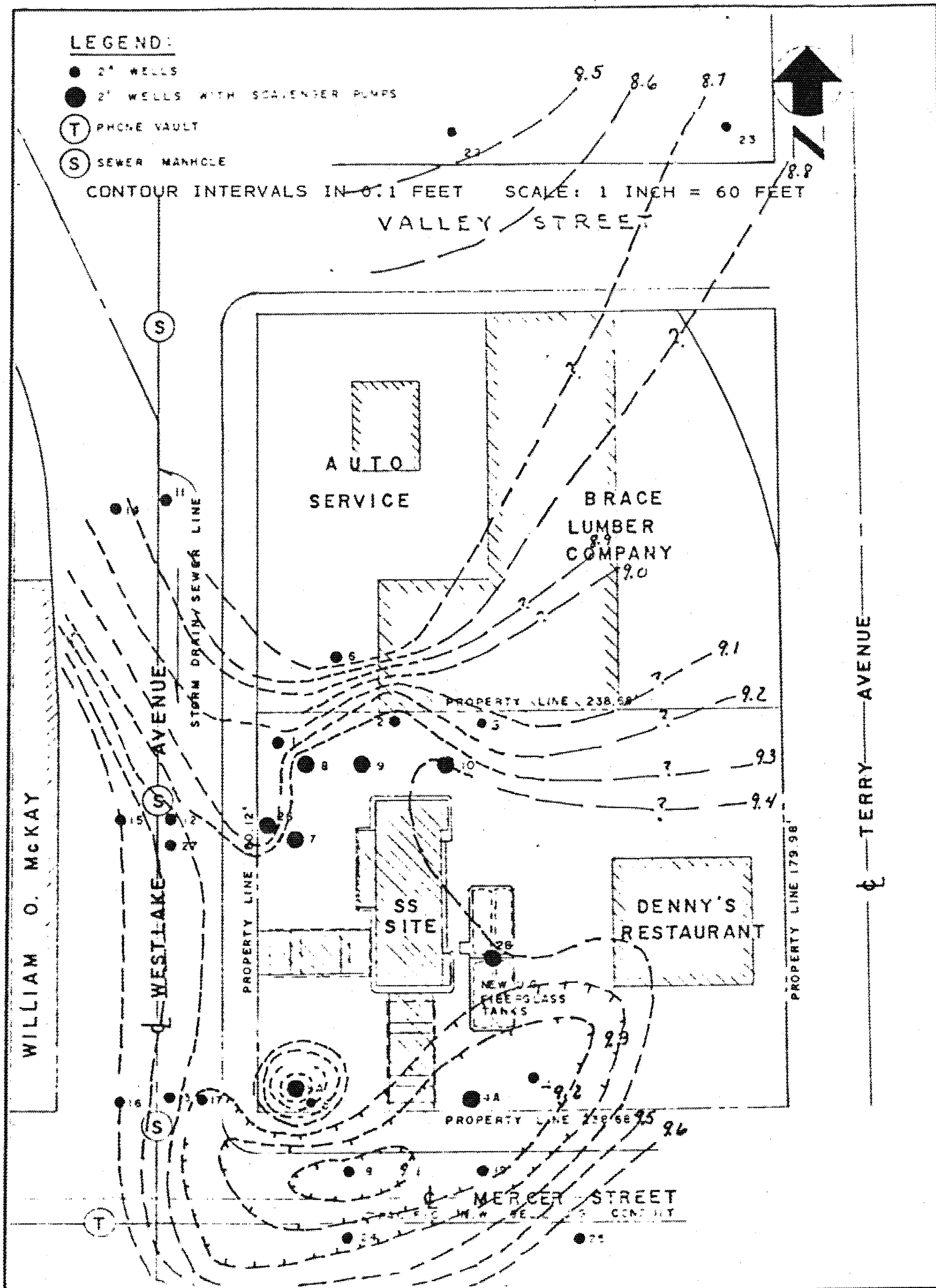
UNION OIL COMPANY DECEMBER 23, 1980 PLATE 3



ROGER LOWE ASSOCIATES INC.

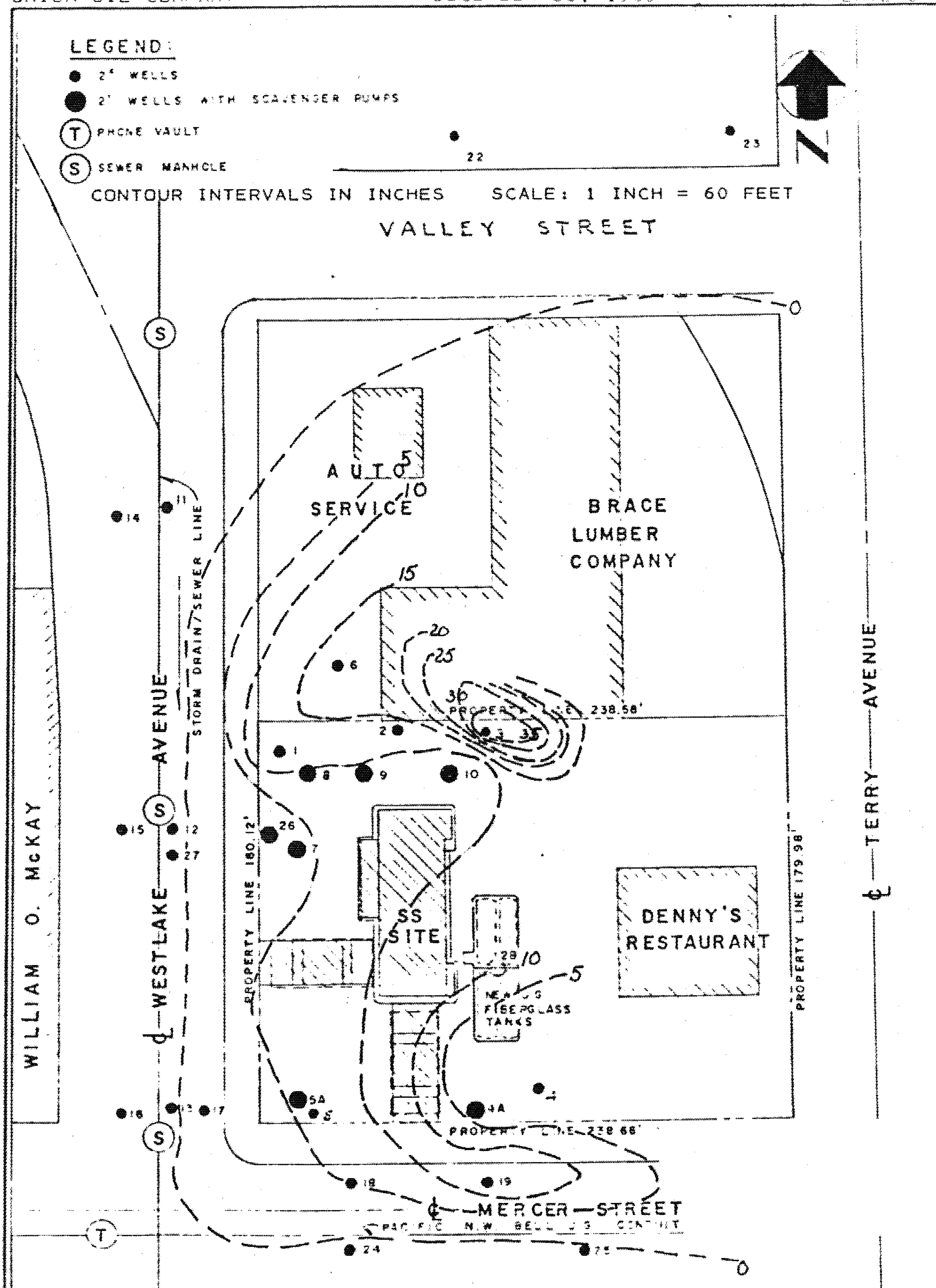
ORIGINAL PIEZOMETRIC ELEVATIONS
JUNE 1980

UNION OIL COMPANY DECEMBER 23, 1980 PLATE 4



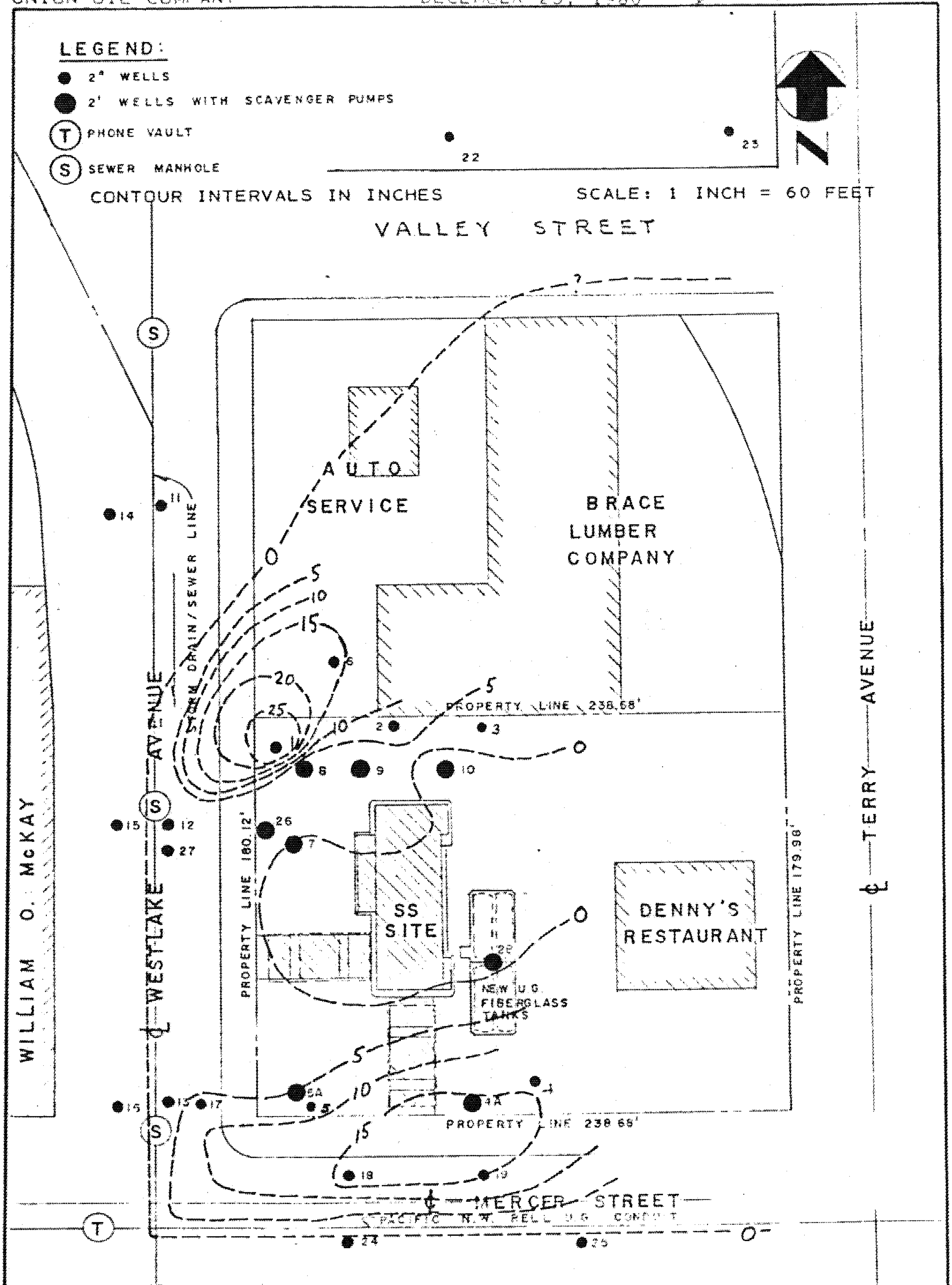
ROGER LOWE ASSOCIATES INC. PIEZOMETRIC ELEVATIONS 12-7-80

UNION OIL COMPANY DECEMBER 23, 1980 PLATE 5



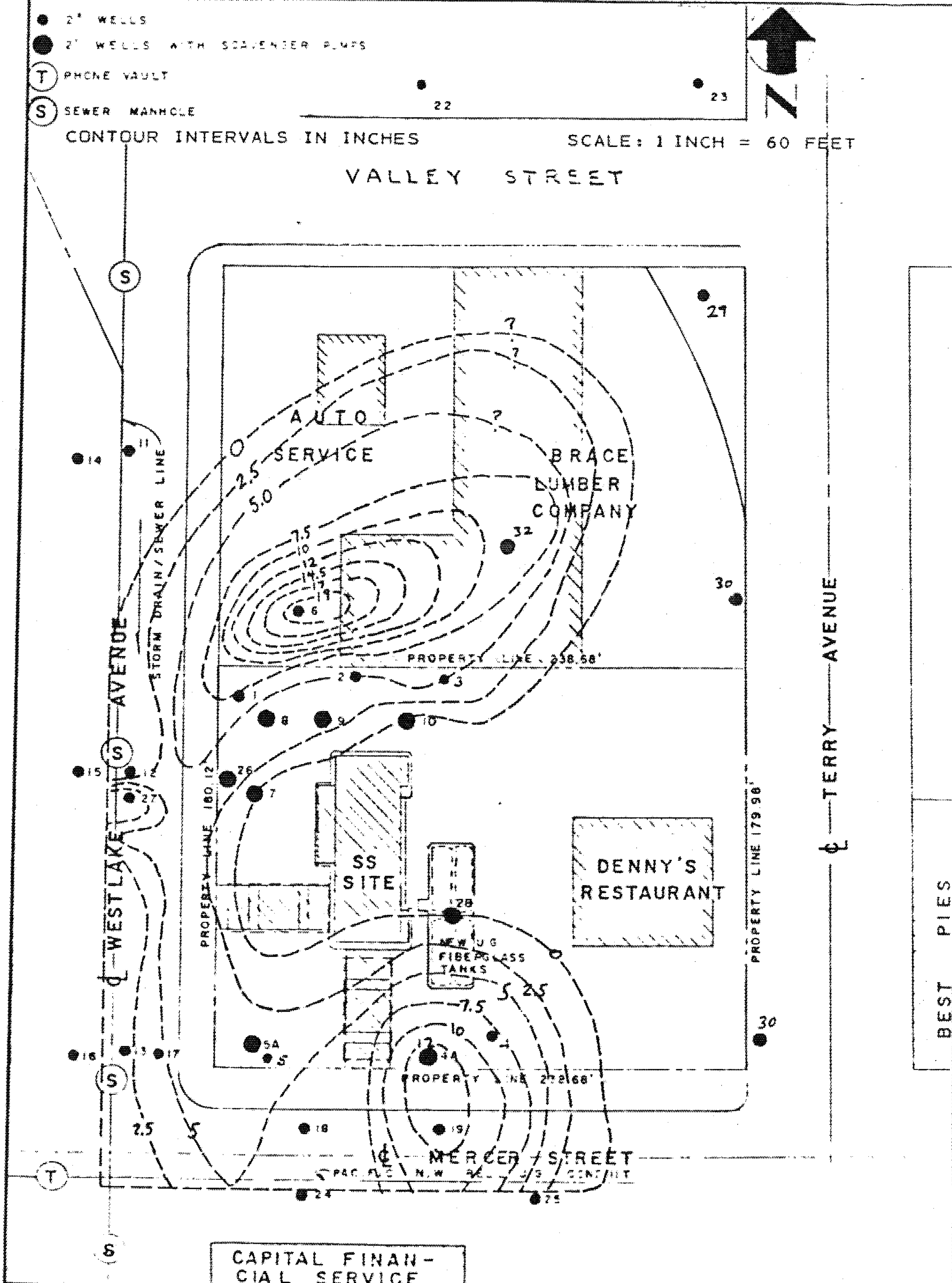
ROGER LOWE ASSOCIATES INC. | ORIGINAL GAS THICKNESSES JUNE 198[illegible]

UNION OIL COMPANY DECEMBER 23, 1980 PLATE 6



ROGER LOWE ASSOCIATES INC. | GASOLINE THICKNESSES 11-18-80

UNION OIL COMPANY DECEMBER 23, 1980 PLATE



ROGER LOWE ASSOCIATES INC.	GASOLINE THICKNESSES 12-7-80

ROGER LOWE ASSOCIATES INC.
EARTH SCIENCES

January 9, 1981

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Progress Report
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Project No. 14, 197,006.07

Gentlemen:

This letter presents our semimonthly status report regarding the monitoring and recovery program for the Westlake and Mercer gasoline spill in Seattle, Washington. A report summarizing our previous services for the project was presented December 23, 1980.

Status Meeting

On January 6, 1981 a meeting was held to discuss the program's current status and future direction. Those in attendance included Jeff Benoit and Bill Driscoll of Union Oil Company, Ed Ingham of Ryan Haworth, Jim Miller of GeoEngineers, and Jim Neyens and Jim Cameron of Harding-Lawson Associates. Jim Neyens is a member of our Houston office with extensive experience in gasoline recovery operations and other environmental engineering concerns.

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LOCATION: BENAROYA BUSINESS PARK, BLDG. 4, SUITE 219 - 300 120th AVE. N.E., BELLEVUE, WA.

Based on discussions in the meeting, we understand that you would like to avoid overt action in order to minimize disturbance to merchant business and public traffic in the station's vicinity. It appears that the spilled gasoline is contained within the confines of the surrounding block, and that adequate ventilation measures are being employed at all areas of detectable gasoline vapor. Due to the apparent control of the gasoline and vapor problems and the subsequent low risk to bodily harm, we feel that the proposed course of direction is acceptable, provided the existing monitoring program is continued. However, should future monitoring indicate potential gasoline or vapor hazards, alternative actions should be available for prompt response.

Two alternative courses of action were discussed in the meeting. They include the following:

1. We feel that it is unlikely that liquid gasoline will enter Lake Union. However, if liquid gasoline is detected in monitoring Well Nos. 22 and 23, and it is felt that gasoline entry into the lake would be hazardous to the lake or to the public, then some means of reversing the gasoline flow back toward the site would be necessary. One possible means would be to install a drawdown pump at the base of the Brace Lumber Yard gasoline sump to depress the local water table. It is estimated

that the existing gasoline sump tank could be quickly fitted to accomodate approximately 5 feet of additional drawdown. The water retrieved from the drawdown pump would have to be stored and trucked off the site or treated and pumped into the storm sewer system. We feel that drawing the water level down at the Brace Lumber Yard gasoline sump would depress the water table sufficiently to reverse lakeward flow of liquid gasoline. However, the drawdown pumping would also tend to draw gasoline off the Union Oil property.

2. If monitoring data indicates potentially serious hazards caused by the gasoline spill, then an alternative method of speeding up the recovery rate would be to deepen existing or install new deep wells as outlined in our letter dated December 23, 1980. Prior to drilling these wells, additional evaluation would be necessary concerning their depth and location.

Questions were raised as to the accuracy of the existing water level and gasoline thickness data which is obtained periodically. Gasoline and water measurements are taken with a wooden dip stick. The volume of gasoline and water which is displaced by the dipstick may be affecting the true liquid readings in the wells, particularly the two-inch diameter monitoring wells.

We recommend that future measurements be obtained with a metal tape or other means which displaces a minimal volume of liquid during measurement.

Additional consideration was given to interpretation of the gasoline thickness data. It appears that the thickness of gasoline measured in a monitor well does not necessarily reflect a corresponding thickness of gasoline liquid in the adjacent soil. For most soils, the measured gasoline thickness will be greater than these actually occurring in the soil. The difference depends primarily on the soil permeability and the local hydraulic gradient. In general, the difference in thickness will be greater in soils of lower permeability than in those of higher permeability. Consequently, the contour plot of gasoline thickness (see Plate 2) may not represent accumulations of gasoline but may actually indicate variations in subsurface permeability. Considering the variety of fill soils encountered in the test borings, it is likely that there are significant differences in permeability and that the measured gasoline thicknesses to some extent reflect this variation. In any case, it is encouraging to note that the measured gasoline thicknesses are probably several times greater than actual thicknesses.

A flash test and a specific gravity test will be performed on samples of gasoline which have been recovered to better evaluate combustibility and potential for contamination. In addition, a survey of utilities and elevations is presently being accomplished in order to construct a comprehensive site plan.

Vapor removal techniques were also briefly discussed at the meeting. Gasoline trapped in the soil will continue to release gasoline vapor long after all of the retrievable liquid gasoline is collected. The vapor hazard may be eliminated by either flushing with air to draw the vapor out of the soil, or by biological degradation through bacterial means. Both phenomena occur natually in the soil but at a very slow rate; vapor removal techniques essentially consist of speeding up the natural processes. One method consists of constructing a network of well points above the water table and forcing air through the unsaturated zone of soil which would both flush the soil of vapor and bring a steady supply of oxygen to aerobic bacteria to decompose the gasoline. In addition, phosphates and nitrates in liquid form may be injected through the wells to increase bacterial growth. Alternatively, vacuum well points could be installed above the water table and would perform the same functions except that air is drawn to the wells rather than away from them. The vacuum method may be advantageous in that it would tend to contain the gasoline vapor at the site. Other methods of gasoline vapor removal may be possible and a literature search of current theories and practices may be quite helpful for this project.

Future Services

Based on the results of the meeting of January 6, 1981 we understand that our future involvement in this project will consist of the following:

1. Continue to reduce data which is periodically collected by Pacific Testing Laboratories.

2. Summarize the results of our data reduction and present the results in biweekly reports.

3. Notify Union Oil Company and discuss alternative actions to be employed, if site data indicates potentially hazardous conditions.

4. Perform a literature search of gasoline vapor removal methods and techniques.

Gasoline Recovery

Gasoline recovery continued to decrease after November 30, 1980. Between November 30 and December 31, 1980 an estimated total of 819 gallons was recovered; 552 gallons from the Brace Lumber pump and 267 gallons from Well Nos. 4A and 8. This brings the total gasoline recovered to date to 33,977 gallons.

Since the last part of December, gasoline recovery from wells on the Union Station property has virtually ceased. We feel this has occured primarily as a result of a decrease in the total amount of gasoline available for recovery by the present recovery means and partially due to the relatively low ground water levels currently experienced by the site. In addition, there appears to have been a continued northward migration of gasoline away from Well No. 8 as an apparent result of a northward descending piezometric surface. We expect that little additional gasoline can be recovered from these wells until the pumps are lowered or the water table rises sufficiently for the piezo-meteric gradient to be reversed.

Piezometric Elevation

Since December 7, 1980 there has been a slight rise in the elevation of the piezometric surface in the monitored area. However, this rise has not been significant enough to affect the recovery rates at the site. In Well Nos. 22 and 23, the increase in elevation has been approximately .5 feet. In other wells, the increase is generally less. Comparison of the piezometric elevations presented on Plate 1 in this report with those of Plate 4 in our report dated December 23, 1980, indicates that the main effect of the rise in piezometric levels has been to broaden the area in which piezometric levels exceed Elevation 9.6. However, there has been little significant change in the overall hydraulic gradient which slopes downward to the north and east. A small depression in the piezometric surface still appears to exist near Mercer Street and in the northwest corner of the Union Station property.

We believe that the slight elevation gain in the piezometric surface does not signify a major trend but merely a minor adjustment to local recharge conditions.

Gasoline Thickness

Plate 2 depicts the recorded gasoline thickness in inches on December 28, 1980. Comparison of this plate with Plate 7 in our report dated December 23, 1980, indicates that the location and thickness of gasoline pools has not changed significantly since December 7, 1980. There are still apparent concentrations of gasoline beneath the Union Station near Mercer Street and just north of the northwestern corner of the Union Station property. The lack of variation in gasoline thickness since December 7 is not surprising considering the relatively small amount of gasoline currently being recovered from pumping operations. However, as noted previously, the contour plot may not be depicting actual gasoline thickness but variations in subsurface permeability.

Explosimeter Readings

Explosimeter readings taken since December 7, 1980 are fairly consistent. All wells with the exception of No. 22 have measurable vapors at a depth of 8 feet. The latest measurement on December 28, 1980 shows that Well No. 23 is also devoid of vapor. However, readings of 100 percent were obtained in this well at a depth of 8 feet in the previous two measurements (on December 14 and December 21, 1980).

At a depth of 4 feet, Well Nos. 14, 16, 22 through 26, and 31, showed no measurable vapor concentrations. Other wells generally measured 100 percent at this depth.

If there are any questions concerning this report or if we can provide additional services, please call.

Yours very truly,

ROGER LOWE ASSOCIATES
A Division of Harding-Lawson Associates

James T. Cameron

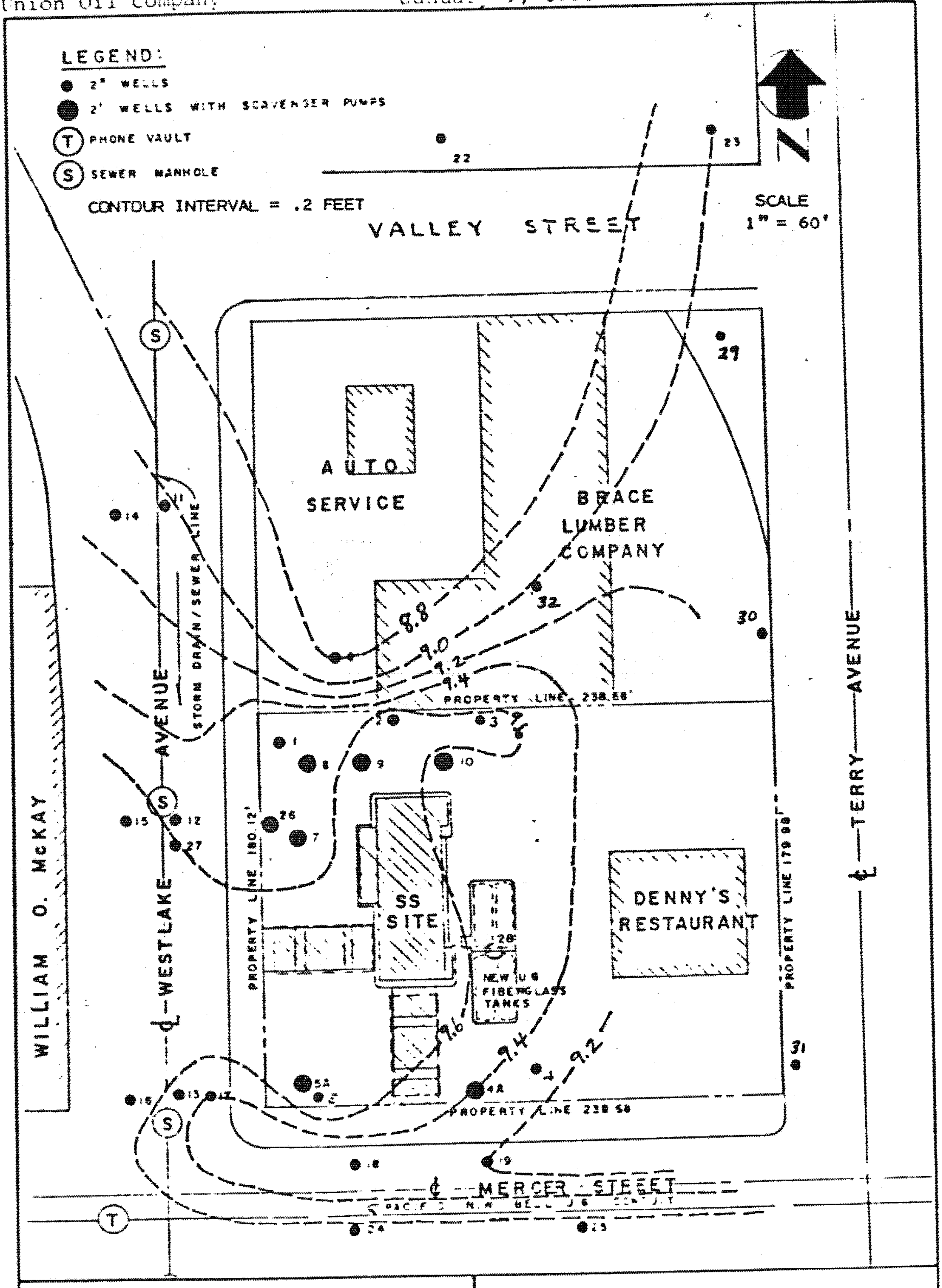
James T. Cameron
Project Manager

Roger A. Lowe

Roger A. Lowe
Principal-in-Charge

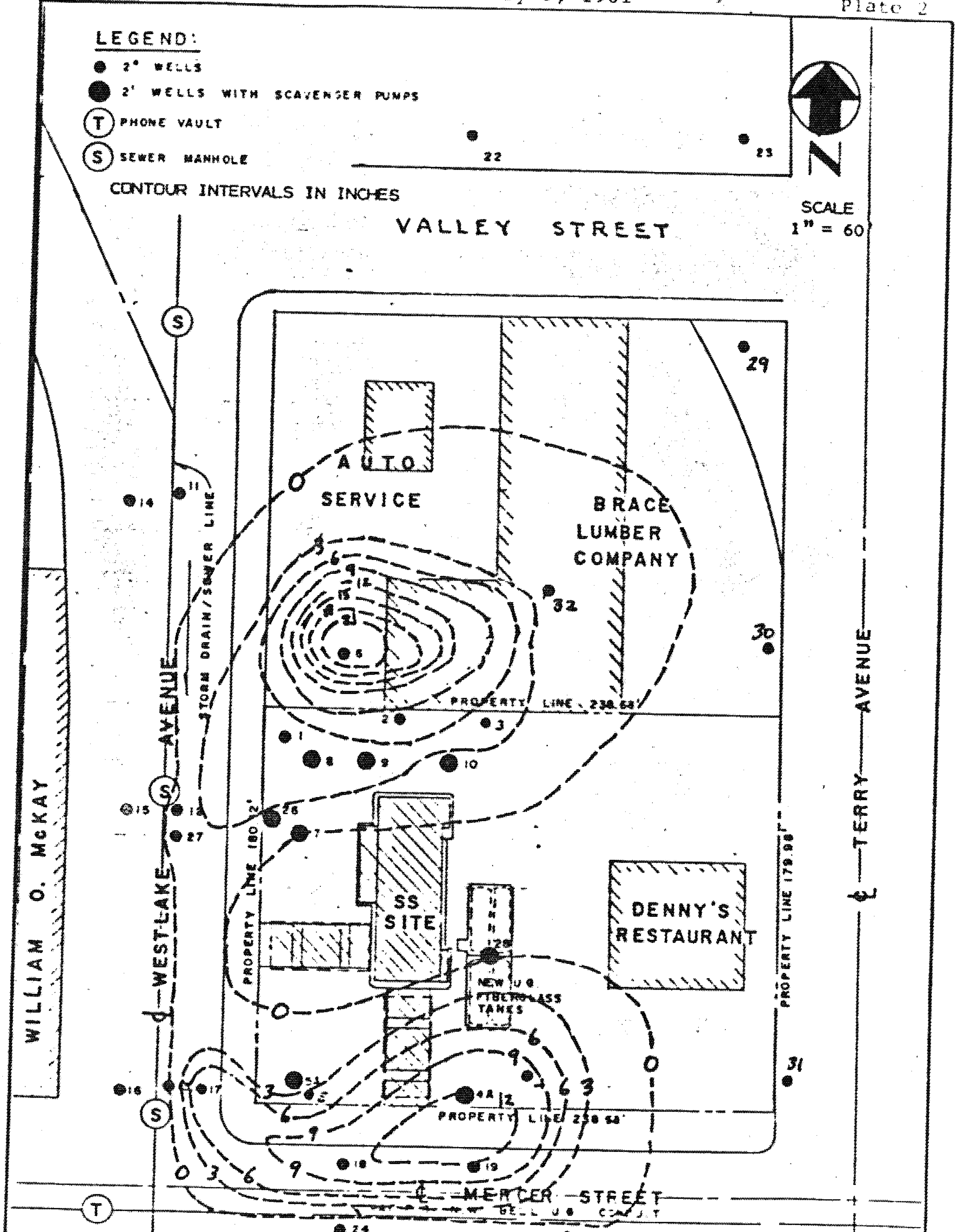
JTC/ld

2 copies submitted
1 Jim Miller
1 Ed Ingham



ROGER LOWE ASSOCIATES INC. PIEZOMETRIC ELEVATIONS 12/28/80

Union Oil Company January 9, 1981 Plate 2



ROGER LOWE ASSOCIATES INC. GASOLINE THICKNESS

ROGER LOWE ASSOCIATES INC.
EARTH SCIENCES

January 26, 1981
14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

COPY

Gentlemen:

Attention: Mr. Jeff Benoit

Progress Report No. 3
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill

This letter presents our semimonthly status report regarding the monitoring and recovery program for the Westlake and Mercer gasoline spill in Seattle, Washington.

Gasoline Recovery

Gasoline recovery has continued to decrease since December. Between December 31, 1980 and January 11, 1981, neither the Brace Lumber holding tank nor the main Union Station holding tank were pumped. Consequently, the total gasoline recovered to date (January 11, 1981) remains at 33,977 gallons.

As noted in our last report, the slowdown in recovery appears to be due to low ground water levels relative to well and pump depths and to a lessening volume of gasoline available for recovery.

Piezometric Elevations

Since December 23, 1981, there has been little significant change in the overall configuration of the piezometric surface

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LOCATION: BENAROYA BUSINESS PARK BLDG 4, SUITE 219 - 300 120th AVE. N.E., BELLEVUE, WA

in the monitored area. As shown on Plate 1, there is a small depression near Mercer Street and a relatively steep dropoff in piezometric elevations near the north end of the Union Station property. The Mercer Street depression has lowered slightly from a base elevation of about 9.2 on December 28, 1980 to about 9.0 on January 11, 1981. Similarly, the piezometric surface near Wells B-1, B-6, and B-8 at the north end of the Union Station has lowered a few tenths of a foot.

Since our last report, we have given additional consideration to the interpretation of the piezometric data. Plate 1 shows a steep drop and a narrow ravine-like configuration of the piezometric surface near Wells B-6, B-8, and B-26. We believe it possible that these features have developed in response to ground water being held up or "dammed" against the buried retaining wall which we understand bounds the northern side of the Union Station property. Since the overall slope of the piezometric surface is downward towards Lake Union, ground water levels on the uphill (south) side of the buried wall should be higher than those on the downhill (north) side. Consequently, a steep waterfall-like flow may have developed near these wells due to "dammed" ground water migrating westward around the wall then downward (northward) toward the lake.

<u>Gasoline Thickness</u>

Plate 2 shows the recorded gasoline thickness in inches as measured on January 11, 1981. Comparison of this plate with

Plate 2 in our last report, dated January 9, 1981, indicates that the location and thickness of gasoline pools has not changed significantly since December 28, 1980. There has been no discernible migration of the gasoline pools northward towards the lake and all spilled gasoline is apparently contained within the confines of the Union Station-Brace Lumber block.

Explosimeter Readings

There has been almost no variation in explosimeter readings taken since December 28, 1980. The latest measurement on January 11, 1981 indicates that all wells except Nos. 22, 23, 29, 30, and 31 have some gasoline vapor at depths of 4 feet, 8 feet, or at both depths. Although Well Nos. 22 and 23, located closest to the lake, did have vapor readings in the middle part of December, there have been none since. Similarly, Well Nos. 27, 30, and 31 have registered no vapor readings since the end of December.

Literature Review

In an attempt to further our understanding of gasoline spills and mitigating measures, we have reviewed some literature available from the University of Washington library.

One article involved a gasoline spill in the Los Angeles area in 1968 in which 250,000 gallons of gasoline were lost to the surrounding soil. The recovery effort used at the site was very similar to that currently being used at the Westlake and Mercer site. Observation wells were drilled to define the areas of contamination. Later, a number of pumping wells were installed to lower the local ground water and skimming wells were used to collect the gasoline at the ground water surface.

It was concluded that it would be essentially impossible to flush out all of the gasoline from the contaminated zone as the gasoline would tend to form small bubbles within the soil mass around which the flushing water would flow. Consequently, water flowing through an area containing finely dispersed gasoline droplets, would tend to remain uncontaminated. The flushing action would also be retarded in areas of high gasoline concentration as a result of the reduced pore space available for the movement of water.

Bacterial degradation was proposed as a final solution to removing the remnant fraction of gasoline. A possible problem with biodegradation is that bacterial slime can build up within the soil mass preventing the necessary oxygen and nutrients from getting to the gasoline.

Some success in removing gasoline from contaminated water at the site was achieved by using activated carbon filters. However, this method was not deemed to be cost effective.

We reviewed another article concerning the case history of a jet fuel storage tank leakage in Virginia during which 85,000 gallons of JP-4 fuel were lost to the surrounding soil. The recovery program involved a 50 well point system in which approximately 21,000 gallons of fuel were recovered within one month. After this time, two new recovery schemes were implemented including a large diameter excavation and a new well point system to increase fuel recovery. However, both systems failed to prove effective. Flushing by cyclic pumping was also used with no visible success.

Prior to the start of recovery operations, it was predicted that the recovery would be on the order of 25 to 50 percent of the spill volume with an absolute maximum approaching 60 percent. In actuality, approximately 25 percent was recovered. It was assumed that an additional 25 percent was lost to evaporation while the rest was bound within the soil mass. As with the site in Los Angeles, it was assumed that the remainder of the fuel would be removed through natural biodegradation.

Other articles reviewed concerning oil and gasoline degradation in soil indicate that aerobic biodegradation processes are much faster than anerobic degradation. Laboratory tests have shown that fungi are the predominant flora which assist in the biodegradation of oil derivitives, and that increasing fungal activity can increase the rate of degradation. However, the length of time required to completely degrade remnant gasoline may still be on the order of 5 to 15 years.

There has also been considerable research on the use of non-organic methods for the clean-up of oil and gasoline spills. Studies have been performed on emulsifiers which unbind the oil from the soil or break it down and allow it to be more readily extracted. However, most emulsifiers are not environmentally safe for injecting into the ground. One new product, called B226, produced by J & M Equipment Company, Inc., out of Sidney, Ohio, does appear to be environmentally acceptable. B226 is a degreasing agent which removes gasoline vapors and sewer and septic odors, and is biodegradable and phosphate-free. This product is currently used for cleaning manholes, but the manufacturer has indicated that they are researching methods by which it can be used to clean contaminated ground. The product works by eliminating soil "binders" which cause the contaminant to adhere to various surfaces. Once the "binders" are removed, the oil derivatives can enter into the solution and be flushed away. This research appears very promising and may prove useful in alleviating gasoline contamination and vapor problems at the Westlake and Mercer site. We intend to pursue investigation of this product.

If there are any questions concerning this report, please call.

Yours very truly,

ROGER LOWE ASSOCIATES, A Division
of Harding-Lawson Associates

James T. Cameron

James T. Cameron, Project Manager

Roger A. Lowe

Roger A. Lowe, Principal-in-Charge

ROGER A. LOWE
STATE OF WASHINGTON
REGISTERED
PROFESSIONAL ENGINEER

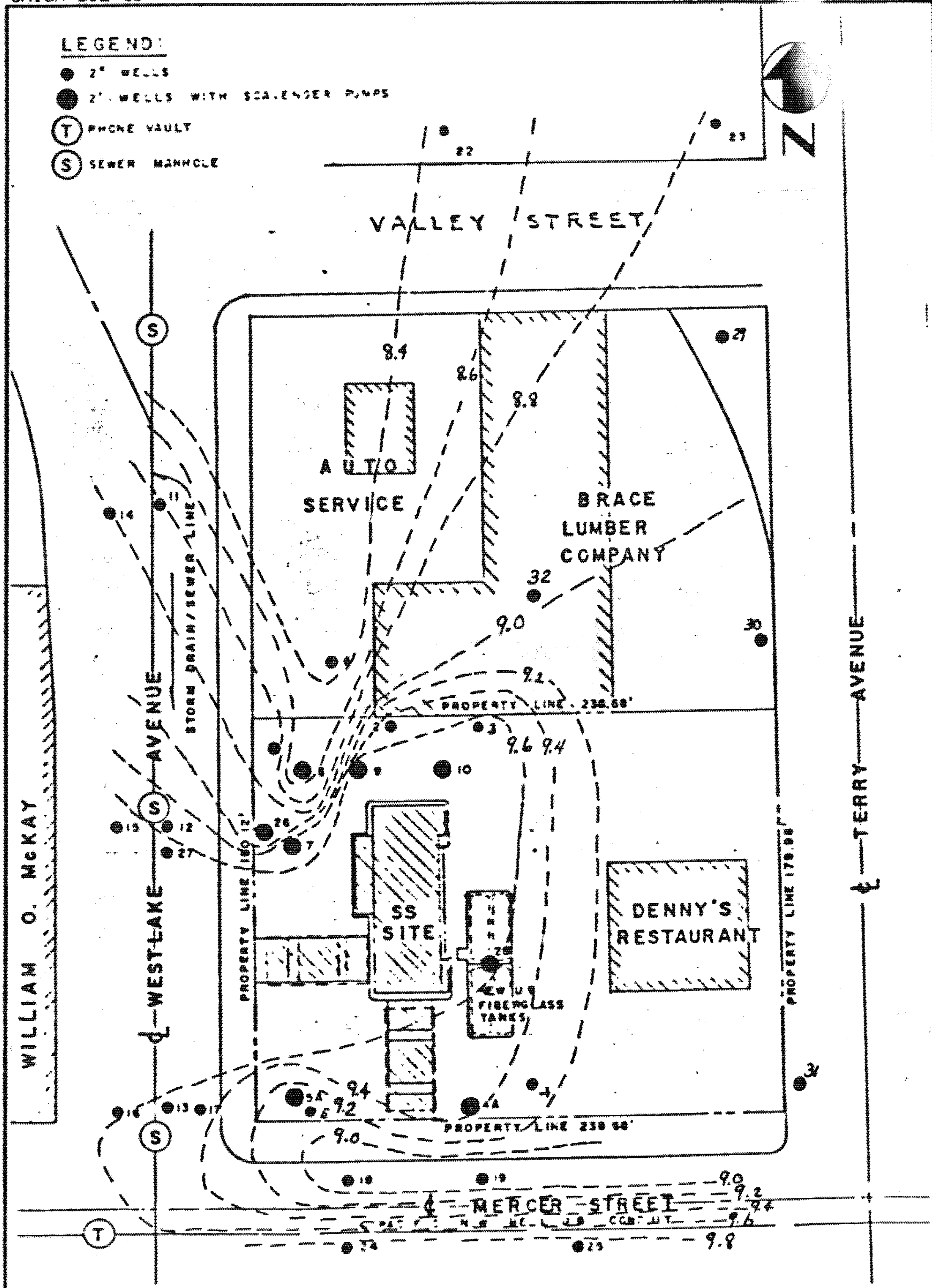
JTC/RAL/ju

2 copies submitted

cc: Jim Miller
Ed Ingham

14,197,006.07
UNION OIL COMPANY

PLATE 1

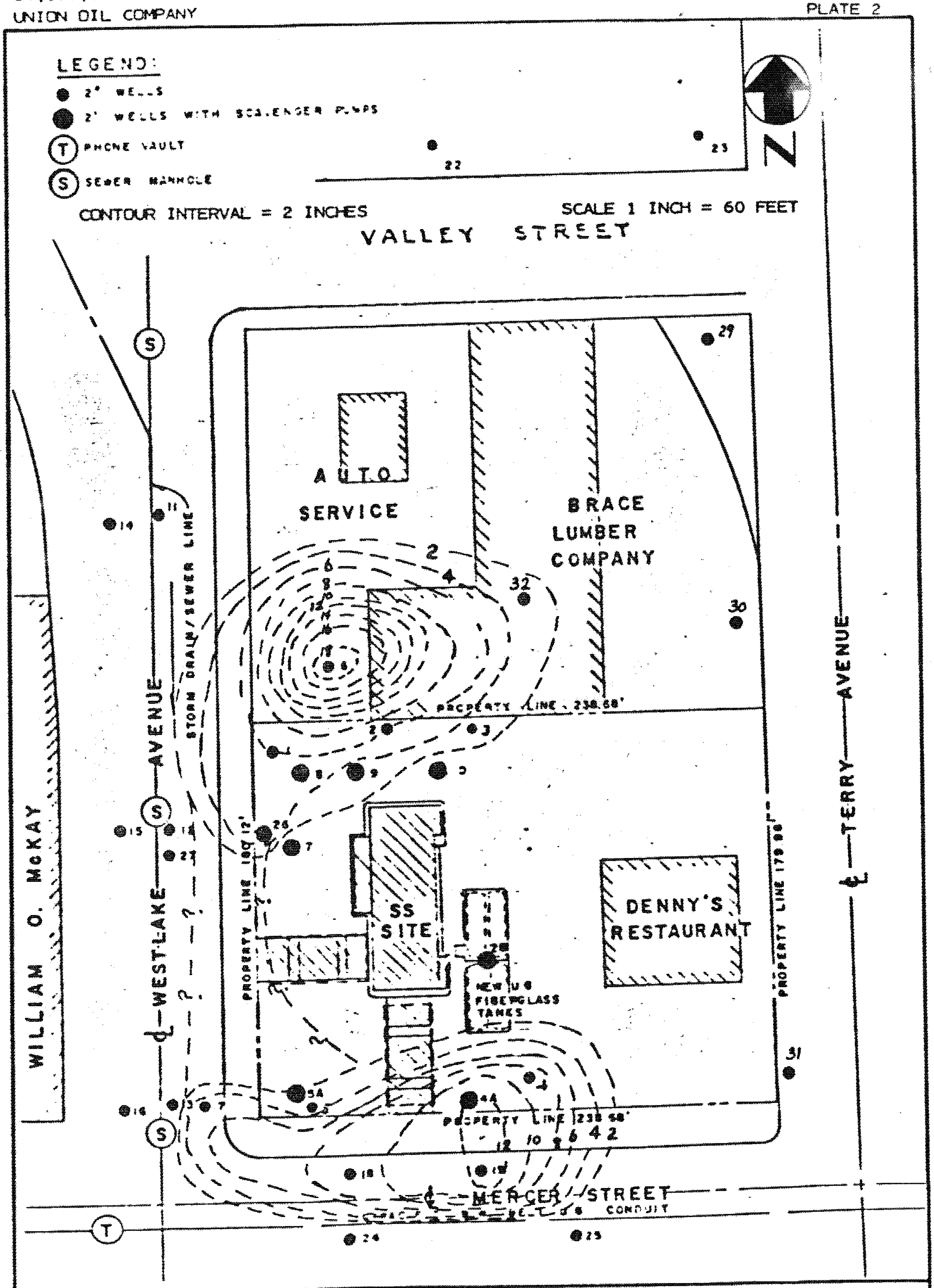


ROGER LOWE ASSOCIATES INC.

PIEZOMETRIC ELEVATIONS 1-11-81

14,197,306.07
UNION OIL COMPANY

PLATE 2



ROGER LOWE ASSOCIATES INC. | GASOLINE THICKNESS 1-11-81

ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

COPY

ALASKA
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ILLINOIS
NEVADA
TEXAS
WASHINGTON
WASHINGTON DC
SAUDI ARABIA

February 6, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 4
Monitoring & Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter presents our semimonthly status report regarding the monitoring and recovery program for the Westlake and Mercer gasoline spill in Seattle, Washington.

Gasoline Recovery

Gasoline recovery is at a virtual standstill. Since December 31, 1980, neither the Brace Lumber holding tank nor the main Union Station holding tank has been pumped. Consequently the total gasoline recovered to date (January 25, 1981) remains at 33,977 gallons.

Piezometric Elevations

Since our last progress report, we have obtained top-of-casing elevations for new monitoring wells 29, 30, 31, and 32. Acquisition of this information has allowed determination of piezometric levels in the eastern portion of the monitored area along Terry Avenue.

In our last progress report, we noted that there appeared to be a narrow ravine-like configuration of the piezometric surface near Wells 6, 8, and 26. The new data from Wells 29, 30, 31, and 32 supports this interpretation and indicates that the "ravine" is an even more pronounced feature than previously thought. The new data also suggests that the local piezometric surface slopes downward towards the monitored area from the east as well as from the south and west.

Since January 11, 1981, there has been little significant change in piezometric elevations across the site. The depression near Mercer Street (see Plate 1) has risen slightly from a base elevation of about 9.0 on January 11, 1981 to 9.3 on January 25, 1981. In other areas, the piezometric surface has risen a few hundredths of a foot.

Gasoline Thickness

Plate 2 shows the recorded gasoline thickness in inches as measured on January 25, 1981. Comparison of this plate with Plate 2 in our report dated January 26, 1981, indicates that the location and thickness of gasoline pools has not changed significantly since January 11, 1981. The fact that no liquid gasoline has been detected in Wells 29, 30, and 31 is probably due to the trapping of free gasoline in the piezometric "ravine" discussed previously. Any migration of gasoline should occur along the "ravine" towards the lake rather than eastward towards Terry Avenue or westward towards Westlake Avenue. Currently, there does not appear to be any active migration since neither liquid gasoline nor gasoline vapor has been detected in monitor Wells 22 and 23, located directly down gradient from, and in-line with, projected gasoline movement. Based on this, we believe that the spilled gasoline is essentially contained within the confines of the Union Station - Brace Lumber block.

Explosimeter Readings

There has been almost no variation in explosimeter readings taken since December 28, 1980. The latest measurements taken on January 25, 1981 indicate that all wells except Wells 22, 23, 29, 30, and 31 have some gasoline vapor at depths of 4 feet, 8 feet, or both.

Yours very truly,

ROGER LOWE ASSOCIATES, A Division of Harding-Lawson Associates

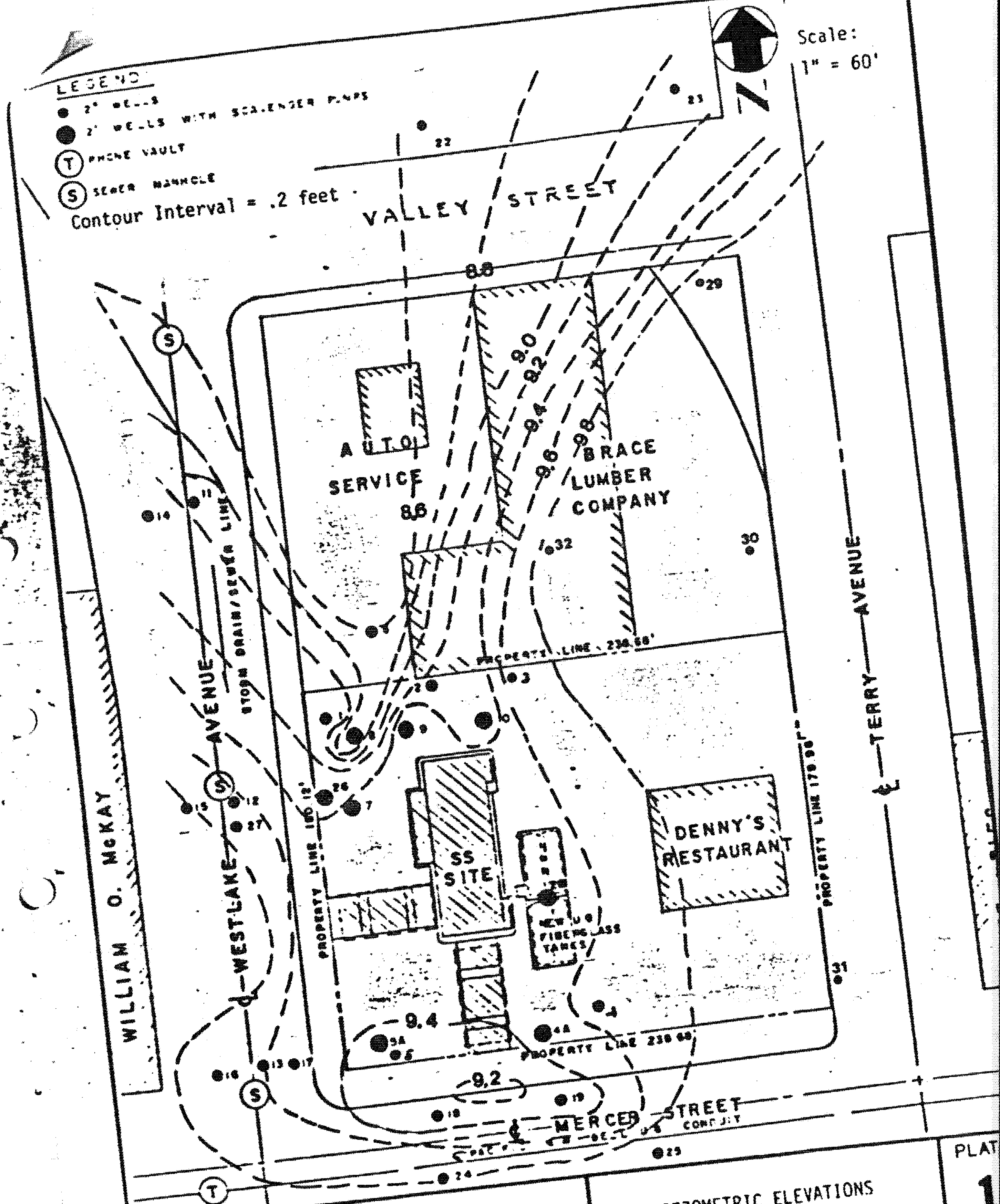
James T. Cameron

James T. Cameron
Project Manager

JTC/MAA/ju

cc: J. Miller
E. Ingham

bcc: Jim Nelfens - Houston - HLA

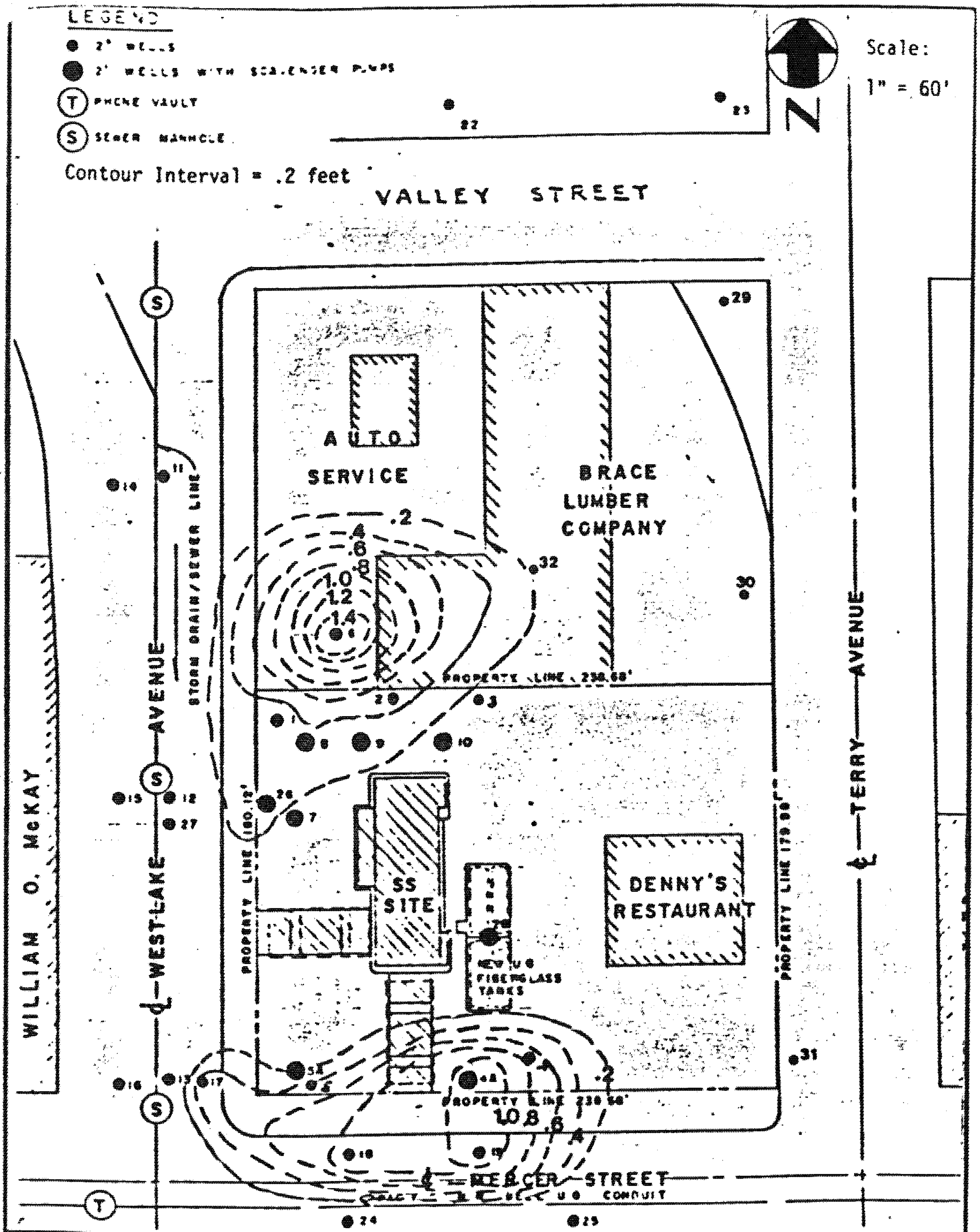


ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

14,197,006.07 APPR ______ DATE 2/5/81

PIEZOMETRIC ELEVATIONS
1-25-81

PLAT
1



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

GAS THICKNESS
1-25-81

PLATE
2

JOB NO 14,197,006.07 APPR ______ DATE 2/5/81

ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers Geologists and Geophysicists

February 23, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

COPY

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 5
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter presents our semi-monthly status report regarding the monitoring and recovery program for the Westlake and Mercer gasoline spill in Seattle, Washington.

Gasoline Recovery

Gasoline recovery is still slow. Between January 25 and February 8, 1981, approximately 48 gallons of gasoline were recovered. The total gasoline recovered as of February 8, 1981 is approximately 34,025 gallons.

Piezometric Elevations

The piezometric elevations for February 8, 1981 are shown on Plate 1. In the northern half of the block there appears to be little significant change from those elevations recorded on January 25, 1981. Piezometric elevations in the southern half of the block appear to have decreased an average of .2 feet within this time period. It is difficult to assess the reason for this general lowering. However, the apparent depression in the southern half of the block indicates that the gasoline is still being retained.

Gasoline Thickness

Plate 2 shows the recorded gasoline thickness (in feet) as measured on February 8, 1981. Comparison of this plate with Plate 2 in our report dated February 6, 1981, indicates that the gasoline pool in the mid-portion of the block has decreased significantly in thickness from a maximum of 1.4 feet to a maximum thickness of approximately .6 feet. Conversely, the gasoline pool in the southern end of the block has increased in maximum thickness on the order of .5 feet. This may indicate a migration of gasoline to the south.

We are informed that the lake level has risen significantly in the last few weeks. Theoretically this would explain gasoline migration toward the south, however, the piezometric readings do not substantiate this. We feel that if gasoline is migrating toward the south, there is no need for concern since the gasoline would eventually be halted as it meets the higher water table surface flowing from the south.

At this time it is difficult to assess the reasons for the significant variations in gasoline thickness at the site. We intend to closely watch subsequent readings of gasoline thickness, piezometric elevations and lake levels in order to explain these discrepancies.

Explosimeter Readings

There have been little to no variations in explosimeter readings taken since December 28, 1980. The latest measurements taken on January 8, 1981, indicate that all wells except 22, 23, 29, 30 and 31 have some gasoline vapor at depths of 4 feet, 8 feet or both.

Research

A meeting was held on February 9, 1981 between the Union Oil Company, Ryan and Haworth Company, GeoEngineers, and ourselves to discuss the possibility of using a degreasing agent at the site to reduce vapor problems. In particular, the product B-226 was discussed.

It was decided that Jim Miller of GeoEngineers and Jim Cameron of Roger Lowe/Harding Lawson Associates, would perform a small test using 55 gallon barrels and fine sand to evaluate the B-226 before introducing it to the site.

It is intended to retrieve as much gasoline as possible using the present recovery scheme. Therefore, any significant modifications will be avoided prior to the beginning of May, when the lake level should again be at its maximum. In this way, the existing recovery program will have been in operation for a full seasonal cycle of lake and weather conditions.

We have been informed that flash tests performed on a sample of recovered gasoline indicates that the gasoline is still explodible at ambient temperatures. Specific gravity tests indicate that the specific gravity of the on-site gasoline is somewhere between that of gasoline and diesel.

Yours very truly,

ROGER LOWE ASSOCIATES, A Division
of Harding-Lawson Associates

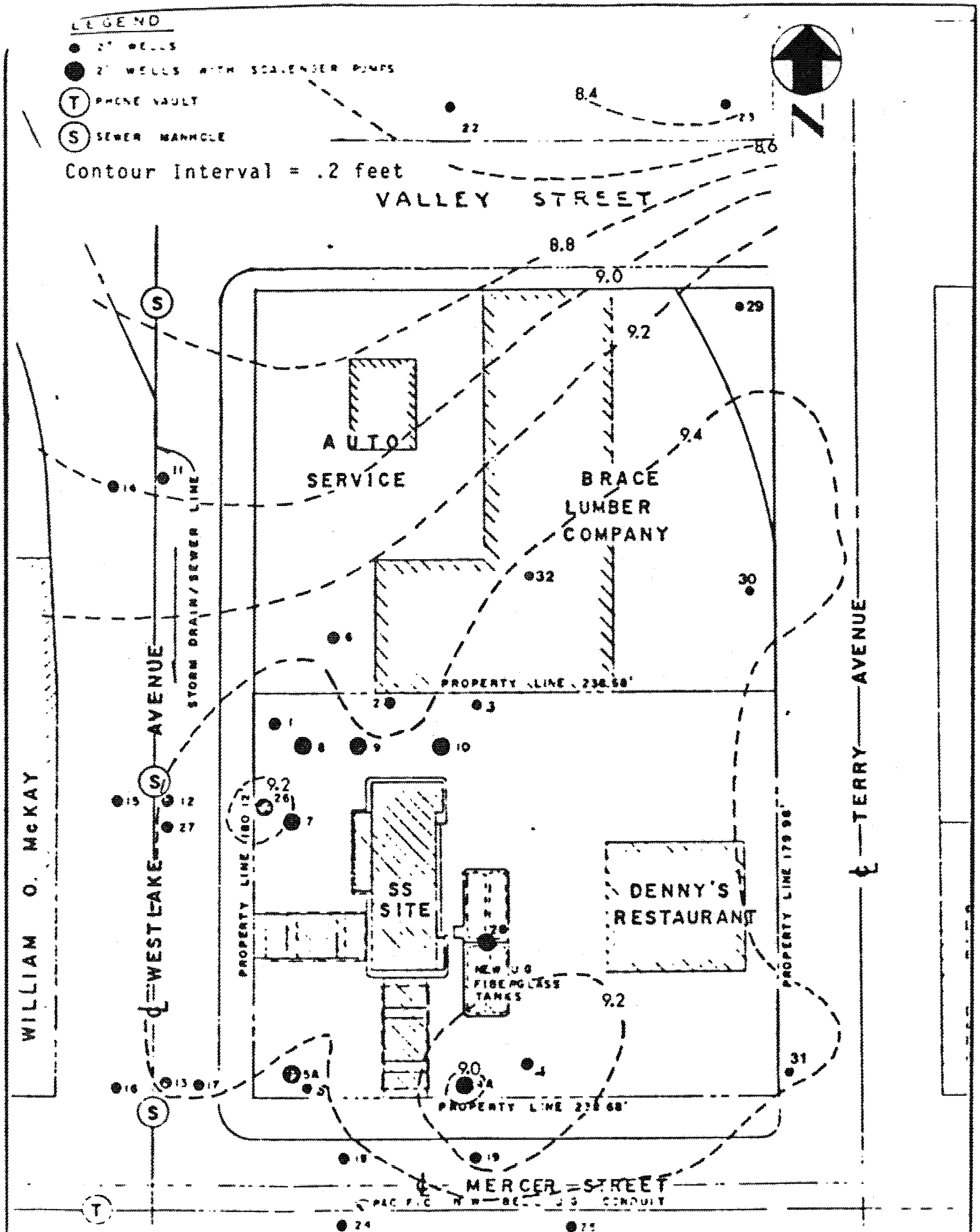
James T. Cameron

James T. Cameron
Project Manager

JTC/ju

cc: Jim Miller - GeoEngineers
Ed Ingham - Ryan, Haworth

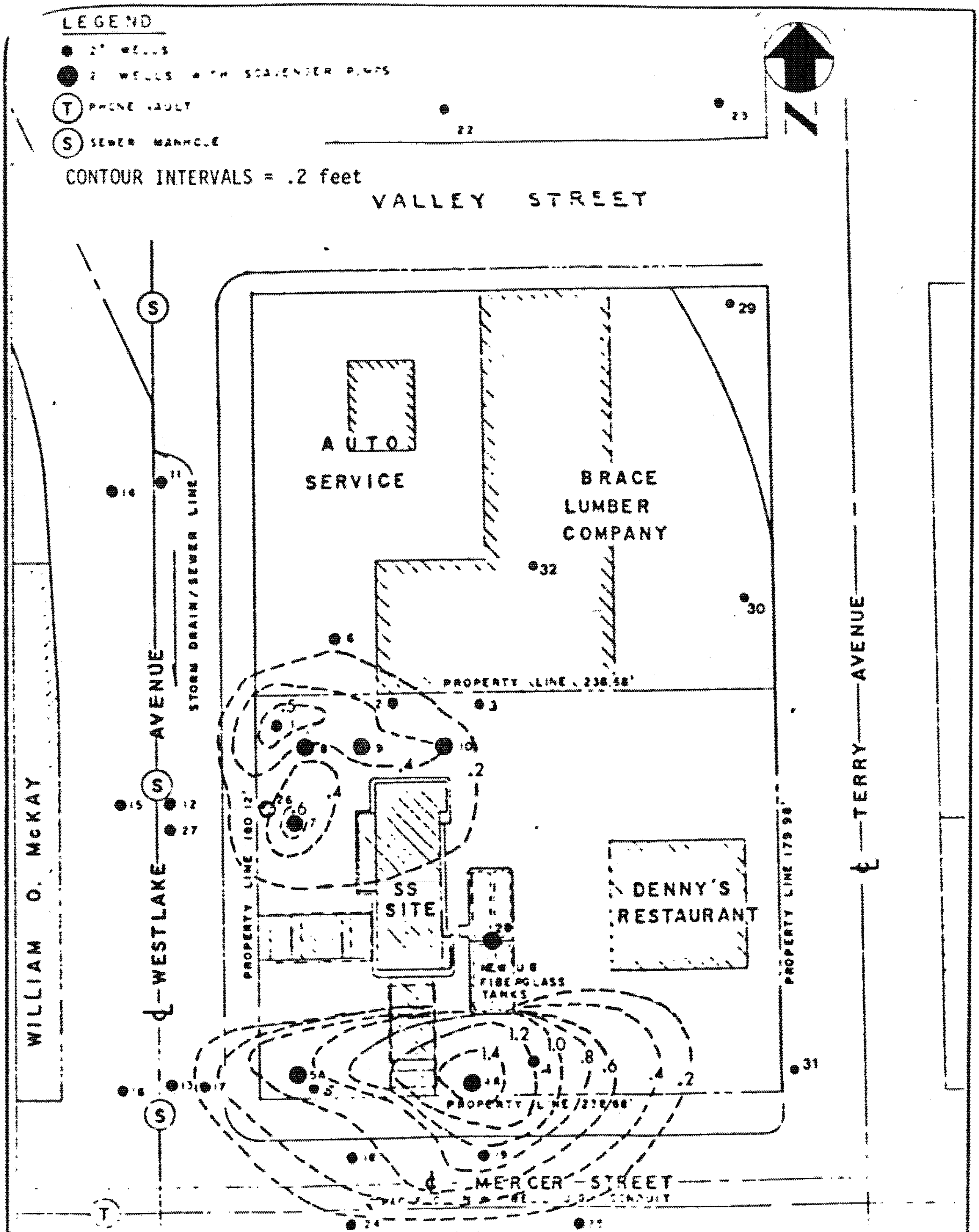
bcc: Jim Neyens - Houston Office



ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

PIEZOMETRIC ELEVATIONS
2-8-81

PLATE
1



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

GASOLINE THICKNESSES
2-8-81

PLATE
2

ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

COPY

ALASKA
CALIFORNIA
HAWAII
ILLINOIS
NEVADA
TEXAS
WASHINGTON
WASHINGTON D.C.
SAUDI ARABIA

March 5, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 6
Monitoring Operations
Westlake & Mercer Gasoline Spill
Seattle, Washington

This letter presents our semimonthly status report regarding the monitoring and recovery program for the Westlake and Mercer gasoline spill in Seattle, Washington.

Gasoline Recovery

We have been informed that some of the depressant and scavenger pumps are being repaired, leaving only one water table depressant pump and two scavenger pumps in operation. We understand that the pumps will be repaired within approximately two weeks. The operating pumps are being alternated between the various wells with apparent fluctuations in gas thicknesses, piezometric elevations, and gasoline recovery rates. Essentially no gasoline was recovered between February 8 and February 22, 1981. Approximately 7,000 gallons of water was pumped from the site into the main holding tank between February 5 and February 17, with no noticeable gasoline recovery. The total gasoline recovered as of February 28, 1981 is approximately 34,025 gallons.

Piezometric Elevations

Piezometric elevations for February 22, 1981 are shown on Plate 1. There appears to be little significant change from those elevations recorded on February 8, 1981 (see our Progress Report No. 5, dated February 23, 1981). Piezometric elevations for the block generally lie between 9.0 and 9.4. There appears to be a local rise in the piezometric elevation measured in Well 5A. However, we feel this is an anomalous reading. Interim readings for this well indicate typical four-to-six-inch variations between successive readings. Based on the well readings, it appears that the gasoline pool is presently immobile.

Gasoline Thickness

Plate 2 indicates the recorded gasoline thickness (in feet) as measured on February 22, 1981. Except for an approximate two-inch increase in gasoline thickness in Well 32, there has been essentially no change in the gasoline thicknessess across the site. The apparent migration of gasoline to the south, noted in our Progress Report No. 5, dated February 23, 1981, has apparently ceased. The gasoline pool in the vicinity of Well 8 has a maximum gasoline thickness of 0.5 feet, while the gasoline pool in the vicinity of Well 4A has a maximum thickness of 1.2 feet. The third pool in the vicinity of the Brace Lumber Yard has a maximum thickness of 0.4 feet. It appears that the effects of raising the lake have diminished.

Explosimeter Readings

Explosimeter readings have not varied significantly since December 28, 1980. The latest measurements taken on February 15, 1981, indicate that all wells except 22, 23, 29, 30 and 31 have some gasoline at depths of four feet, eight feet, or both.

Research

A meeting was held on February 27, 1981 between Jim Miller of GeoEngineers and the author, regarding the test procedure for evaluating the B-226 degreasing agent. The test is scheduled to be performed during the week ending March 14, 1981.

Yours very truly,

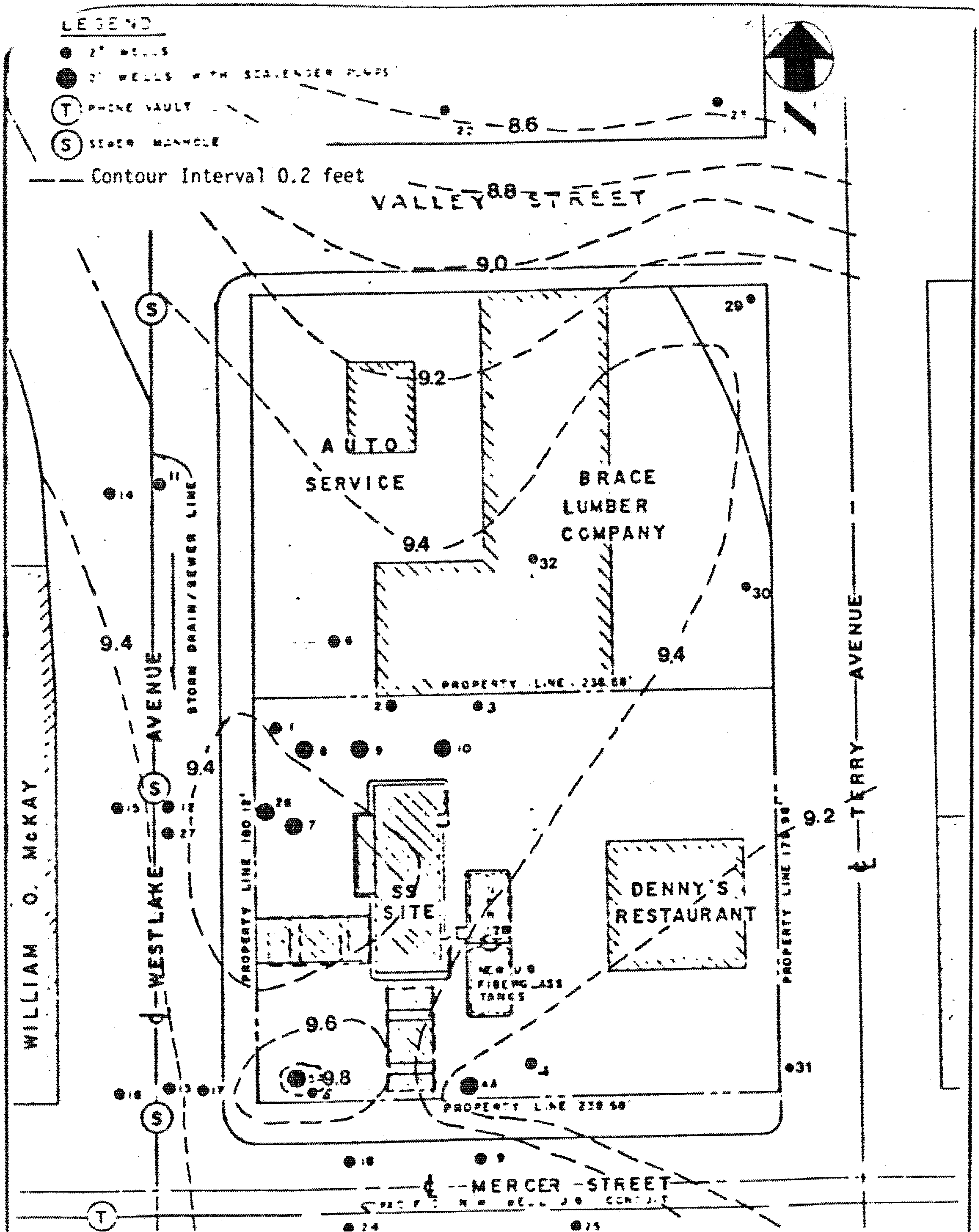
ROGER LOWE ASSOCIATES, A Division
of Harding-Lawson Associates

James T. Cameron

James T. Cameron
Project Manager

JTC/RAL/ju

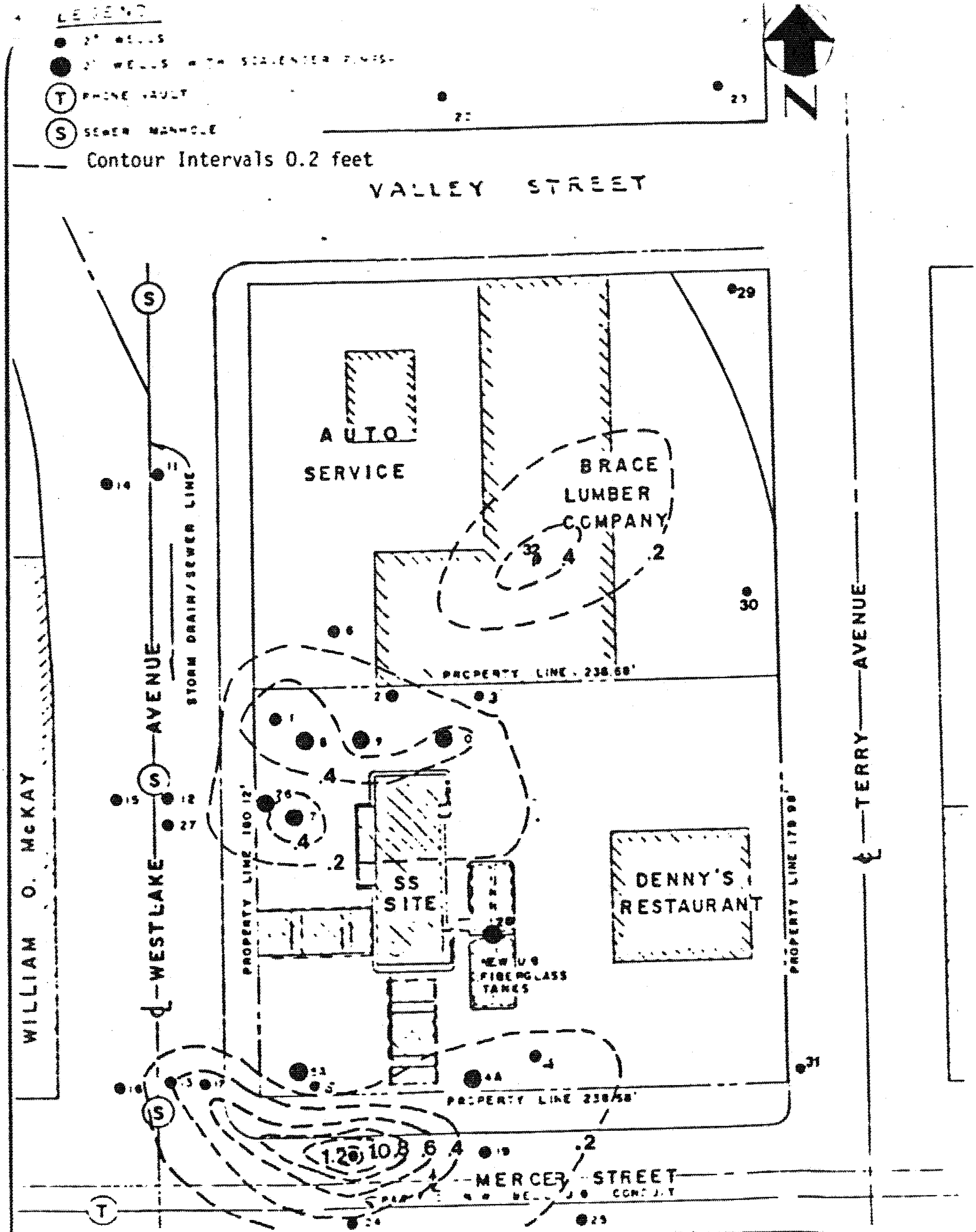
cc: Jim Miller
Ed Ingham



ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

Piezometric Elevations
2-22-81

PLATE
1



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

Gasoline Thicknesses
2-22-81

PLATE
2

JOB NO. 14,197,006.07 APPR. DATE 3/5/81

ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

March 24, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 7
Monitoring Operations
Westlake & Mercer Gasoline Spill
Seattle, Washington

This letter presents our semi-monthly status report regarding the monitoring and recovery program for the Westlake and Mercer gasoline spill in Seattle, Washington.

Gasoline Recovery

Gasoline recovery at the site increased somewhat in the latter part of February and early March. Between the period February 22 through March 8, 1981, approximately 249 gallons of gasoline were recovered, bringing the total gasoline recovered as of March 8 to approximately 34,277 gallons.

Piezometric Elevation

Piezometric elevations at the site on March 8, 1981 are shown on Plate 1. Although there are a number of minor variations in the piezometric elevations when compared with those recorded on February 22, 1981, the general shape of the piezometric surface appears to be similar. In general, the depressions which previously existed in the northwesterly corner of the gasoline station property and along Mercer Street, appear to have nearly disappeared. Currently, there is a broad, flat piezometric surface near the middle of the Union Station-Brace Lumberyard block, which slopes gently down towards Lake Union at its north end. There is also a relatively steep drop of the piezometric surface south of Denny's restaurant.

Gasoline Thickness

Plate 2 indicates the recorded gasoline thickness in inches as measured on March 8, 1981. Comparison of this plate with Plate 2 in our report dated March 5, 1981, indicates that the location of apparent concentrations of gasoline have not changed significantly since January 22, 1981. However, there has been a fairly significant decrease in the recorded thickness of gasoline. Comparison of Plate 2 in this report with Plate 2 in the previous three reports, shows a consistent decrease in the maximum thicknesses of gasoline measured and a reduction in the apparent extent of the gasoline.

Explosimeter Readings

Explosimeter readings have not varied significantly since December 28, 1980. The latest measurements taken on March 8, 1981, indicate that all wells except 22, 23, 29, 30, and 31 have some gasoline at depths of four feet, eight feet, or both.

Yours very truly,

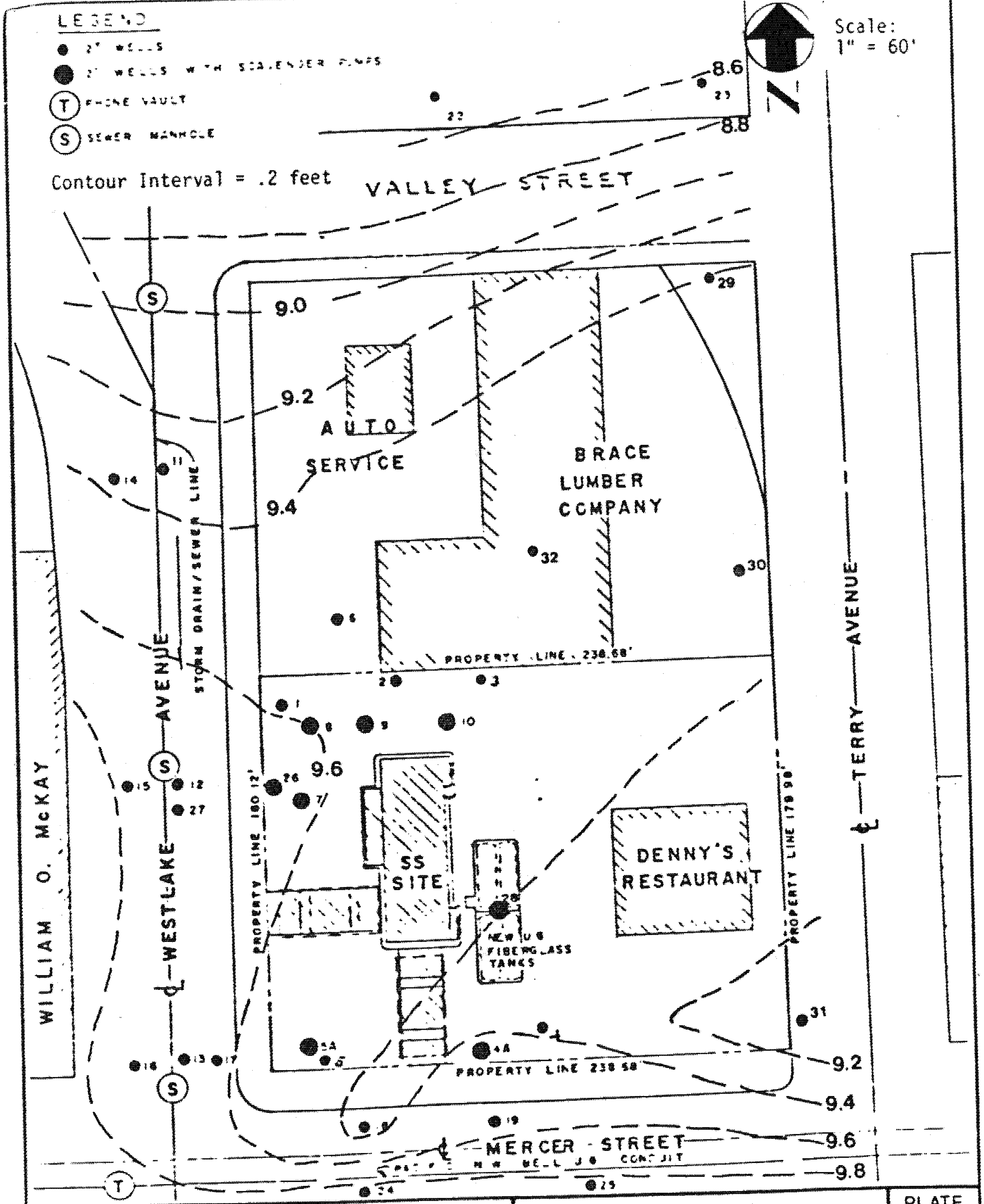
ROGER LOWE ASSOCIATES, A Division
of Harding-Lawson Associates

James T. Cameron

James T. Cameron
Project Manager

JTC/MAA/ju

cc: Jim Miller
Ed Ingham



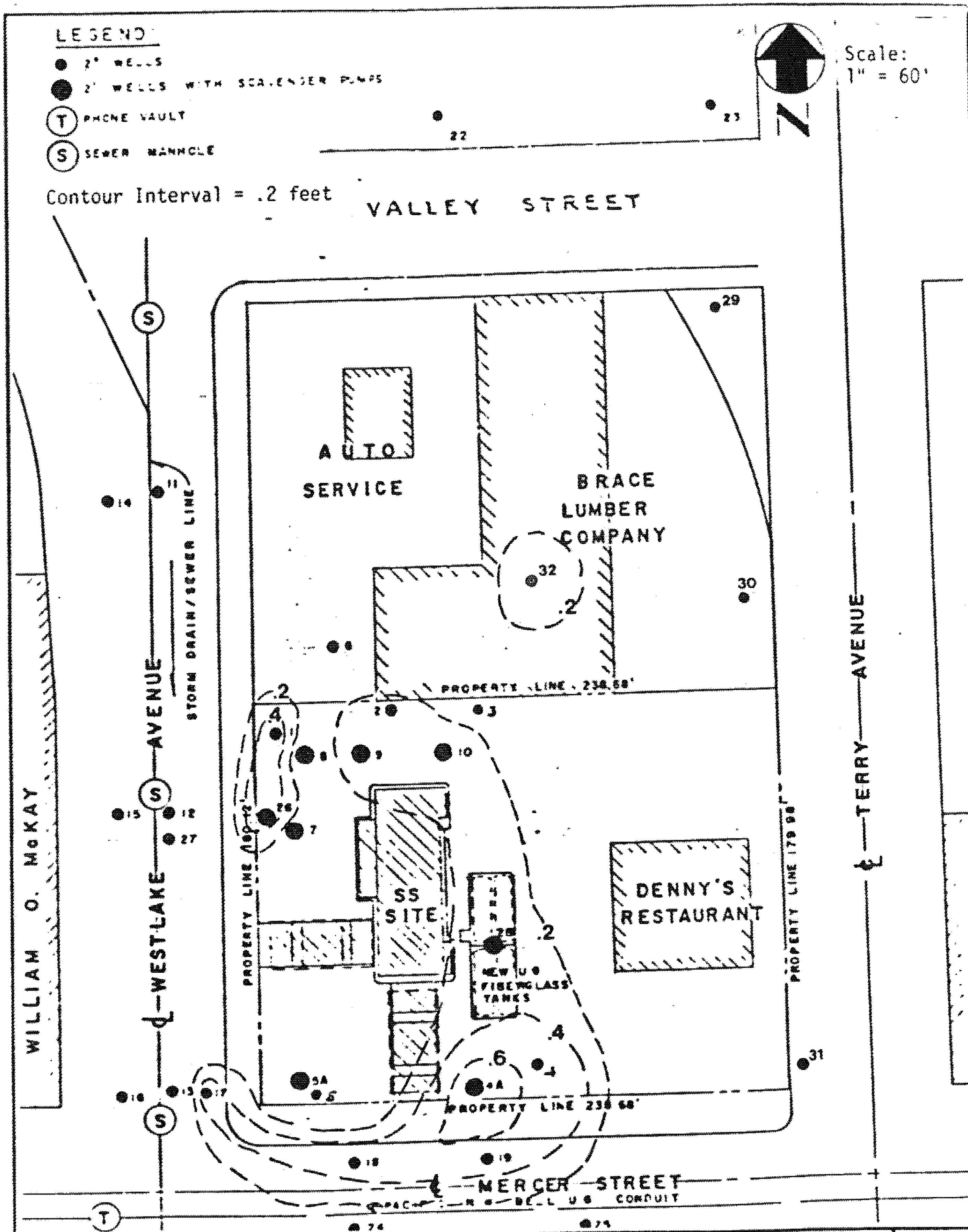
ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

JOB NO 14.197.006.07 APPR RC DATE 3/24/81

PIEZOMETRIC ELEVATIONS

Union Oil Company
Seattle, Washington
3-08-81

PLATE
1



ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

JOB NO [illegible] APPR [illegible] DATE 3/24/81

GASOLINE THICKNESSES

Union Oil Company
Seattle, Washington
3-08-81

PLATE
2

ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

COPY

ALASKA
CALIFORNIA
HAWAII
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NEVADA
TEXAS
WASHINGTON
WASHINGTON, D.C.
SAUDI ARABIA

April 3, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Semi-Monthly Progress Report #8
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

Gasoline Recovery

Gasoline recovery at the site continues to be moderate. Between the period of March 9 through March 22, 1981, approximately 373 gallons of gasoline were recovered, bringing the total gasoline recovered as of March 22, 1981 to approximately 34,650 gallons.

Piezometric Elevations

Piezometric elevations at the site on March 22, 1981 are shown on Plate 1. In general, there is very little deviation from those recorded on March 8, 1981. There appears to be a broad, flat piezometric surface near the middle of the Union Station/Brace Lumber Yard block which then slopes downward to Lake Union to the north. There also appears to be a relatively steep drop of the piezometric surface at the south end of the site.

Gasoline Thicknesses

Currently, there appears to be very little significant change in gasoline thicknesses throughout the site. Plate 2 indicates the recorded gasoline thicknesses in inches as measured on March 22, 1981. When compared to the gasoline thicknesses recorded on March 8, 1981, it appears that the apparent gasoline concentration in the middle portion of the site may be shifting or spreading out slightly. However, the measured gasoline thicknesses are minor. The apparent gasoline concentration at the south end of the block has remained essentially stationary since March 8, 1981.

Explosimeter Readings

Explosimeter readings have remained essentially constant for the last few months. Recently it appears that vapor readings may be diminishing slightly in Wells 11, 12 and 25. All three of these wells recorded 100 percent vapor readings at eight feet on February 15, 1981. As of March 15, 1981, these wells have recorded explosimeter readings of 70, 95, and 45 percent in Wells 11, 12, and 25, respectively. As of February 15, 1981, all wells except 22, 23, 29, 30, and 31 have some gasoline in depths of four feet, eight feet, or both depths.

Yours very truly,

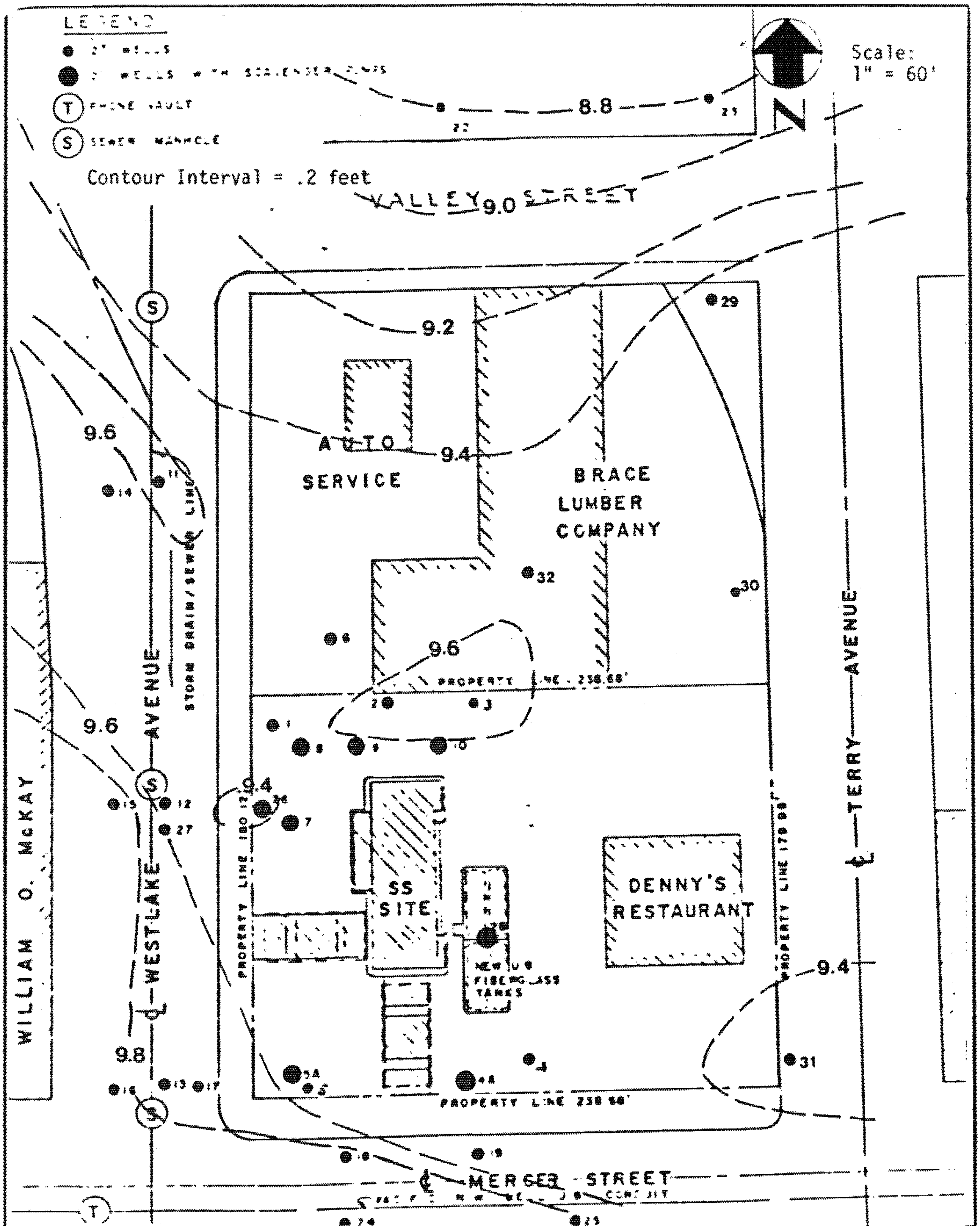
ROGER LOWE ASSOCIATES, A Division of Harding-Lawson Associates

James T. Cameron

James T. Cameron
Project Manager

JTC/ju

cc: Jim Miller
Ed Ingham



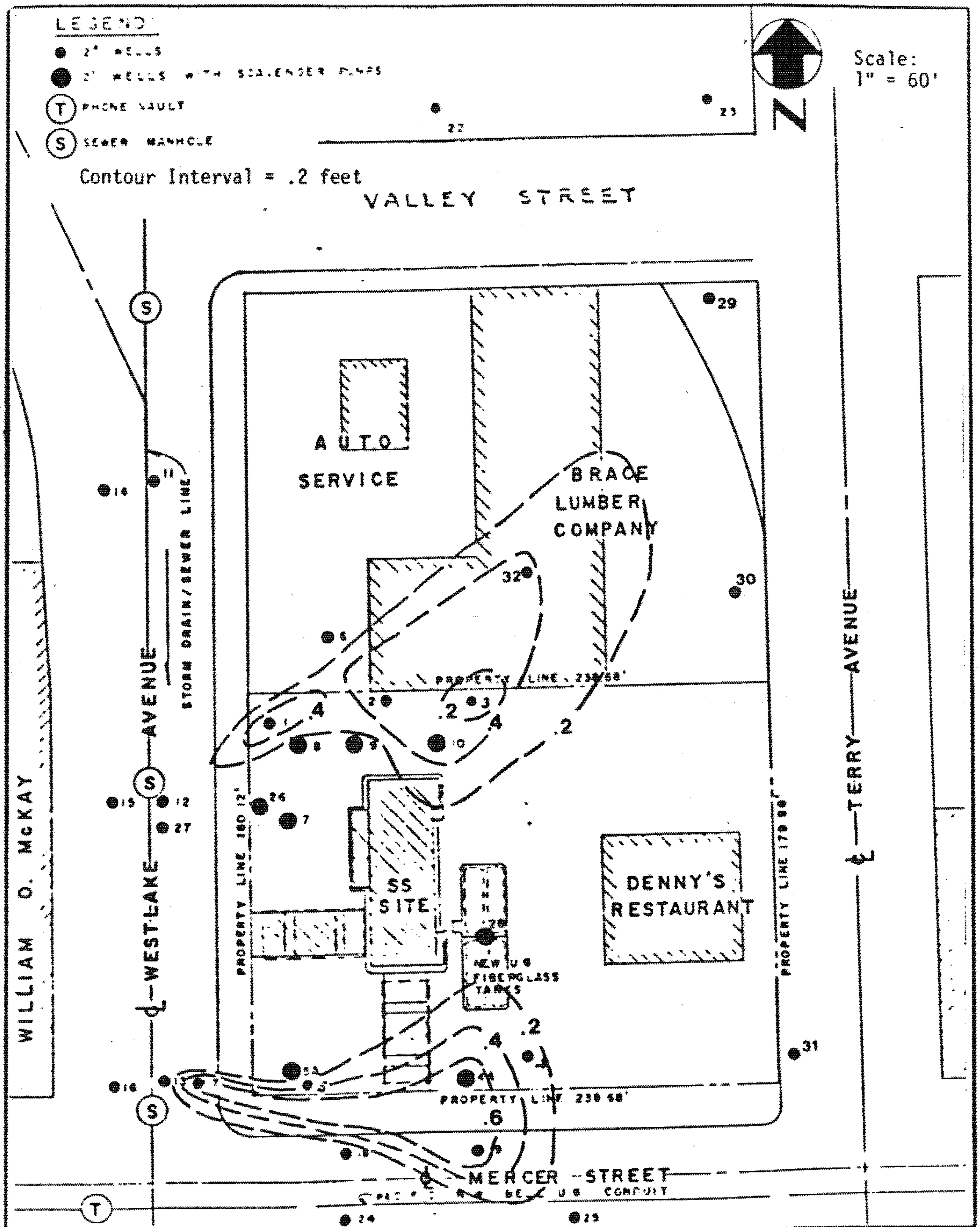
ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

JOB NO 14.197.006.07 APPR. /7C DATE 4/3/81

PIEZOMETRIC ELEVATION 3/22/81

Union Oil Company
Seattle, Washington

PLATE 1



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

JOB NO 14,197,006.07 APPR /7C DATE 4/3/81

GASOLINE THICKNESSES 3/22/81

Union Oil Company
Seattle, Washington

PLATE
2

ROGER LOWE ASSOCIATES
Engineers, Geologists and Geophysicists

April 16, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

COPY

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report #9
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

Gasoline Recovery

Between March 22 and April 5, 1981, no gasoline was pumped from the holding tanks. The total volume of gasoline recovered thus remains at 34,650 gallons. The rate of gasoline recovery will likely remain low as a consequence of the diminishing quantities of gasoline available for recovery.

Piezometric Elevations

Piezometric elevations at the site on April 1, 1981 are shown on Plate 1. In general, the elevations have not changed significantly since at least the beginning of March, 1981. There is still a broad flat area beneath the gas station property and two small "dimples" in the piezometric surface near Mercer Street and at the north edge of the gas station. To the north, the piezometric surface descends towards Lake Union.

Gasoline Thickness

Gasoline thicknesses, as recorded on April 1, 1981 and shown on Plate 2 appear to have remained essentially the same as those recorded on March 22, 1981. With the exception of wells B-1 and B-4, all wells show either no free gasoline or a small amount (less than three inches). In well B-1, five inches of gasoline was measured and in B-4, 8.5 inches.

Explosimet~~ric~~er Readings

Explosimeter readings taken since March 22, 1981 have remained essentially the same as those taken the prior few months. As of the latest readings on April 3, 1981 all wells except B-22, 23, 29, 30 and 31 show some gasoline vapor at depths of both four and eight feet. Most vapor readings measure at or near 100 percent.

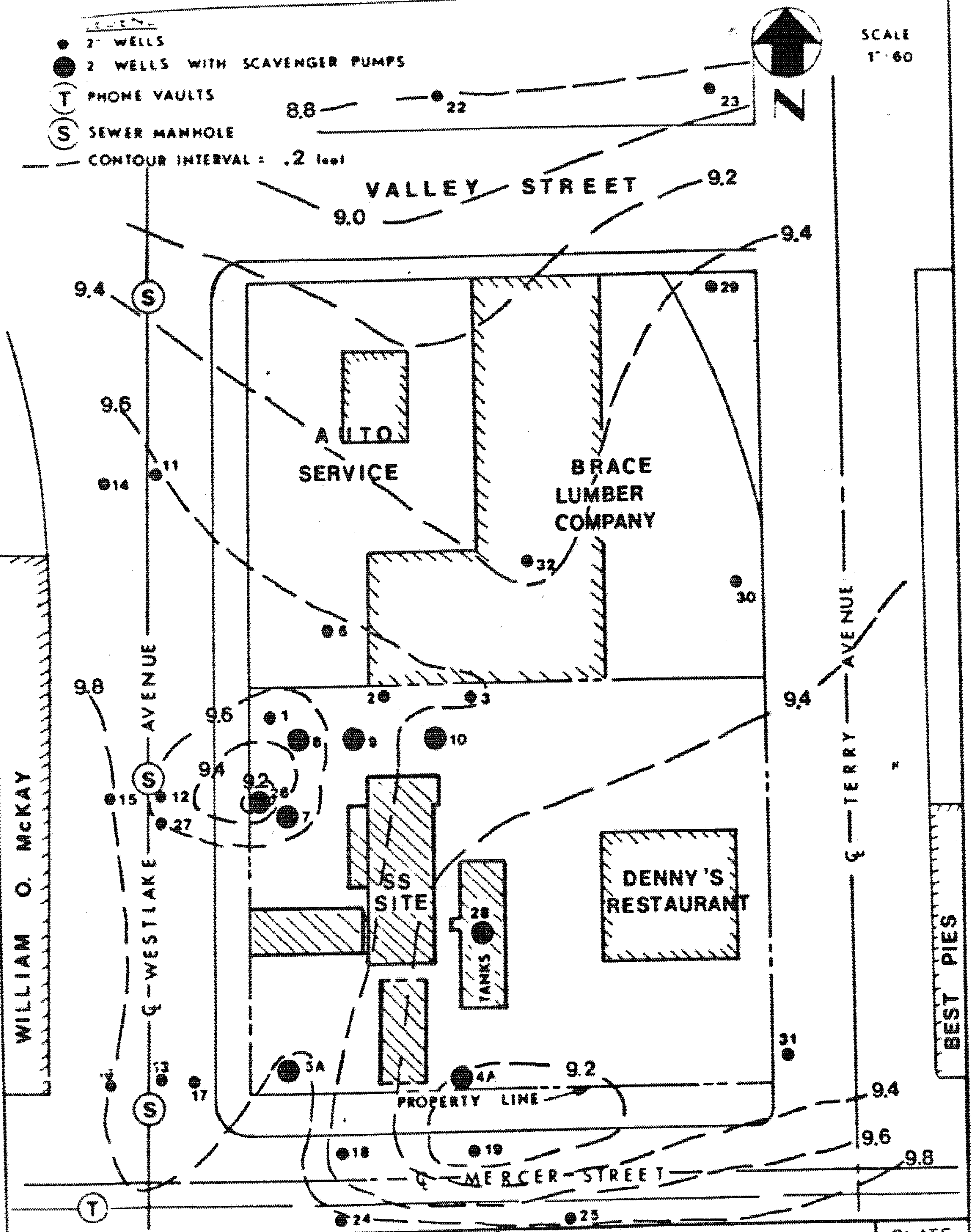
Yours very truly,

ROGER LOWE ASSOCIATES, A Division
of HARDING-LAWSON ASSOCIATES

Mark A. Adams

Mark A. Adams
Geologist

MAA/cjg



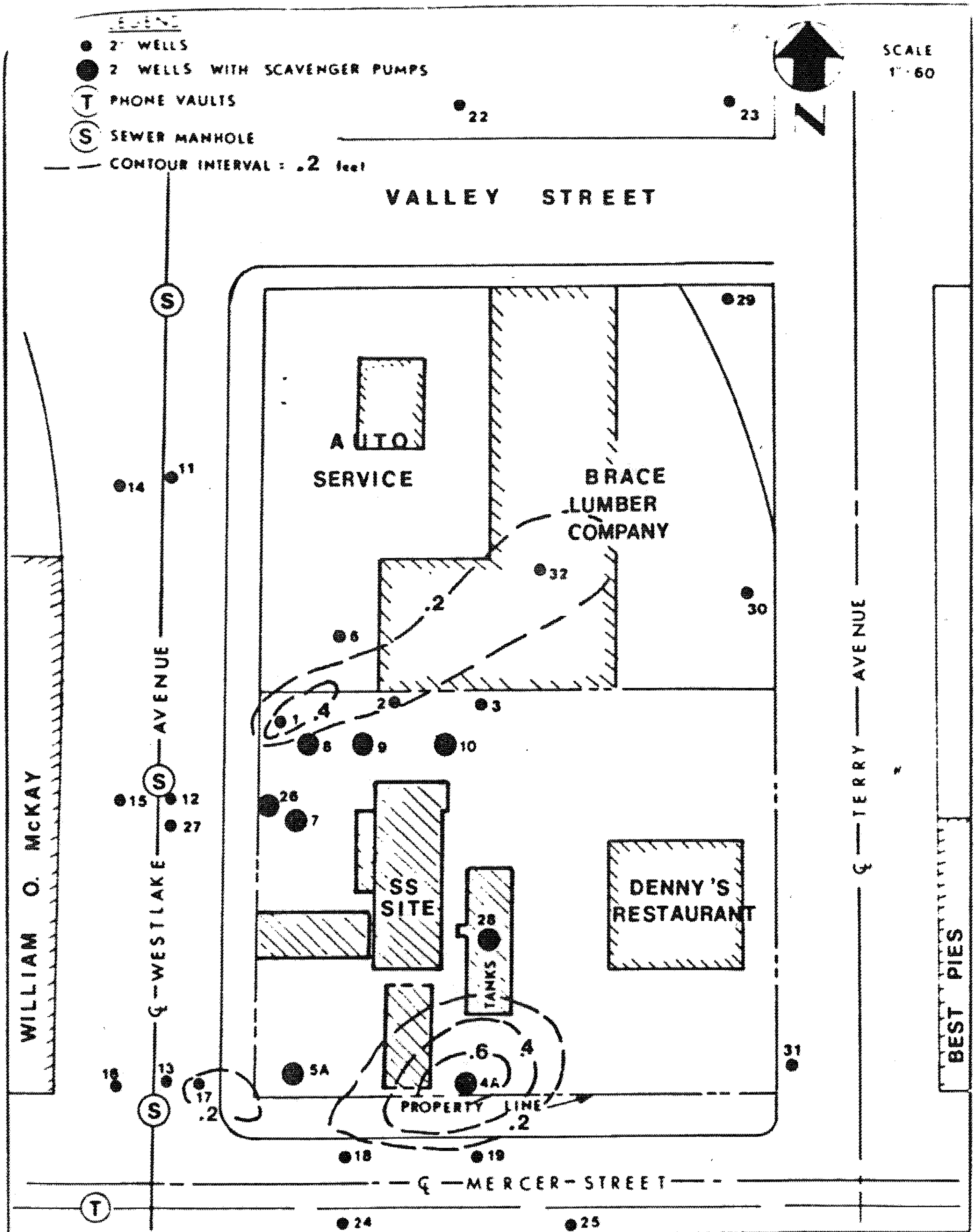
ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

P.N. 14,197,006.07 APPR MAA DATE 4/17/81

PIEZOMETRIC ELEVATION 4/1/88

Union Oil Company
Seattle, Washington

PLATE
1



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

34.197.006.07 MAA 4/1/81

GASOLINE THICKNESSES 4/1/81

Union Oil Company
Seattle, Washington

PLATE
2

HARDING-LAWSON ASSOCIATES

COPY

April 30, 1981

14,197,006.07

Union Oil of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 10
Monitoring & Recovery Operations
Westlake & Mercer Gasoline Spill
Seattle, Washington

Gasoline Recovery

Between April 6 and April 19, 1981, approximately 354 gallons of gasoline were pumped from the site; 185 gallons were pumped on April 13th from the Brace Lumber Yard tank and 169 gallons of gasoline were pumped on April 17th from the main holding tank. The total volume of gasoline recovered at the site is currently 35,251 gallons.

On April 13, 1981, the site had reached its 300th day of pumping. A graph of the total gasoline recovered against the logarithm of the days since start of pumping plots essentially linear except for periods of construction and pump repairs. Based on this graph, we can expect the rate of gasoline recovery in the immediate future will be on the order of 400 to 500 gallons per month. We feel that the low rates of return occur as a consequence of the diminishing gasoline quantities available for recovery.

Piezometric Elevations

Piezometric elevations on April 19, 1981, are shown on Plate 1. In general, the elevations have not changed appreciably since April 1, 1981. It appears that the piezometric surface has been lowered as much as five inches in the vicinity of Well 4A, however, upon review of previous data for this well, it was found that the sudden decrease in piezometric elevation is due to a reduced gasoline thickness in this well. On April 1, 1981, there was approximately nine inches of gasoline in Well 4A; currently there is none. Apparently, skimmers were placed in this well during the interim. The piezometric surface continues to grade gently downward to the north with a total relief of approximately one foot. There are high zones in the piezometric surface in the vicinity of Wells 2, 26, and 17. However, these zones are relatively small in extent and are only raised above the surrounding levels by a minor amount.

Gasoline Thickness

Gasoline thicknesses as recorded on April 19, 1981, are shown on Plate 2. Recent readings indicate that the gasoline in the vicinity of Well 4A has reduced from approximately .7 feet as recorded on April 1, 1981, to 0 feet on April 19th. Currently there is .1 feet of gasoline to the south in the vicinity of Wells 5A, 17, and 19. There has been essentially no change since the April 1st recordings in the middle portion of the site. The thicknesses recorded in this area are still on the order of .1 to .3 feet.

Explosimeter Readings

Currently, vapor readings of 100 percent have been measured at both four and eight foot depths in Wells 1 through 10, 15, 17 through 19, 26, 28, and 32. No vapors are measured in Wells 22, 23, and 29 through 31. The remaining wells indicate vapor readings for the four foot, eight foot, or both depths. The smaller vapor percentages appear to occur mainly within the wells on the streets which border the site, indicating that the gasoline has been contained within the block.

Yours very truly,

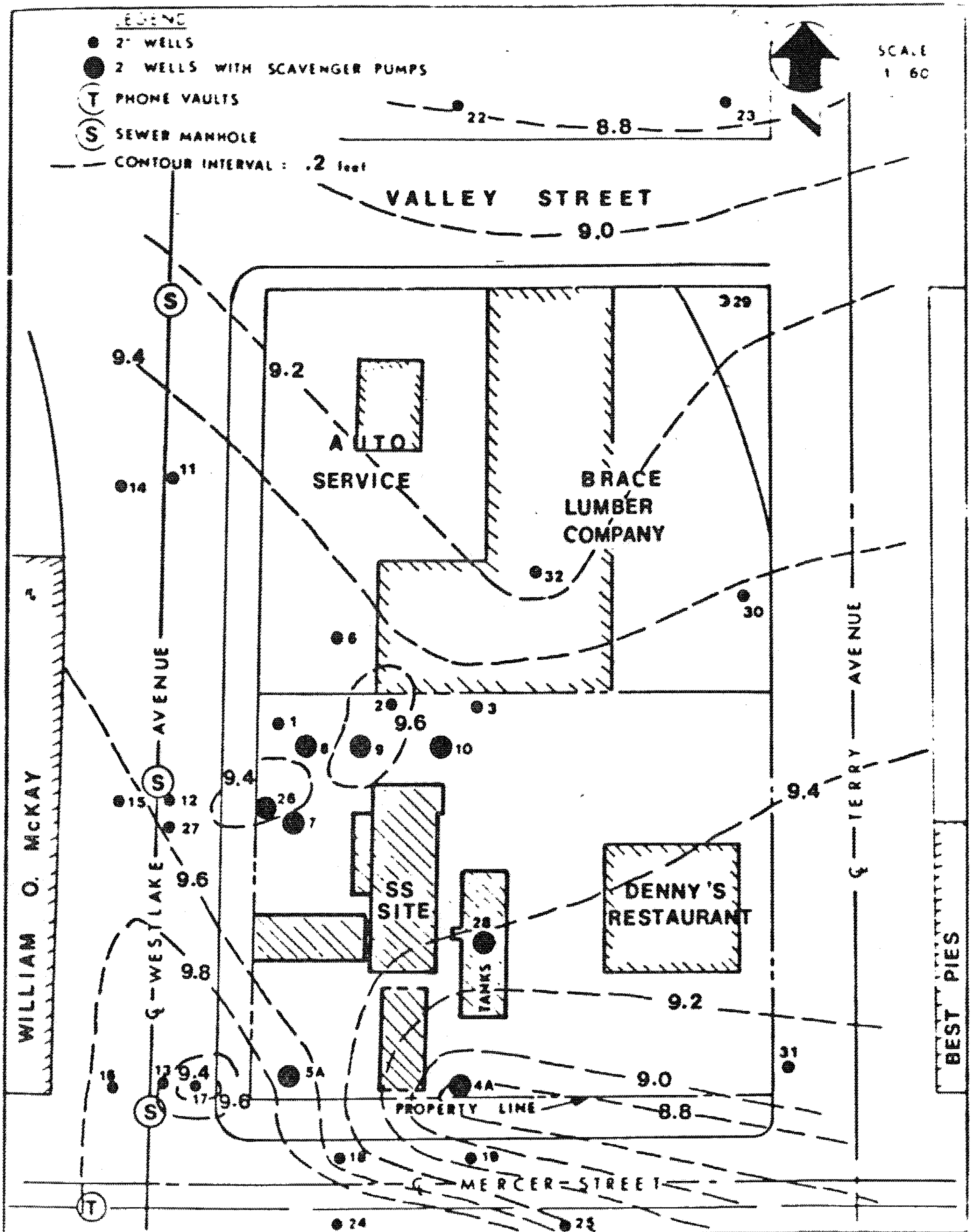
ROGER LOWE ASSOCIATES, A Division
of Harding-Lawson Associates

James T. Cameron

James T. Cameron
Project Manager

JTC/ju

cc: Jim Miller
Ed Ingham

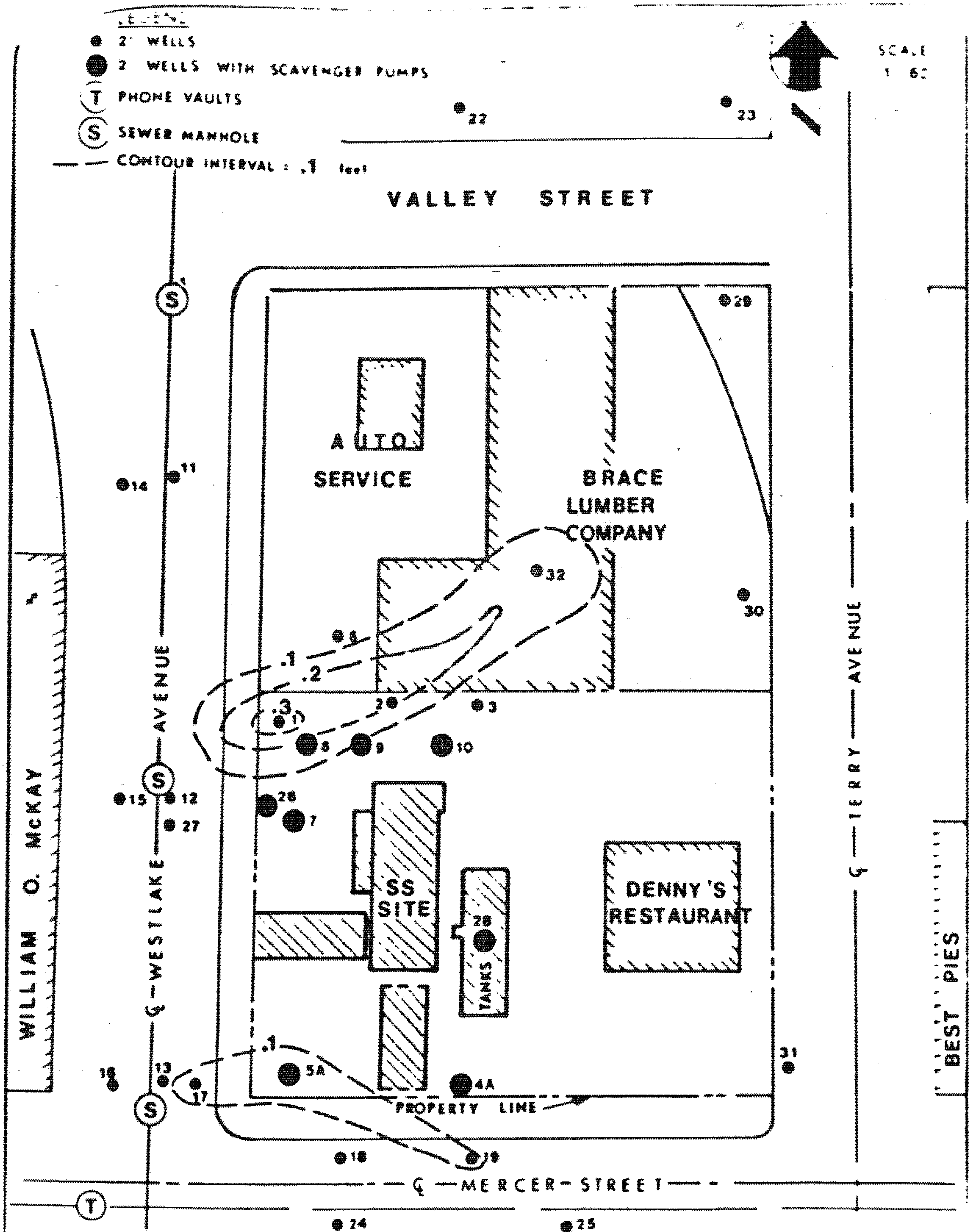


ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

PIEZOMETRIC ELEVATIONS 4/19/81

Union Oil Company
Seattle, Washington

PLATE
1



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

GASOLINE THICKNESSES 4/19 81

Union Oil Company
Seattle, Washington

PLATE
2

HARDING-LAWSON ASSOCIATES

COPY

May 18, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 11
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

Gasoline Recovery

During the interim of April 20, 1981 to May 2, 1981, no gasoline was pumped from the holding tanks. The total volume of gasoline recovered thus remains at 35,251 gallons. Note that this volume is 100 gallons greater than the volume erroneously recorded in our progress report No. 10, dated April 30, 1981.

Piezometric Elevations

Piezometric elevations recorded on May 2, 1981, are shown on Plate 1. Some shifting in the piezometric surface has occurred. The most noteworthy differences are in the north half of the site, where the piezometric surface has risen between .4 and .8 feet. The piezometric elevations in the south half of the site have not varied appreciably. The rise of the piezometric surface at the north end flattened the typical northward gradient (toward Lake Union). The changes in the surface do not appear great enough to adversely alter the flow direction. The total relief of the piezometric surface across the site is on the order of one-half foot. A local high piezometric level is present in the vicinity of Well 5A; it is probably due to removal of a skimmer or pump.

We contacted the U.S. Army Corps of Engineers regarding recent water levels in Lake Union. They informed us that the lake has been raised gradually from Elevation 20 (U.S. Army Corps datum) on February 15, 1981, to Elevation 21.85 at present. The City of Seattle datum is approximately 12.98 feet below that of the Army Corps. Therefore, an elevation of 21.85 (U.S. Army Corps datum) corresponds to Elevation 8.87 (City of Seattle datum). We have been using the City of Seattle datum in all of our previous progress reports. Therefore, the rise in piezometric elevations at the north end does not appear to be the result of a sudden increase in lake level.

Historic piezometric readings at Well 22 indicate an average 3 to 4 inch raise in the surface since February 15, 1981. We therefore suspect that either the readings are erroneous or the ground water was somehow surcharged from the landward side. We will closely monitor the piezometric levels for Wells 22 and 23 in the future to determine the validity of the most recent readings.

Gasoline Thickness

Gasoline thicknesses as recorded on May 2, 1981, are shown on Plate 2. These most recent readings indicate that there are still two areas of gasoline fluid at the site; one in the vicinity of Well 1, and the other in the vicinity of Well 18. It appears that the measured gasoline thicknesses have increased .1 to .2 feet since our previous report of April 30, 1981. The thicknesses of gasoline in these areas vary between .1 and .5 feet in the vicinity of Well 1 and .1 to .3 feet in the vicinity of Well 18. Based on the most current readings, it appears that the free gasoline is still being sufficiently retained on the site.

Explosimeter Reading

Vapor readings at the 4-foot and 8-foot depths have not varied appreciably from those readings recorded on April 19, 1981. Vapor readings of 100 percent have been measured at both the 4 and 8-foot depths in Wells 1 through 10, 15, 17 through 19, 26, 28 and 32. No vapors were measured in Wells 22, 23, and 29 through 31. The remaining wells indicate vapor readings for the 4-foot, 8-foot, or both, depths.

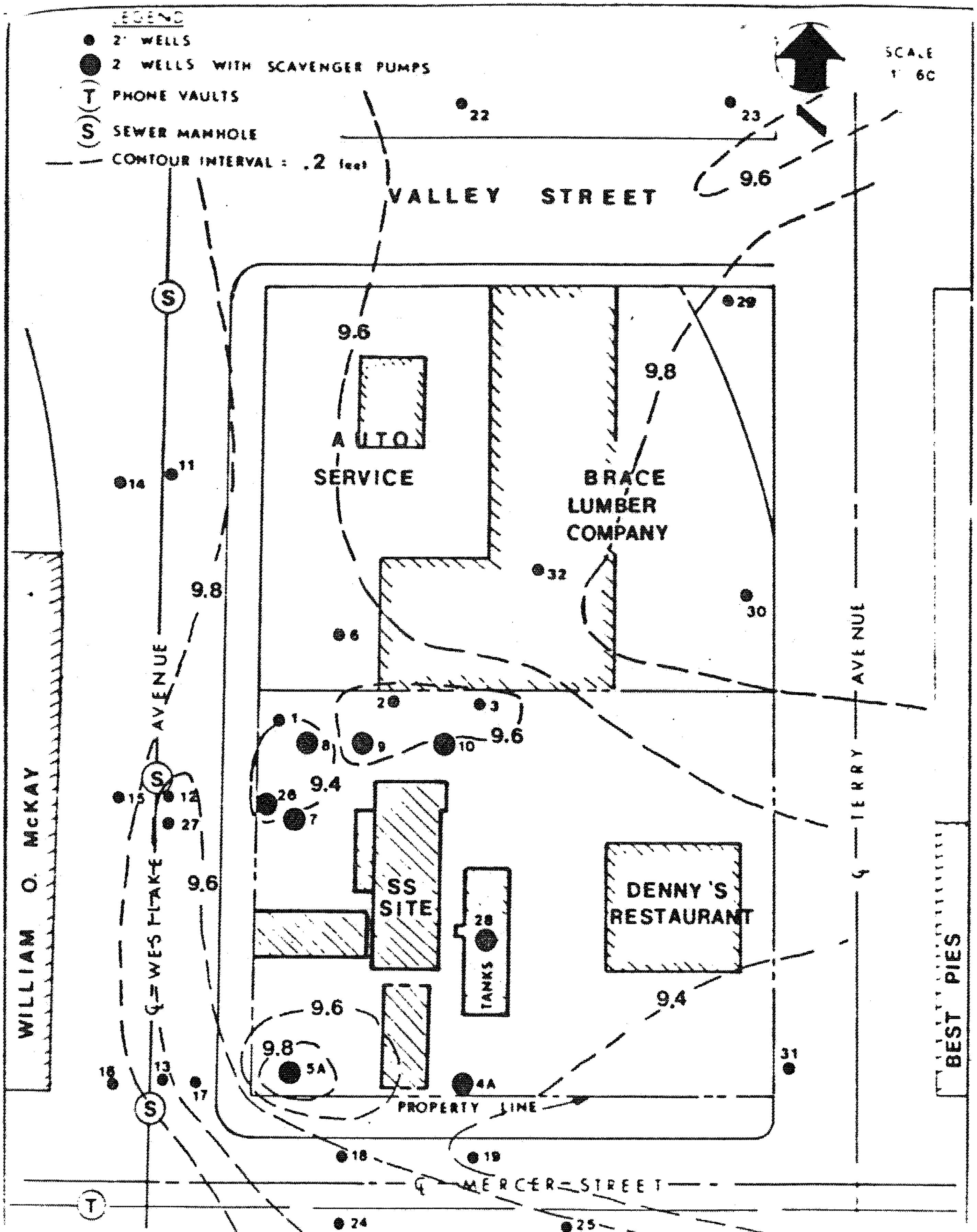
Yours very truly,

ROGER LOWE ASSOCIATES, A Division of Harding-Lawson Associates

James T. Cameron

James T. Cameron
Project Manager

JTC/ju
cc: Jim Miller
Ed Ingham

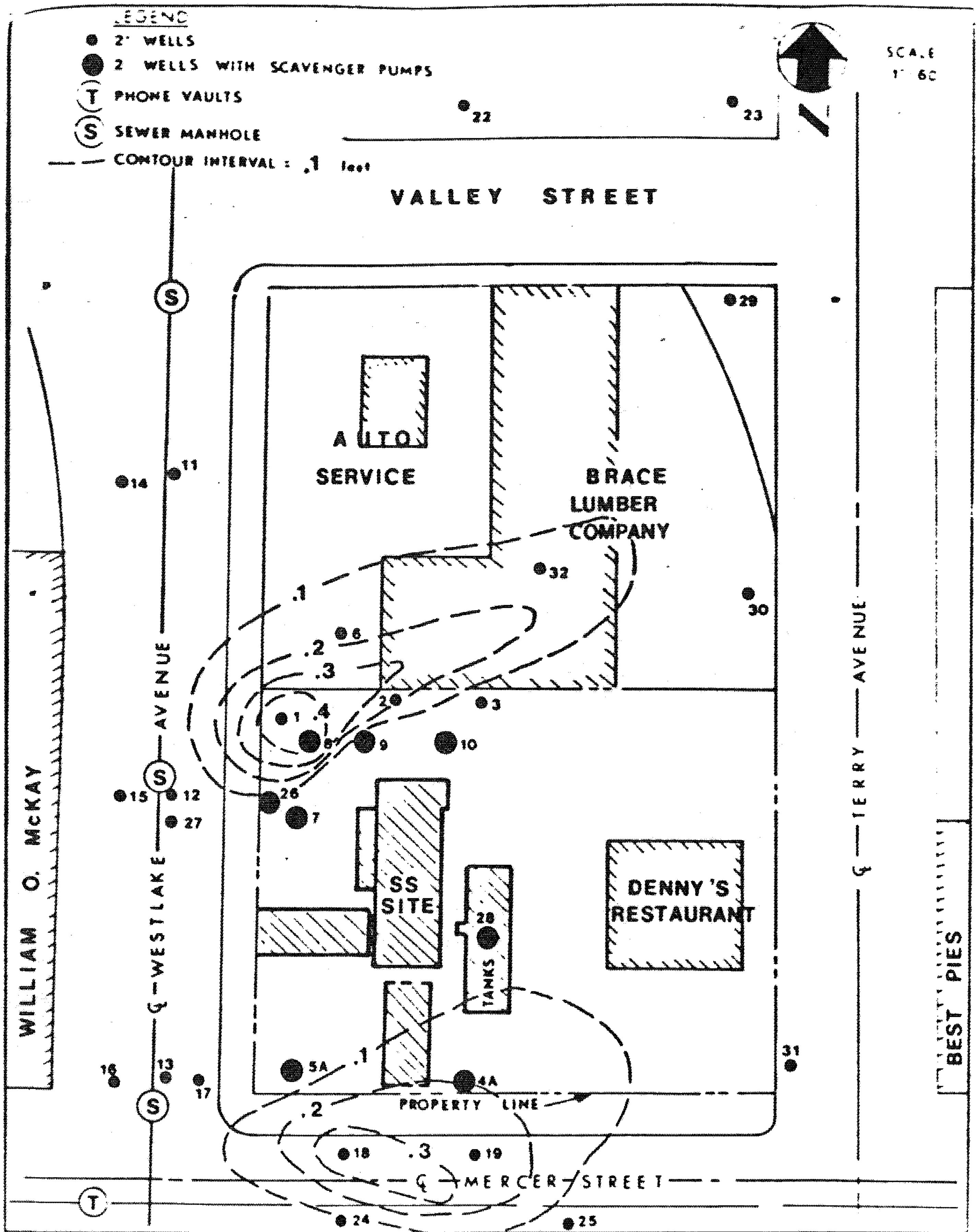


ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

PIEZOMETRIC ELEVATIONS
Union Oil Company
Seattle, Washington

5/2/81

PLATE
1



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

GASOLINE THICKNESS
Union Oil Company
Seattle, Washington

F 2 '81

PLATE
2

HARDING-LAWSON ASSOCIATES

June 3, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 12
Monitoring & Recovery Operations
Westlake & Mercer Gasoline Spill
Seattle, Washington

Gasoline Recovery

Between May 3 and May 17, 1981, approximately 340 gallons of gasoline were pumped from the site; all from the main holding tank. The total volume of gasoline recovered is currently 35,591 gallons. In the last two months, gasoline recovery has averaged approximately 350 gallons per month.

Piezometric Elevations

Piezometric elevations recorded on May 17, 1981 are shown on Plate 1. The piezometric surface is very similar to that recorded May 2, 1981, wherein there was a sudden rise in the piezometric surface in the north half of the site. It appears that the May 2 piezometric elevations, presented in our May 18 progress report, were not anomalous. The water level in the northern half of the block has indeed risen to an elevation of approximately 9.6 feet. Substantiating this general rise in water level across the site is the fact that the main holding tank is filling at an increasing rate.

Piezometric levels are also rising along the east side of the site. The recovery program appears to be very effective in keeping the piezometric surface low in the center of the site and preventing migration of gasoline off the block area. The total relief of the piezometric surface across the site is on the order of one-half foot.

Gasoline Thickness

Gasoline thicknesses, as recorded on May 17, 1981, are shown on Plate 2. These most recent readings indicate that the areas of gasoline fluid have reduced in thickness between .1 to .3 foot since those recorded on May 2, 1981. The zone of gasoline in the middle portion of the block near Well 1 has reduced from approximately .4 foot to about .1 foot, while the gasoline thickness at the southern end of the block near Well 18 has reduced from .3 foot to about .2 foot. It appears that the zones of gasoline fluid are breaking up and forming smaller zones with less fluid in them. This breaking up is probably also due to the general rise in the water level at the site.

Explosimeter Readings

Explosimeter readings in Wells 11, 12, 13, and 14, have risen between 10 and 25 percent at the four-foot level and 5 to 30 percent at the eight-foot level since those readings recorded on May 2, 1981. Except for these variances, vapor radings over the remainder of the wells were essentially the same as those recorded May 2, 1981.

Yours very truly,

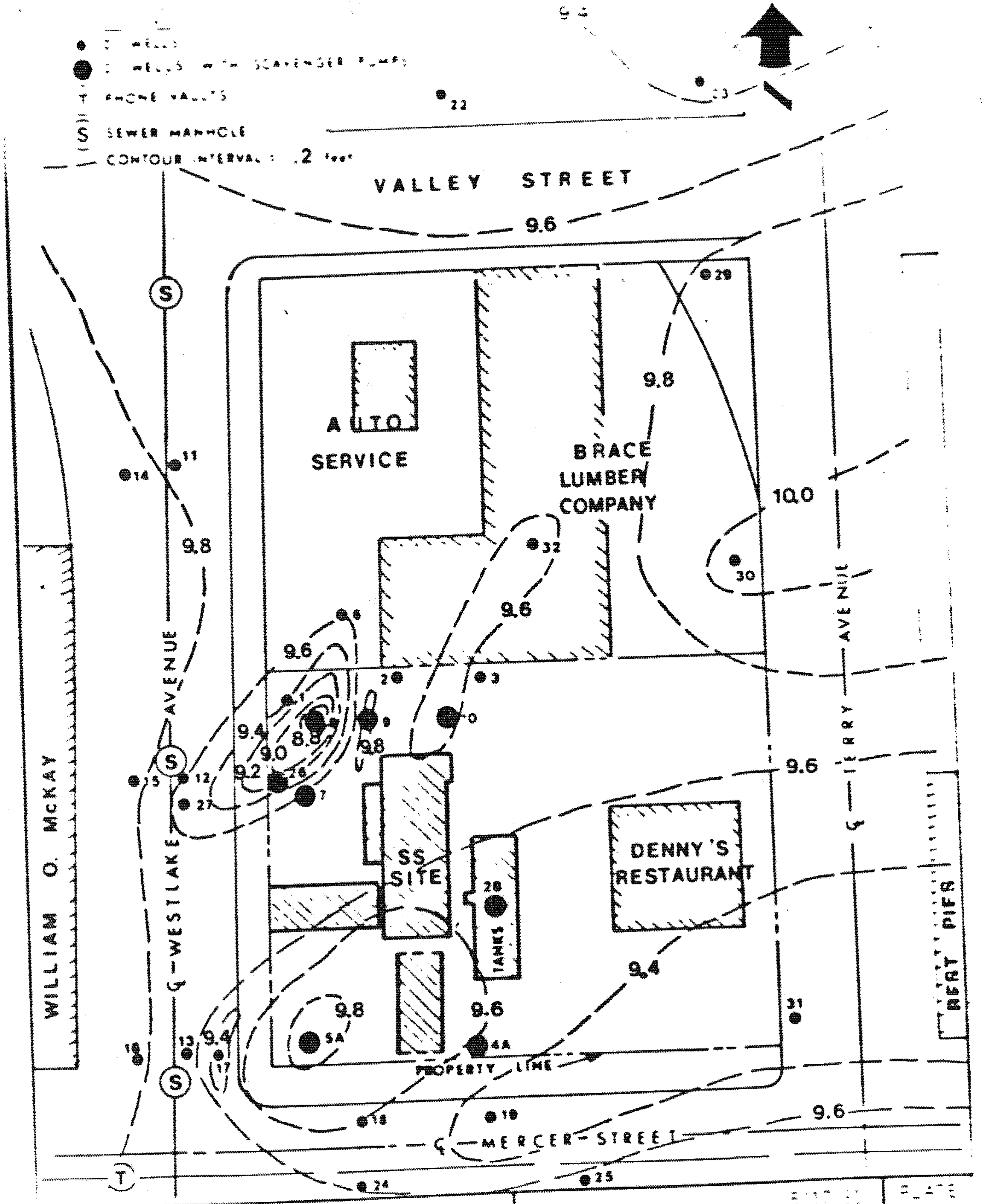
ROGER LOWE ASSOCIATES, A Division
of Harding-Lawson Associates

James T. Cameron

James T. Cameron
Project Manager

JTC/ju

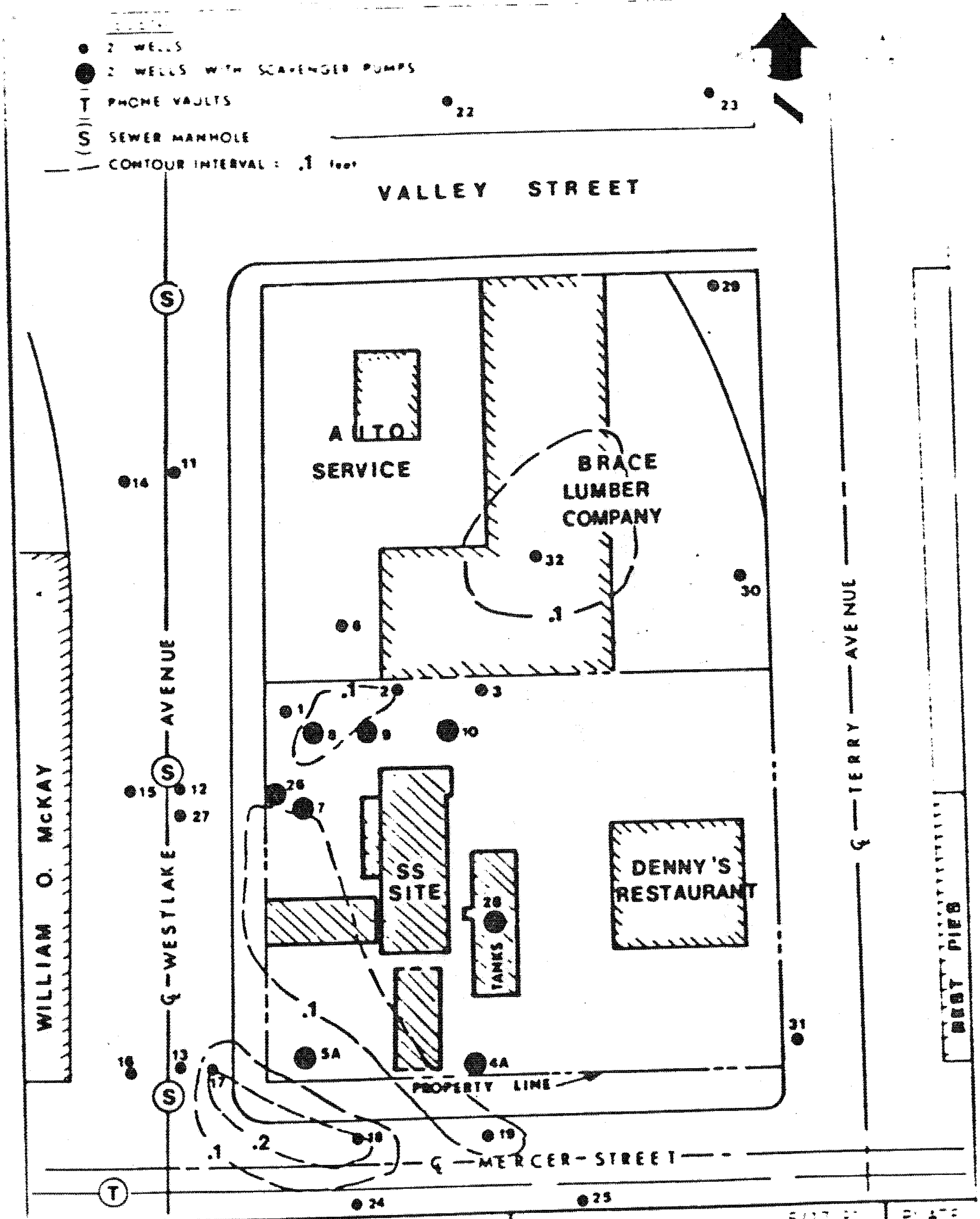
cc: Ed Ingham
Jim Miller



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

PIEZOMETRIC ELEVATIONS
UNION OIL COMPANY
SEATTLE, WASHINGTON

PLATE
1



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

14.197.036.07 76 6/1/7

5/17/81

GASOLINE THICKNESS
UNION OIL COMPANY
SEATTLE, WASHINGTON

PLATE
2

file

ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

ALASKA
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WASHINGTON
WASHINGTON D.C.
SAUDI ARABIA

June 12, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

COPY

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 13
Monitoring and Recovery Operations
Westlake & Mercer Gasoline Spill
Seattle, Washington

Gasoline Recovery

Between May 18 and May 31, 1981, approximately 338 gallons of gasoline were pumped from the site; all from the main holding tank. The total volume of gasoline recovered is currently 35,929 gallons. The gasoline recovery rate is still averaging about 350 gallons per month.

Piezometric Elevations

Piezometric elevations recorded on May 31, 1981 are shown on Plate 1. The piezometric surface has not varied significantly from that recorded on May 17, 1981, except for an approximate .4 to .6 foot decrease along the northern border of the site. The piezometric levels at the northern end, Wells 22 and 23, are very near those levels recorded approximately six weeks ago (April 19, 1981). The total relief of the piezometric surface across the site is on the order of one foot.

The present piezometric levels indicate two general depressions at the site; one in the vicinity of Well 8 and the other in the vicinity of Well 5. They also indicate that the pumping program is effectively lowering the piezometric surface for collection and removal of fluid gasoline.

Gasoline Thickness

Gasoline thicknesses recorded on May 31, 1981 are shown on Plate 2. These most recent readings indicate that the greatest thickness of gasoline across the site is on the order of .16 foot, which occurred in Wells 18 and 32. Smaller amounts of gasoline fluid occur near Wells 1 and 7. The amount of fluid gasoline is decreasing weekly.

Explosimeter Readings

Explosimeter readings in Wells 13 and 14 have risen 10 to 15 percent at the four foot level and 0 to 25 percent at the eight foot level, since those readings recorded on May 17, 1981. Except for these variances, vapor readings over the remainder of the wells were essentially the same as those recorded on May 17, 1981.

Yours very truly,

ROGER LOWE ASSOCIATES, A Division
of Harding-Lawson Associates

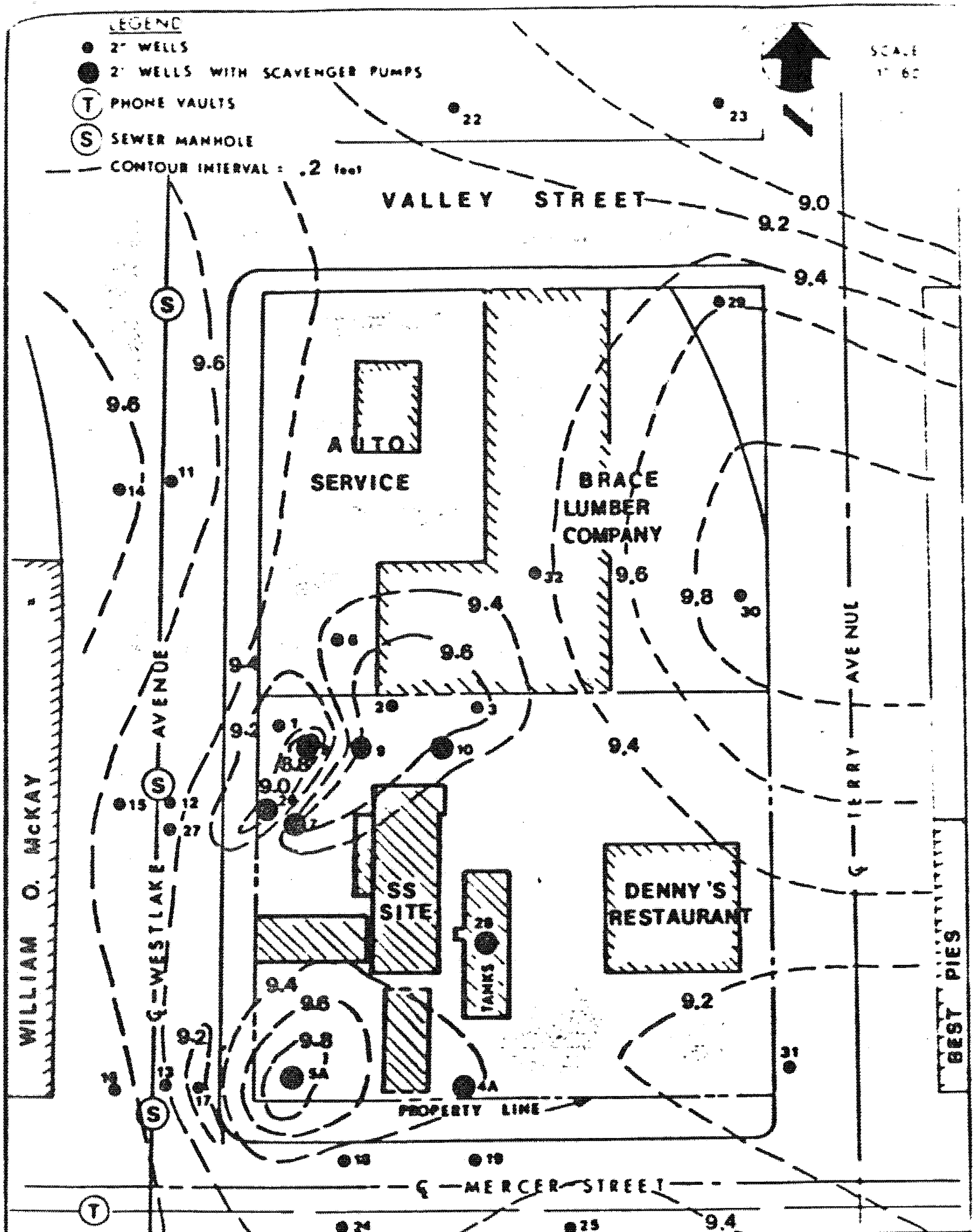
James T. Cameron

James T. Cameron
Project Manager

JTC/cjg

cc: Ed Ingham
Jim Miller

bcc: Jim Neyens-Houston



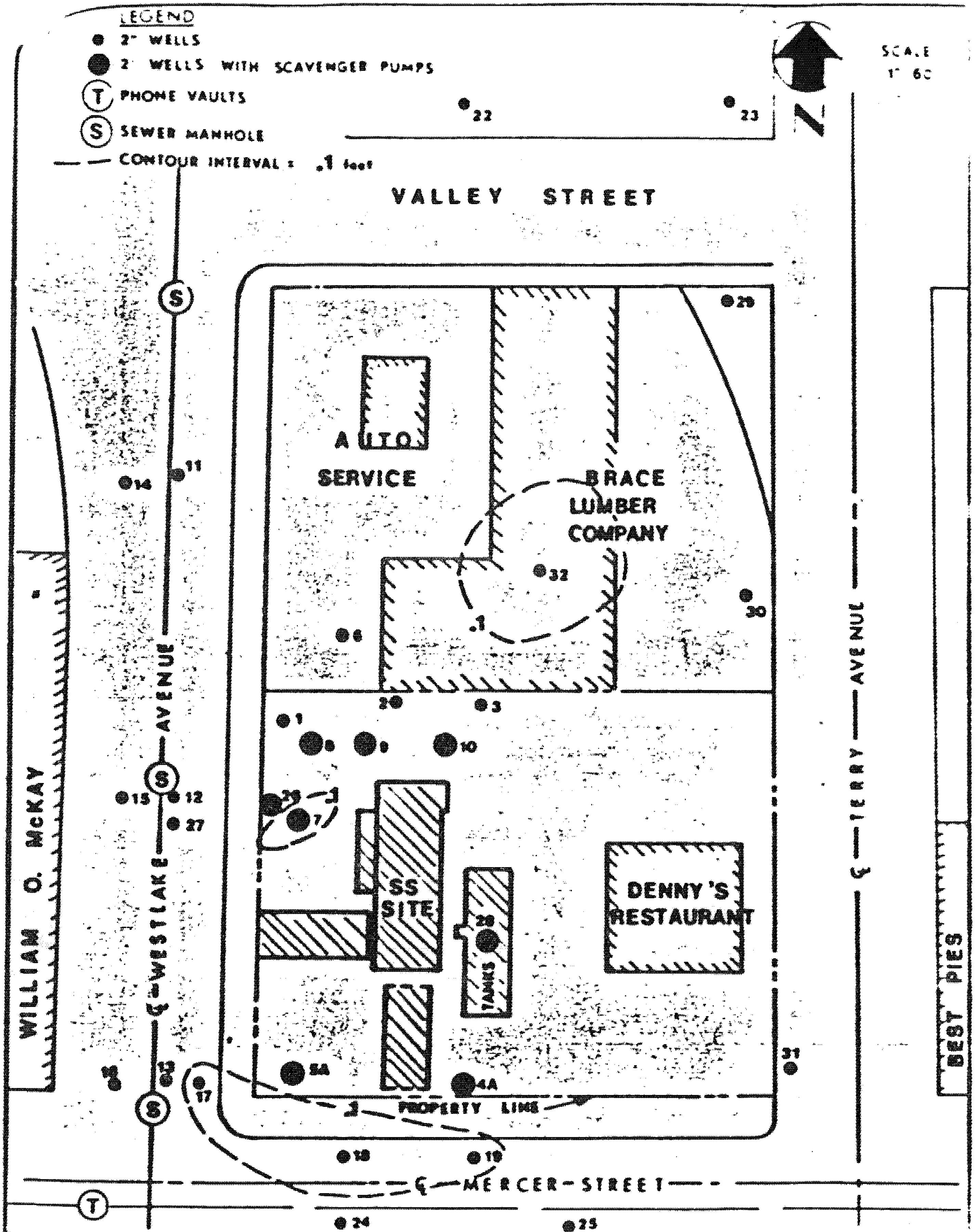
ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

PIEZOMETRIC ELEVATIONS 5/31/81

Union Oil Company of California

PLATE

1



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

GASOLINE THICKNESS 5/31/81

Union Oil Company of California

PLATE 2

JR

ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

COPY

June 25, 1981
14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report #14
Monitoring & Recovery Operations
Westlake & Mercer Gasoline Spill
Seattle, Washington

Gasoline Recovery

Between June 1 and June 14, 1981, no gasoline was pumped from the site. The total volume of gasoline recovered thus remains at 35,929 gallons.

Piezometric Elevations

Piezometric elevations recorded on June 14, 1981 are shown on Plate 1. The shape of the piezometric surface has not varied significantly from that recorded on May 31, 1981; however, piezometric elevations at the south end of the block have risen between .2 and .4 feet. The total relief of the piezometric surface across the site remains at approximately one foot.

The present piezometric levels indicate one general depression in the vicinity of Well 8, and a slight mound in the vicinity of Well 5A. The depression is most likely caused by the pumping in Well 8. The mound may be caused by the recent removal of a pump and a subsequent ground water recharge in its nearby vicinity. The previously low gradient might have caused the area to excessively recharge and we expect that over time this mound will level out to the surrounding piezometric levels. Alternatively, surficial water may be entering in the vicinity of Well 5A, thereby creating a local 'mound' in the piezometric surface.

300 120TH AVENUE N.E. P.O. BOX 3885 BELLEVUE, WASHINGTON 98009 206/453-8383

The pumping program is adequately lowering the piezometric surface for the collection and removal of gasoline.

Gasoline Thickness

Gasoline thicknesses recorded on June 14, 1981 are shown on Plate 2. These most recent readings indicate very little fluid gasoline remaining on the site. The maximum thicknesses recorded were at Wells 7, 19, and 32; which were .1,.17, and .13 feet respectively. There still appear to be two local areas of fluid gasoline; one in the middle portion of the site in the vicinity of Well 8, and the other at the south end of the site in the vicinity of Well 18. The amount of measurable fluid gasoline continues to decrease weekly.

Explosimeter Readings

Explosimeter readings in Well 13 at the four-foot level and Well 25 at the eight-foot level have decreased approximately 25 percent and 10 percent, respectively, since those readings recorded on May 31, 1981. Except for these variances, vapor readings in the remainder of the wells were essentially the same as those recorded on May 31, 1981.

Yours very truly,

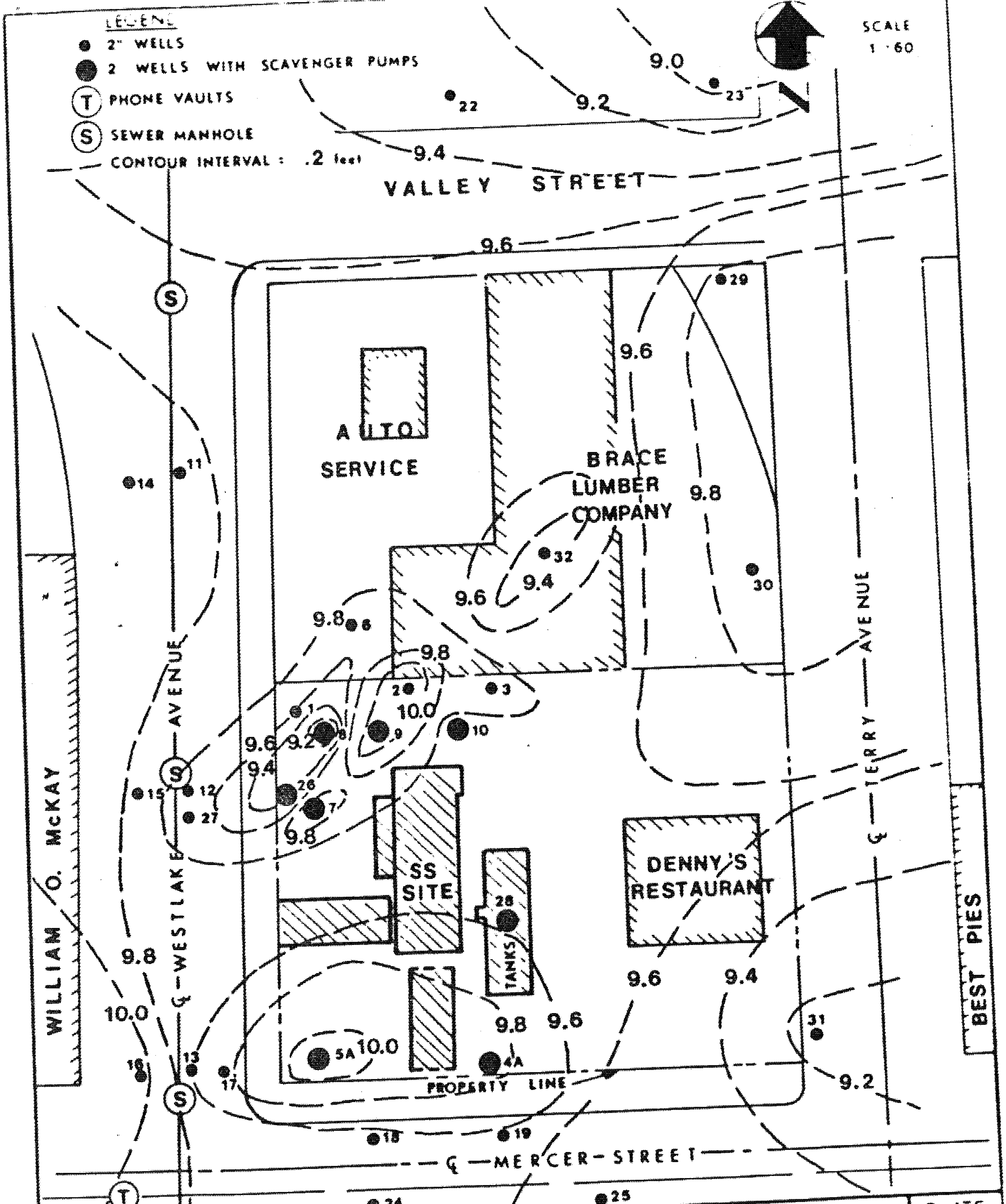
ROGER LOWE ASSOCIATES, A Division of Harding-Lawson Associates

James T. Cameron

James T. Cameron
Project Manager

JTC/ju

cc: Ed Ingham
Jim Miller



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

JOB NO. 14,197,006.07 APPR JTC DATE 6/25/81

PIEZOMETRIC ELEVATIONS 6/14/81

Union Oil Company
Seattle, Washington

PLATE
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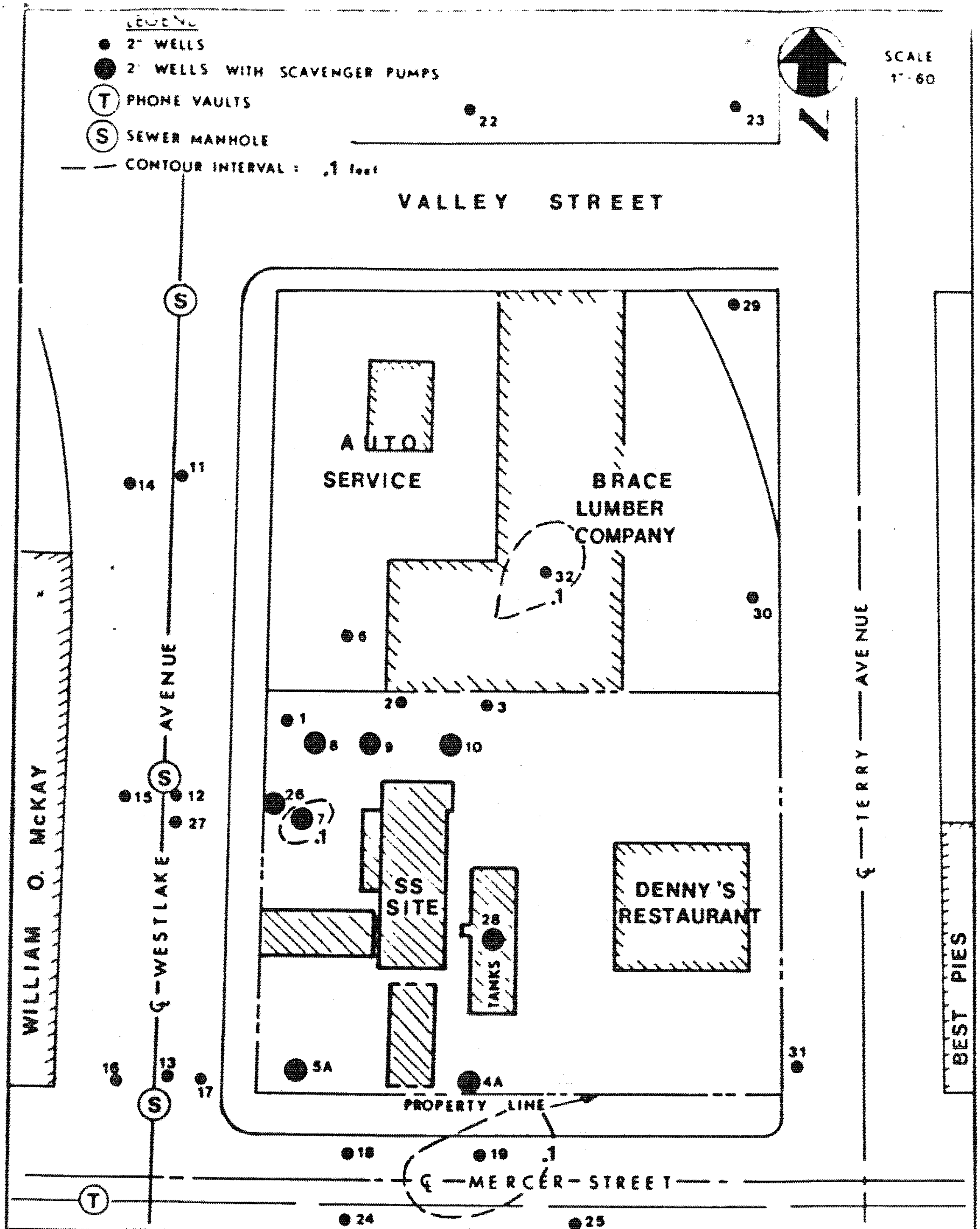

ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

JOB NO. 14,197,006.07 APPR JC DATE 6/25/81

GASOLINE THICKNESS 6/14/81

Union Oil Company
Seattle, Washington

PLATE
2

Copy

ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

ALASKA
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TEXAS
WASHINGTON
WASHINGTON, D.C.
SAUDI ARABIA

July 13, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

COPY

Gentlemen:

Progress Report No. 15
Monitoring & Recovery Operations
Westlake & Mercer Gasoline Spill
Seattle, Washington

Gasoline Recovery

Between June 15 and June 28, 1981, approximately 258 gallons of gasoline were pumped from the main holding tank at the site. The total volume of gasoline recovered is currently 36,187 gallons. The gasoline recovery rate has decreased in the past month to about 260 gallons per month.

Piezometric Elevations

Piezometric elevations recorded on June 28, 1981 are shown on Plate 1. The shape of the piezometric surface has not varied significantly from that recorded on June 14, 1981. Piezometric elevations have dropped about .1 foot relatively uniformly over the entire site.

The depression in the vicinity of Well 8 is less pronounced. Likewise, the slight mound in the vicinity of Well 5 appears to be leveling to the surrounding piezometric surface. The pumping program continues to be adequately lowering the piezometric surface for the collection and removal of gasoline.

Union Oil Company of California
Page Two - July 13, 1981

Gasoline Thickness

Gasoline thicknesses recorded on June 28, 1981 are shown on Plate 2. These readings indicate that the little remaining fluid gasoline is concentrated primarily in two depressions in the piezometric surface in the vicinity of Wells 19 and 32, both with maximum gasoline thicknesses of about .16 feet. The amount of measurable gasoline continues to decrease.

Explosimeter Readings

Explosimeter readings in Well 11 at the four-foot level and Wells 16 and 25 at the eight-foot level have decreased by 5, 15, and 10 percent, respectively, since the June 14 readings. At the four-foot level measurements in Well 13 and Well 12 at the eight-foot level have increased by 30 and 5 percent, respectively. These are all in wells with no measurable fluid gasoline. Except for these changes, vapor readings in the remainder of the wells were the same as those recorded on June 14, 1981.

Yours very truly,

ROGER LOWE ASSOCIATES, A Division
of Harding-Lawson Associates

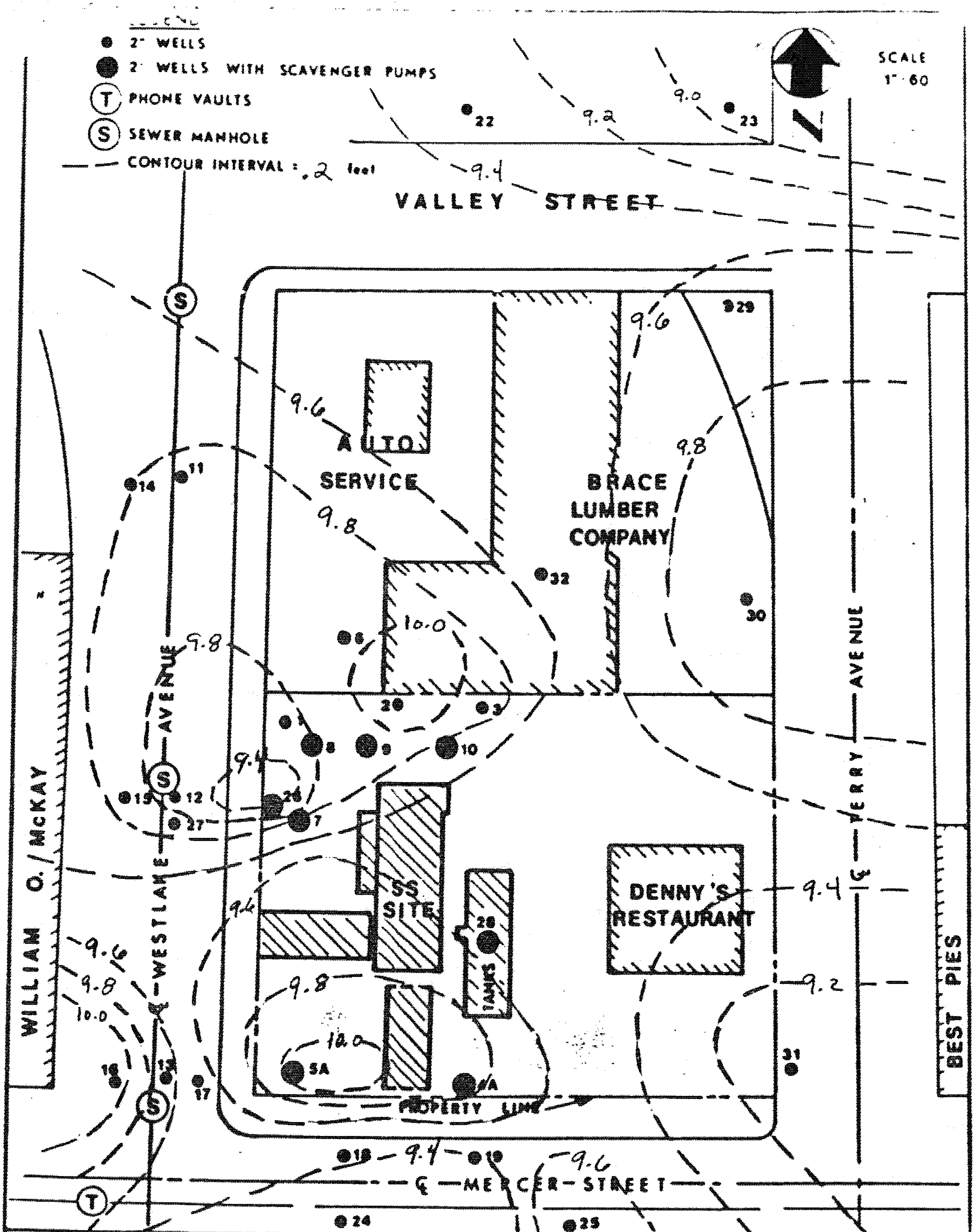
James T. Cameron

James T. Cameron
Project Manager

VPL/JTC/cjg

cc: Ed Ingham
Jim Miller

bcc: Jim Reyens



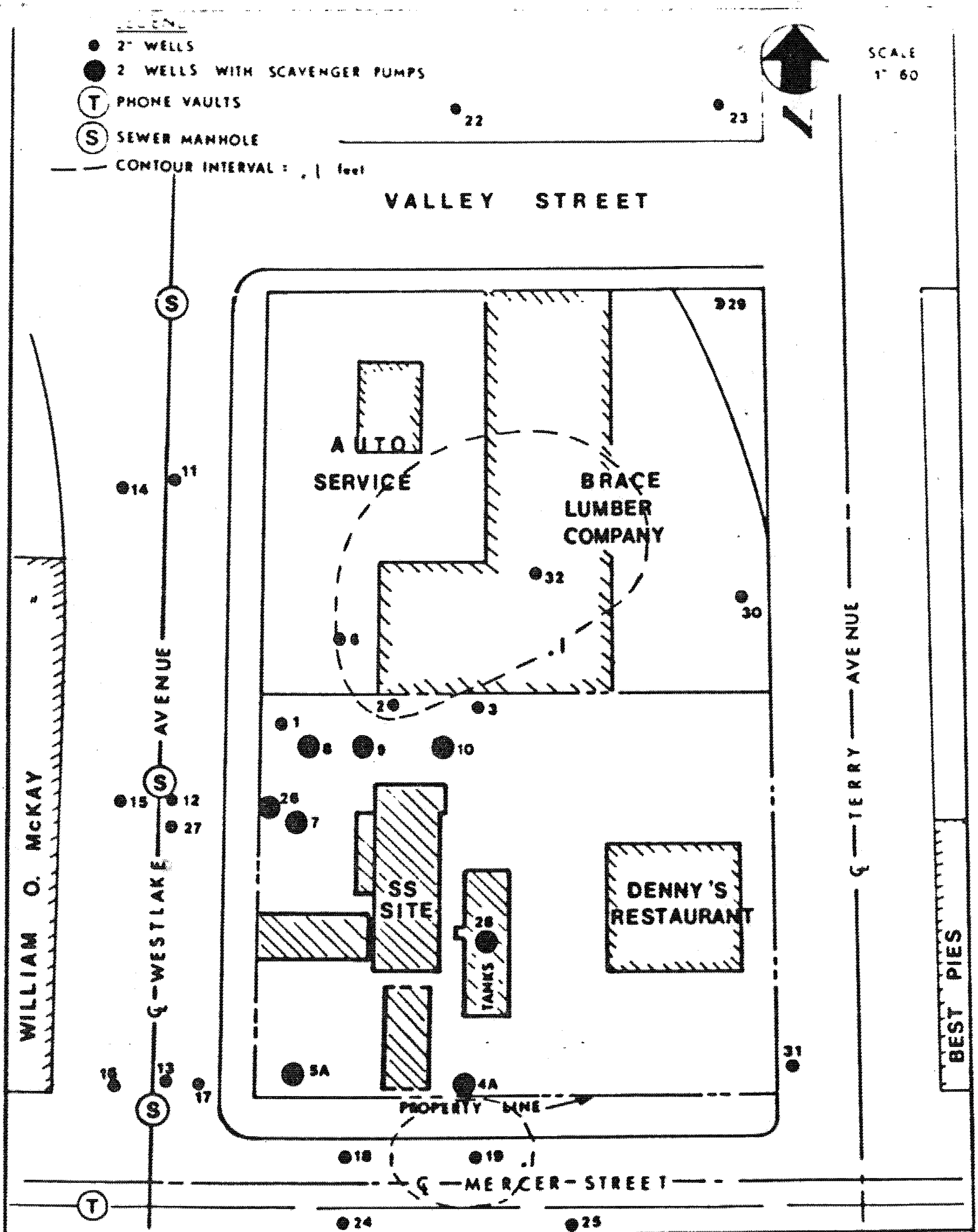
ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

JOB NO 14,197,006.07 APPR [initials] DATE 7/13/81

PIEZOMETRIC ELEVATIONS 6/28/81

Union Oil Company
Seattle, Washington

PLATE
1



ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

JOB NO 14.197.006.07 APPR. JTC DATE 7/13/81

GASOLINE THICKNESS 6/28/81

Union Oil Company
Seattle, Washington

PLATE
2

HARDING-LAWSON ASSOCIATES

COPY

July 23, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 16
Monitoring & Recovery Operations
Westlake & Mercer Gasoline Spill
Seattle, Washington

Gasoline Recovery

No gasoline was recovered from the site between June 29 and July 10, 1981. The total volume of gasoline recovered thus remains at 36,187 gallons.

Piezometric Elevations

Piezometric elevations recorded on July 10, 1981 are shown on Plate 1. The piezometric surface has changed somewhat from that recorded on June 28, 1981. The piezometric surface has risen approximately .2 to .4 foot on the eastern side of the site in the vicinity of Well 30. It has dropped .5 to 1.0 foot in the vicinity of Wells 8, 9, and 10, and in the vicinity of Wells 4a, and 5a. Currently there is approximately 1 foot of relief in the piezometric surface across the site.

At present there is a relatively strong downward gradient toward the drawdown pumps and skimmers. This downward gradient will tend to concentrate liquid gasoline in the areas of the skimmers for removal.

Gasoline Thickness

Gasoline thicknesses recorded on July 10, 1981 are shown on Plate 2. The current readings indicate an increase in the gasoline thickness of .2 to .3 feet at the site. The readings indicate that the fluid gasoline is concentrated primarily in the vicinity of Wells 1 and 3, in the middle portion of the site and in the vicinity of Wells 18 and 19, in the southern end of the site. A maximum gasoline thickness of .46 foot was recorded in Well 19 on July 19, 1981.

The increase in gasoline thickness appears to be a direct result of the increase in the slope of the piezometric surface, discussed earlier. More gasoline is collecting due to the relatively deeper and steeper downward gradients in the piezometric surface at the drawdown pump locations.

Explosimeter Readings

Explosimeter readings in Well 14 at the 4-foot level, and Well 16 at the 8-foot level have increased by 30 and 20 percent, respectively, since the June 28 readings. The explosimeter reading at the 8-foot level in Well 25 has decreased approximately 25 percent since the previous readings. Except for these discrepancies, vapor readings in the remainder of the wells were within 10 percent of those recorded on June 28, 1981.

Yours very truly,

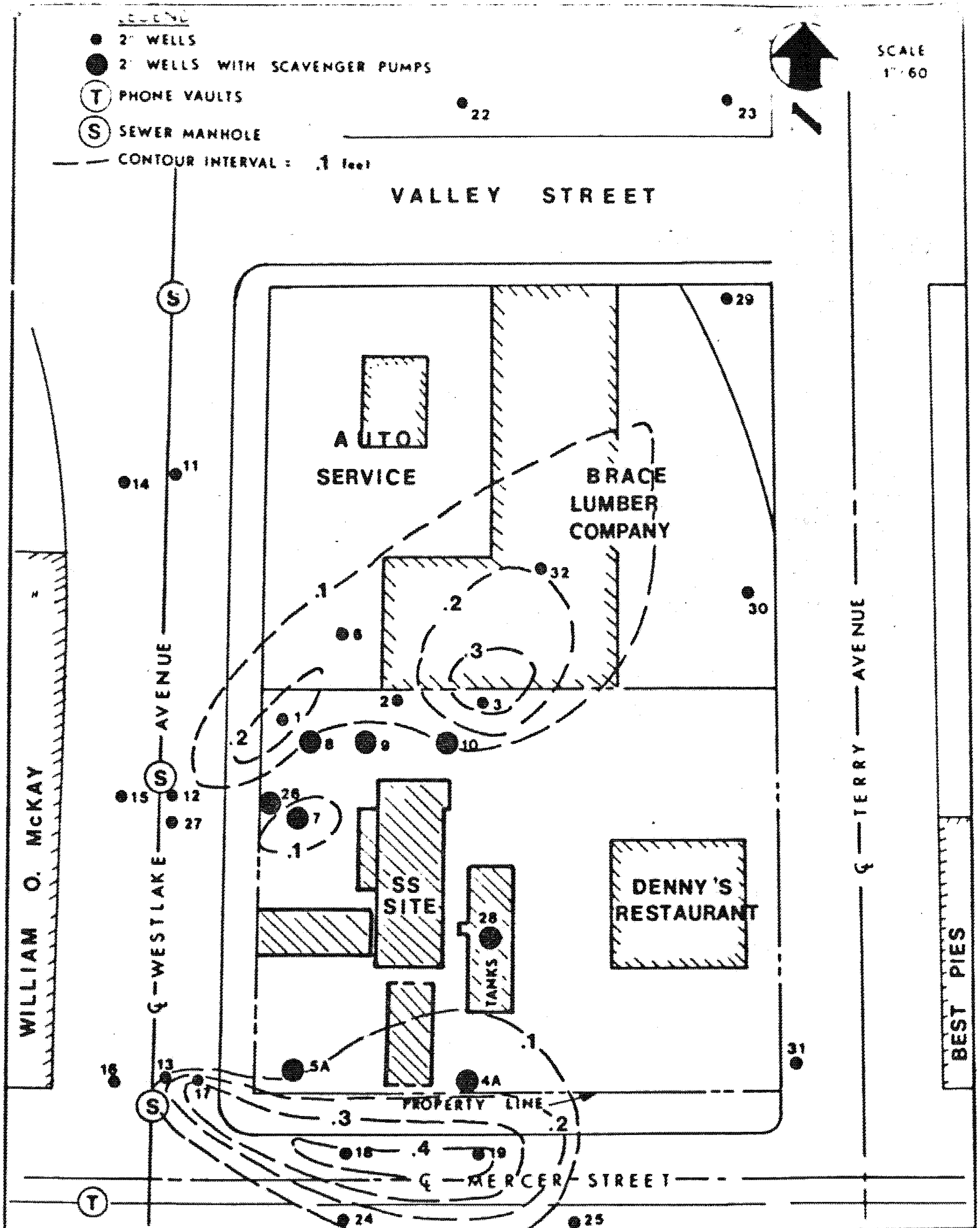
ROGER LOWE ASSOCIATES, A Division
of Harding-Lawson Associates

James T. Cameron

James T. Cameron
Project Manager

JTC/ju

cc: Mr. Ed Ingham
Mr. Jim Miller



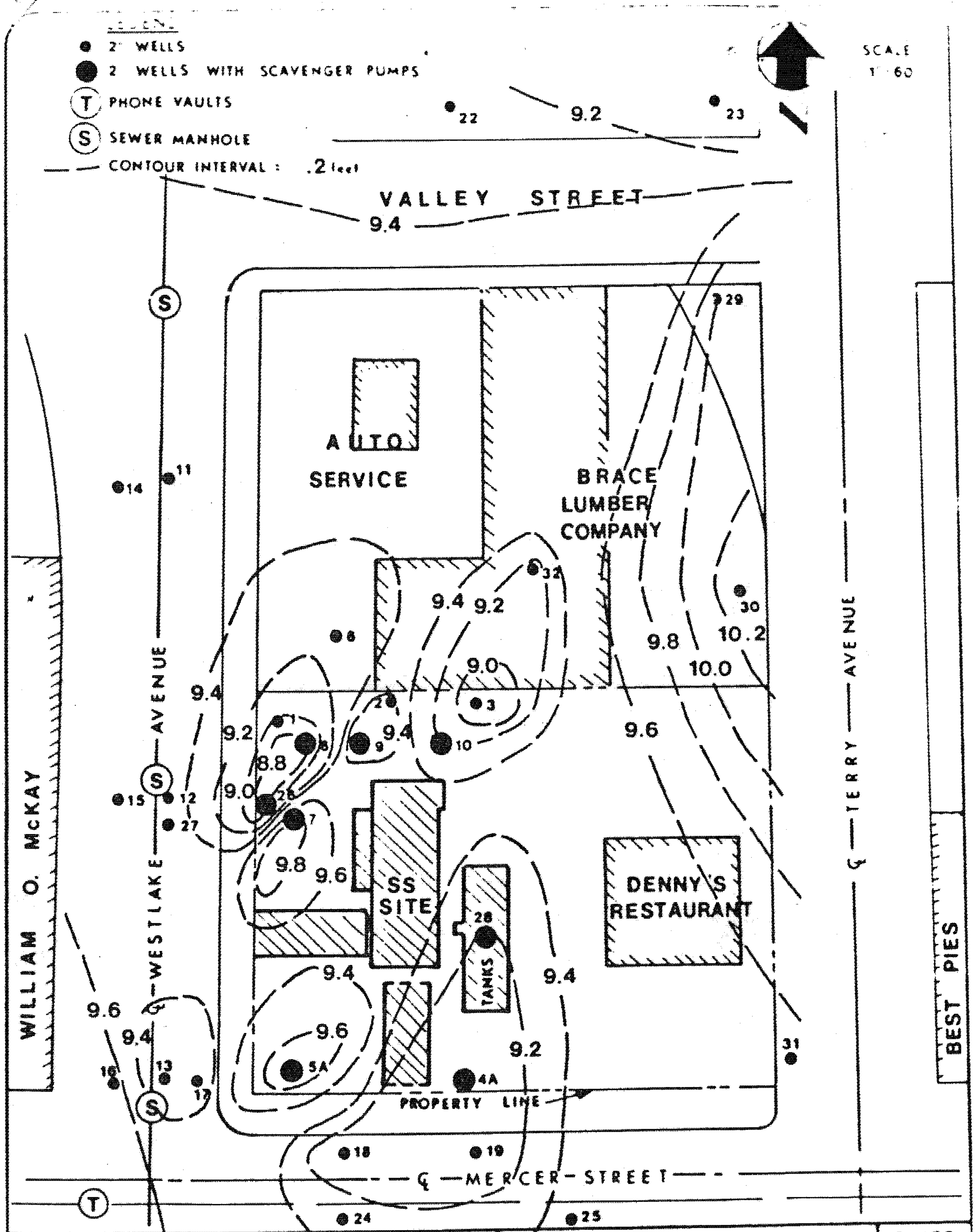
ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

14,197,006.07 APPR. 7C DATE 7/24/81

GASOLINE THICKNESS 7/10/81

Union Oil Company
Seattle, Washington

PLATE
2



ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

JOB No. 14,197,006.07 APPR *[illegible]* DATE *7/24/81*

PIEZOMETRIC ELEVATIONS 7/10/81

Union Oil Company
Seattle, Washington

PLATE
1

HARDING-LAWSON ASSOCIATES
ENGINEERS GEOLOGISTS AND GEOPHYSICISTS
300 120TH AVENUE NE
PO BOX 3885
BELLEVUE, WASHINGTON 98009 206/453-5383

ALASKA
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TEXAS
WASHINGTON
WASHINGTON, D.C.
SAUDI ARABIA

August 7, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 17
Monitoring & Recovery Operations
Westlake & Mercer Gasoline Spill
Seattle, Washington

This letter reports our recovery and monitoring operations for the period between July 11 and July 24, 1981. In our previous Report No. 16, dated July 23, 1981, we noted a relatively marked increase in recorded gasoline thicknesses. The most recent recorded thicknesses are equal to or greater than those recorded in our previous report; however, there has not been a corresponding increase in gasoline recovery from the recovery wells. If more gasoline was introduced or somehow the existing spilled gasoline became more concentrated, then there would be a corresponding increase in gasoline recovery.

There appears to be a strong correlation between decreasing water levels and increasing measured gasoline thicknesses in the site wells. When plotted against time, peaks and troughs in the two graphs occur simultaneously. Recent measurements of increases in gasoline thickness and decreases in water levels and the ratios of the two variables, for a number of wells, are given in the following table (note all measurements are given in inches):

Well No.	Increase Gasoline Thickness (A)	Decrease Water Level (B)	Approximate Ratio (A/B)
1	6	12	.5
2	6	12	.5
3	8	15	.5
6	4	8	.5
7	2	8	.25
8	6	21	.25
10	2.5	6	.33
17	5	6	1
18	9	9	1
19	8	10	1
27	1	1	1

Wells 1, 2, 3 and 6 (all in the middle portion of the site) have approximate ratios of .5. Wells 7, 8 and 10 are 2-foot diameter wells which are placed within a gravel backfill; these wells all indicate a ratio of .25 to .33. Wells 17, 18, 19 and 27 all occur along the perimeter of the site. Wells 17, 18 and 19 are grouped at the southern end and indicate substantial increases in gasoline thickness. Well 27 is on the west side and indicates only a one-inch increase in gasoline thickness. All four of these wells have ratios of approximately 1.0.

The reason for the correlation is not clear and perhaps it would be beneficial to take a closer look into the statistical correlation between gasoline thicknesses and water levels. As a preliminary evaluation, we may be observing an apparent increase in gasoline thickness due to an increase in the capillary fringe as the water table drops. The finer-grained soils will tend to drain more slowly and the upper surface of gasoline will therefore remain at essentially its same elevation for a period of time after the water table lowers. In coarser-grained soils the upper surface of the gasoline will tend to follow the water table down at a faster rate. Based on the above assumptions, one would expect a strong correlation between decrease in water levels and increase ingasoline thickness in fine-grained soils and a lesser correlation for coarse-grain soils. There are indications that this is occurring as indicated by the lower ratio for those wells which lie in gravel fill.

Other explanations for the correlation are possible and feasible; however, if more gasoline is concentrating at the site then one would expect an increase in recovery from the skimmers, which has not occurred.

Gasoline Recovery

On July 24, 1981, approximately 351 gallons of gasoline were pumped from the main holding tank. The previous pumping occurred almost exactly one month earlier on July 23, 1981, in which 258 gallons were removed. The total volume of gasoline recovery is currently 36,538 gallons.

The gasoline recovery rate is approximately 250 to 300 gallons per month. A plot of total gasoline recovered against the log of the number of days since the beginning of pumping is presented on Plate 1. Based on well theory for a finite reservoir, the relationship between these two variables should be approximately linear during periods of constant pumping. As Plate 1 indicates, the plot is linear except for the periods where the pumps were turned off during construction and when pumping originally occurred at the Brace Lumber Yard to remove a local pool of gasoline. Increasing rates of recovery would tend to steepen the plot; no such indications are apparent.

Piezometric Elevations

Piezometric elevations recorded on July 24, 1981 are shown on Plate 2. Except for a local drop in the piezometric surface in the vicinity of Well 8 in the middle portion of the site, there has been no significant change in the piezometric surface from that recorded in our previous report dated July 23, 1981. Currently there is approximately two feet of relief in the piezometric surface across the site. The most recent readings indicate that the piezometric surface at Well 8 has dropped approximately 11 inches in the last two weeks. The reason for this is not apparent.

Gasoline Thickness

Gasoline thicknesses recorded on July 24, 1981 are presented on Plate 3. The current readings indicate an increase in gasoline thickness of .2 to .3 feet at the site. The readings indicate that the fluid gasoline is still concentrated primarily in the same two zones noted in our previous report: One in the middle portion of the site near Wells 1, 2, and 3; the other in the southern end near Wells 4 and 5. A maximum recorded gasoline thickness of eight inches occurred in Wells 3 and 19 on July 24, 1981.

Explosimeter Readings

Except for Wells 22, 25 and 26, current explosimeter readings have not changed significantly from those recorded previously. On July 17, 1981 the recorded explosimeter readings in Well 22 at the north end of the site (which had 0 percent readings at both the 4-foot and 8-foot levels previously) indicate a sudden rise to approximately 50 percent at the 4-foot level and 100 percent at the 8-foot level. Conversely, Well 26, in the middle portion of the site, with consistent explosimeter readings of 100 percent at both the 4-foot and 8-foot levels, has suddenly decreased to approximately 20 percent at the 4-foot level and 60 percent at the 8-foot level. We suspect that readings in these two wells have been reversed. In addition, Well 25 at the southern end of the site with consistent explosimeter readings of approximately 60 percent at the 8-foot level, has suddenly dropped to 0 percent: We will closely inspect future readings of these wells. Except for these discrepancies, vapor readings in the remainder of the wells are within 15 percent of those recorded on July 10, 1981.

Yours very truly,

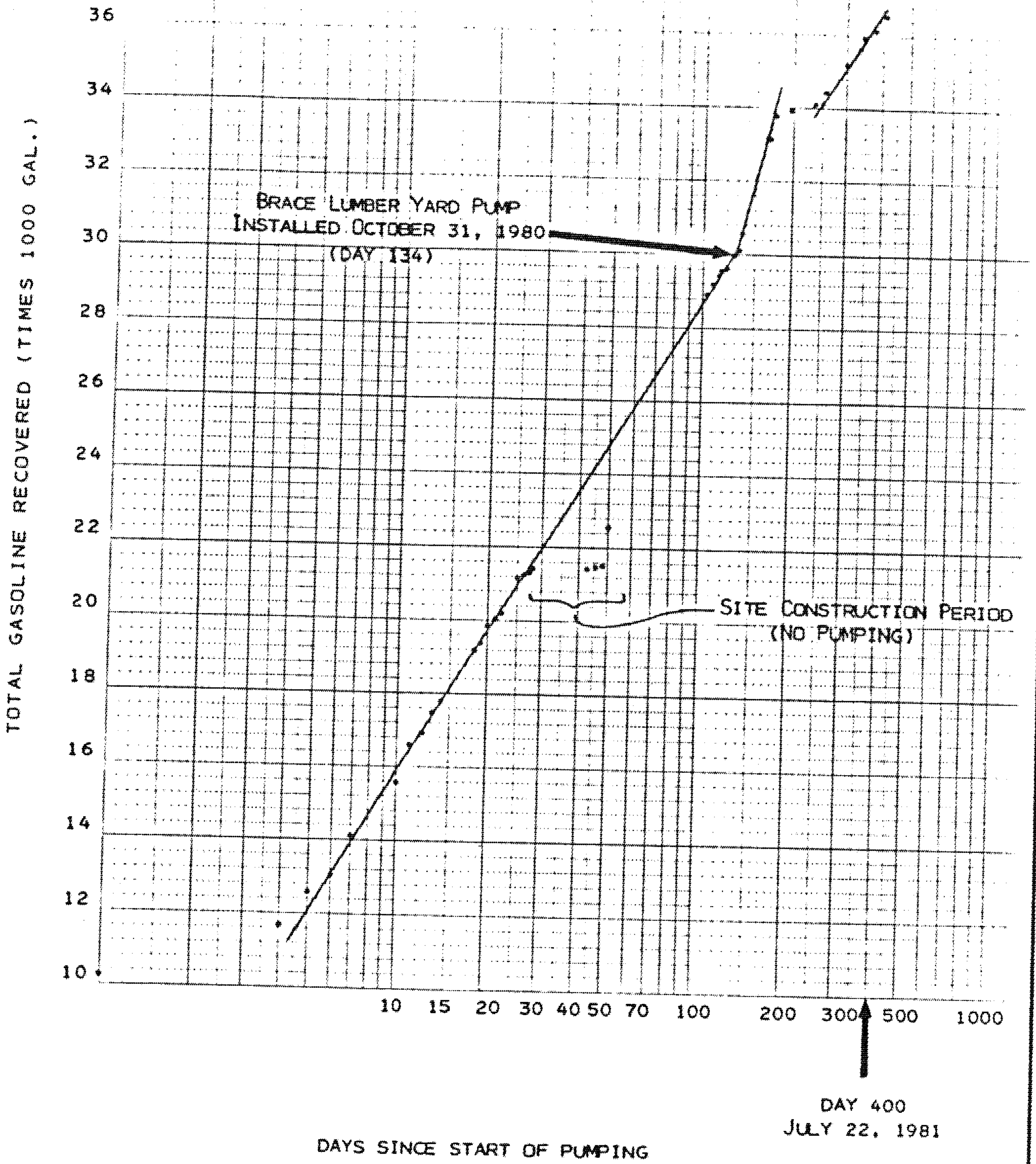
HARDING-LAWSON ASSOCIATES

James T. Cameron

James T. Cameron
Project Manager

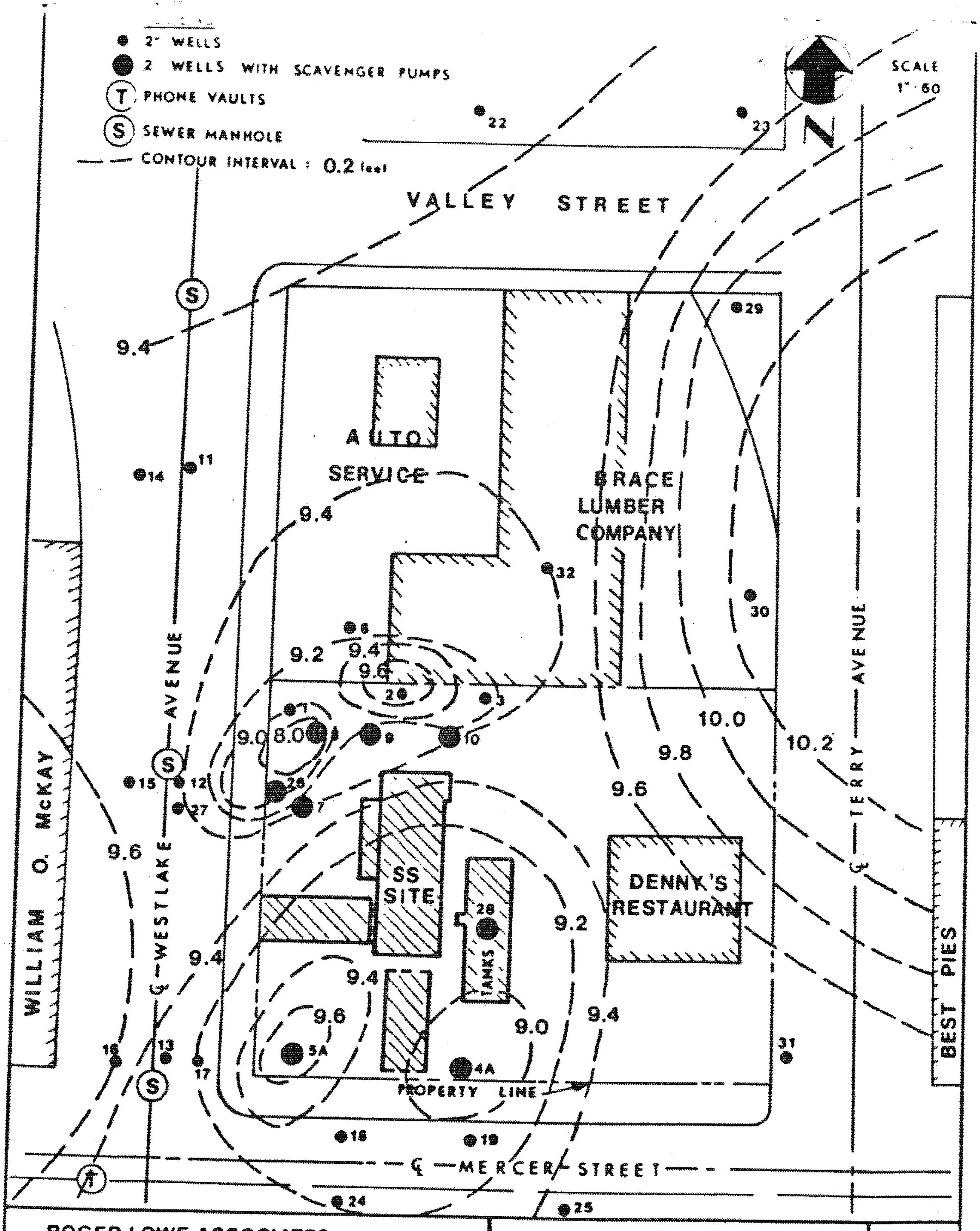
JTC/ju

cc: Jim Miller
Ed Ingham



NOTE: START OF PUMPING ON JUNE 19, 1980

ROGER LOWE ASSOCIATES A Division of HARDING-LAWSON ASSOCIATES *Engineers, Geologists and Geophysicists*	TOTAL GASOLINE RECOVERY 7/24/81 Union Oil Company Seattle, Washington	PLATE **1**
JOB NO 14,197,006.07 APPR JTC DATE 8/7/81		

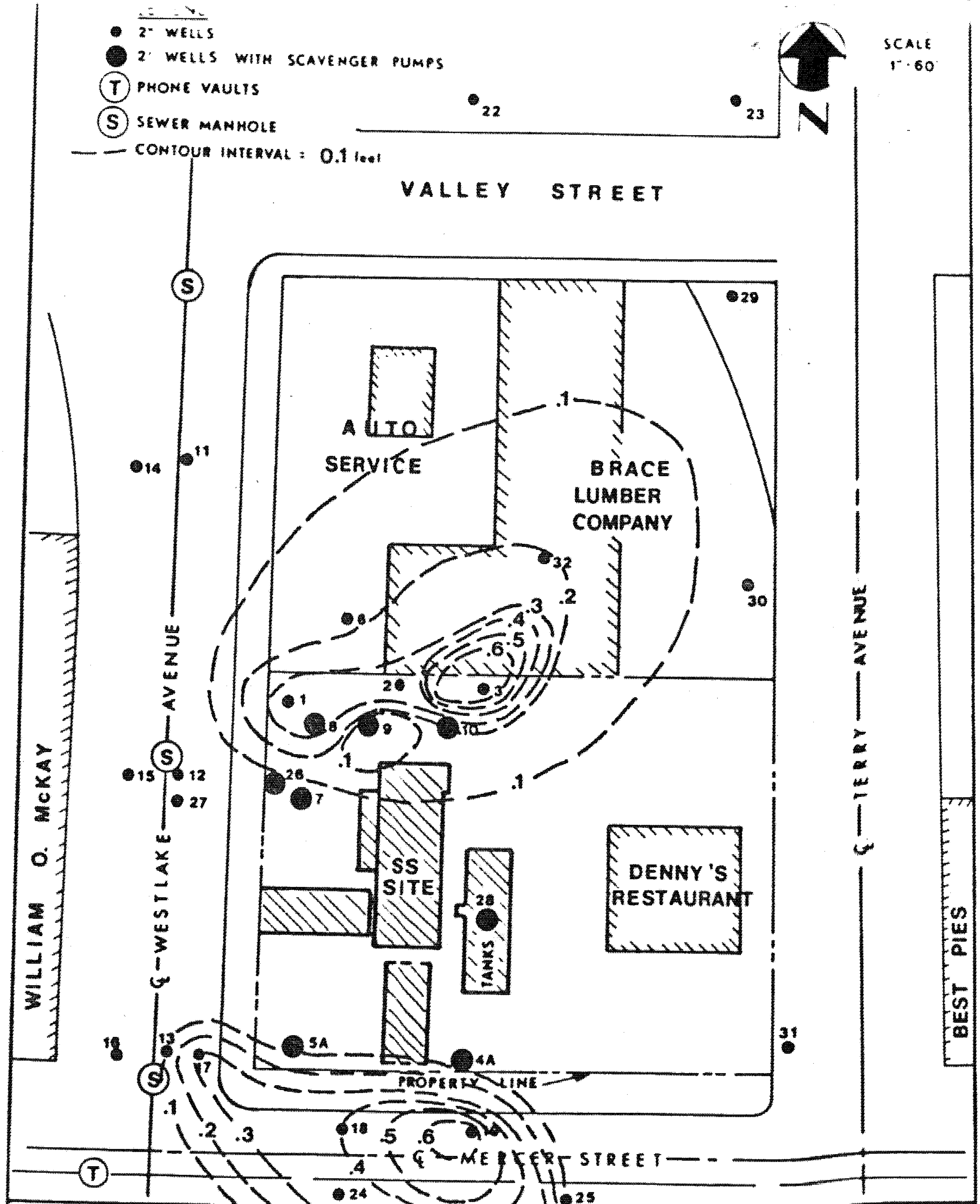


ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

JOB NO 14,197,006.07 APPR JL DATE 8/7/81

PIEZOMETRIC ELEVATIONS 7/24/81
Union Oil Company
Seattle, Washington

PLATE
2



ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

JOB NO 14,197,006.07 APPR TC DATE 8/7/81

GASOLINE THICKNESS 7/24/81
Union Oil Company
Seattle, Washington

PLATE
3

HARDING-LAWSON ASSOCIATES

August 21, 1981
#14,197,006.07

Union Oil of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 18
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on recovery and monitoring operations for the period between July 25 and July 31, 1981. In our previous report, No. 17, dated August 7, 1981, we described a correlation between decreasing water levels and increasing measured gasoline thicknesses in the site wells. In order to clarify our proposed reason for this relationship, we have prepared the following discussion and the attached Plate 1.

Capillary Zone Effects

Due to the closeness of the soil particles and the cohesive effects between the soil and water, small conduits of water will rise above the ground water table level and form a capillary zone which is partially saturated with water. Gasoline, which is introduced to the soil from above, will first fill the unsaturated portions of the capillary zone, then saturate the soil immediately above the capillary zone. Beneath the water table, horizontal water flow can occur relatively freely. Between the upper surface of the gasoline and the top of the capillary zone, gasoline can flow relatively freely. Within the capillary zone, there is little to no flow of gasoline or water.

If a well is drilled from the ground surface to some distance below the water table, the following occurs:

1. Gasoline which is free to flow will flow into the well and rest on the water table within the well.

2. As gasoline accumulates, the weight of the gasoline will tend to depress the water surface in the well below the water table.

3. The gasoline will continue to flow into the well depressing the water surface until the bouyancy of the water equalizes the overlying weight of gasoline.

The upper surface of gasoline within the well will reach equilibrium at the same elevation as the upper surface of gasoline within the soil. However, the lower surface of the gasoline within the well will be at some point beneath the water table. Therefore, the measured thickness of gasoline within the well will be somewhat greater than the actual thickness of mobile, or recoverable, gasoline within the soil. The difference between these two measurements is a function of the thickness of the capillary zone; finer grained soils have greater capillary action, and therefore a thicker capillary zone, than coarser grained soils.

Based on the above, we can propose a possible reason for the correlation between a decrease in water table level and an increase in gasoline thickness measured in the wells. As the water table lowers, the capillary zone is temporarily thickened as the gasoline and water are acquiring a new state of equilibrium within and above the capillary zone. As the water table in the soil depresses an equal lowering of water will be seen within the well. Mobile gasoline above the capillary zone will flow into the top of the well to refill it to its previous level. We can therefore see that the gasoline thickness measured in a well will increase as the water table drops. In finer grained soils, where flow is relatively slow, there will be a longer time lag for the gasoline and water to reach equilibrium than in coarser grained soils. This will tend to make the ratio of gasoline thickness increase to water level decrease approach unity. Coarser grained soils, which are more permeable, will have a lower ratio. Over time, this ratio at a particular well should decrease as gasoline is removed from the site.

Based on the above, there is no indication that gasoline is accumulating or concentrating in those wells which have recently indicated an increase in gasoline thickness. It is our opinion that the increases in measured thicknesses are merely due to the lag time between lowering of the water table and the attendent lowering of the mobile gasoline and capillary zones. We expect that over time the upper surface of the gasoline will follow the water table down and the measured amounts of gasoline within the wells should approach their previous low levels.

Gasoline Recovery

Between July 25 and July 31, 1981, there was no gasoline removed from the site. The total volume of gasoline recovery therefore remains at 36,538 gallons.

Piezometric Elevations

Piezometric elevations recorded on July 31, 1981, are shown on Plate 2. There has been a minor drop of .1 to .2 feet in the piezometric surface across the site from those levels recorded in our previous report dated August 7, 1981. Currently there is approximately 2 feet of relief in the piezometric surface across the site.

Gasoline Thickness

Gasoline thicknesses recorded on July 31, 1981, are presented on Plate 3. Except for Well 4A, which increased in gasoline thickness from approximately .1 to .45 feet, the remaining wells indicate approximately the same gasoline thicknesses as those recorded on July 24, 1981. The recent trend of increasing gasoline thicknesses appears to have slowed down substantially. A maximum reported gasoline thickness of 9 inches occurred in Well 18 on July 31, 1981.

Explosimeter Readings

Except for Wells 12, 13, 14, and 22, explosimeter readings have changed less than 10 percent from those recorded previously. Wells 13 and 22 at the 4-foot level and Well 14 at the 8-foot level have increased 20 percent from those readings recorded on July 24, 1981. Well 12, at the 8-foot level has decreased by 20 percent from the previous reading. Explosimeter readings in Wells 22, 25 and 26 still appear anomolous from those recorded prior to July 17, 1981. We will continue to closely inspect these readings as we receive more data.

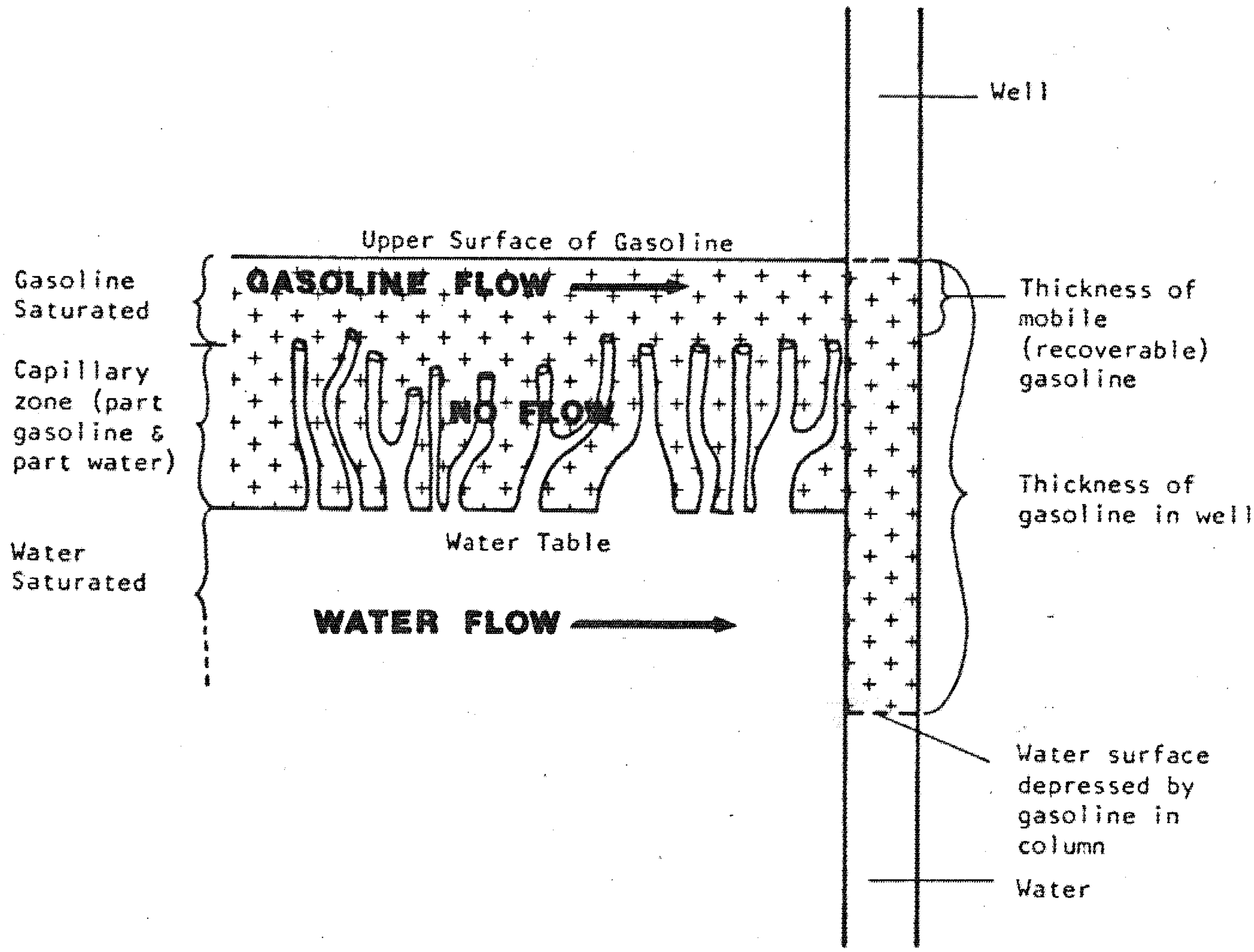
Yours very truly,

HARDING-LAWSON ASSOCIATES

James T. Cameron

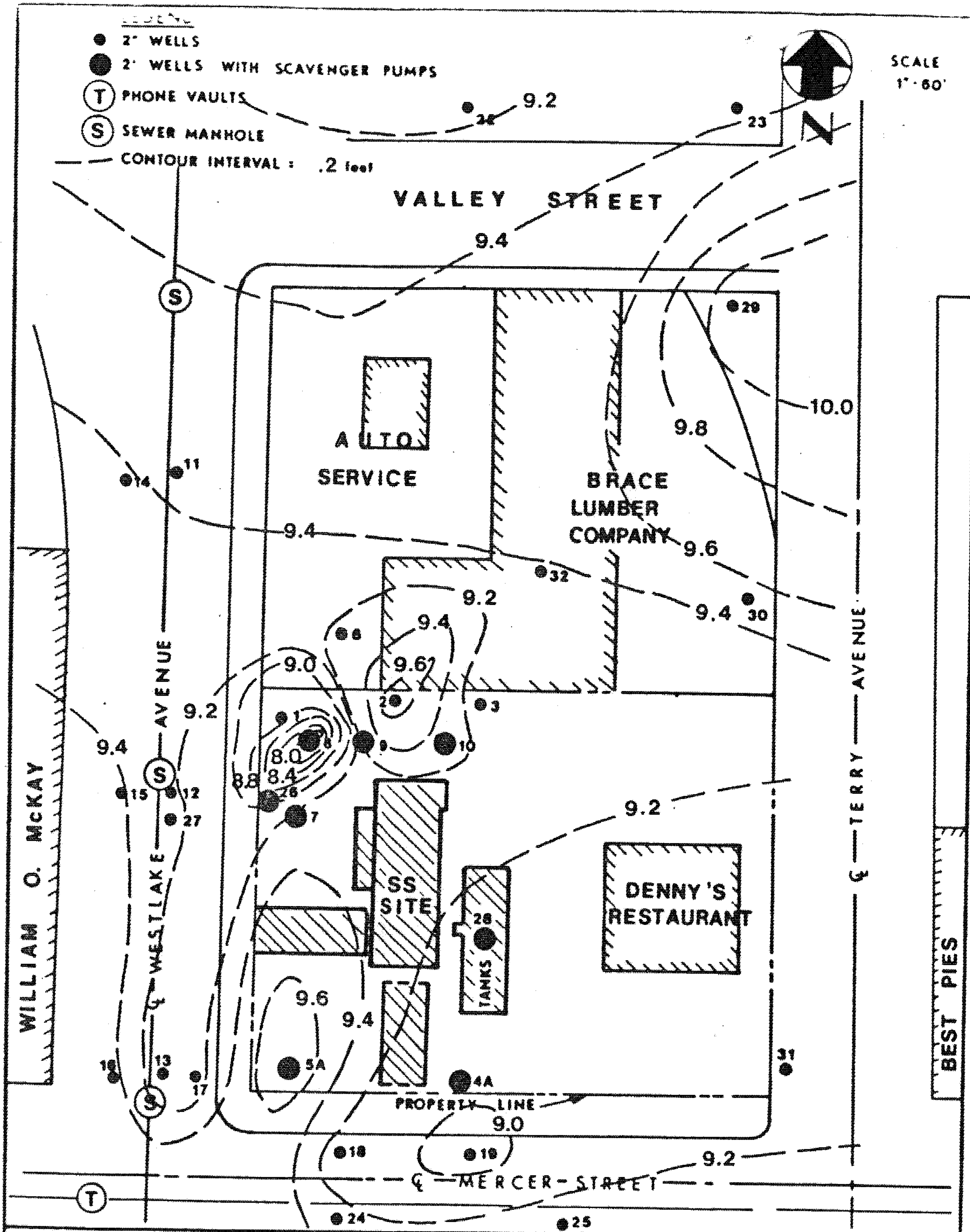
James T. Cameron, Project Manager

JTC/cag
cc: Jim Miller
Ed Ingham



FLUID THICKNESSES AND FLOW CHARACTERISTICS
OF GASOLINE-WATER INTERFACE IN SOIL AND WELL

ROGER LOWE ASSOCIATES A Division of **HARDING-LAWSON ASSOCIATES** *Engineers, Geologists and Geophysicists*	GASOLINE-WATER INTERFACE Union Oil Company Seattle, Washington	PLATE **1**
JOB NO 14,197,006.07 APPR [illegible] DATE 8/21/81		

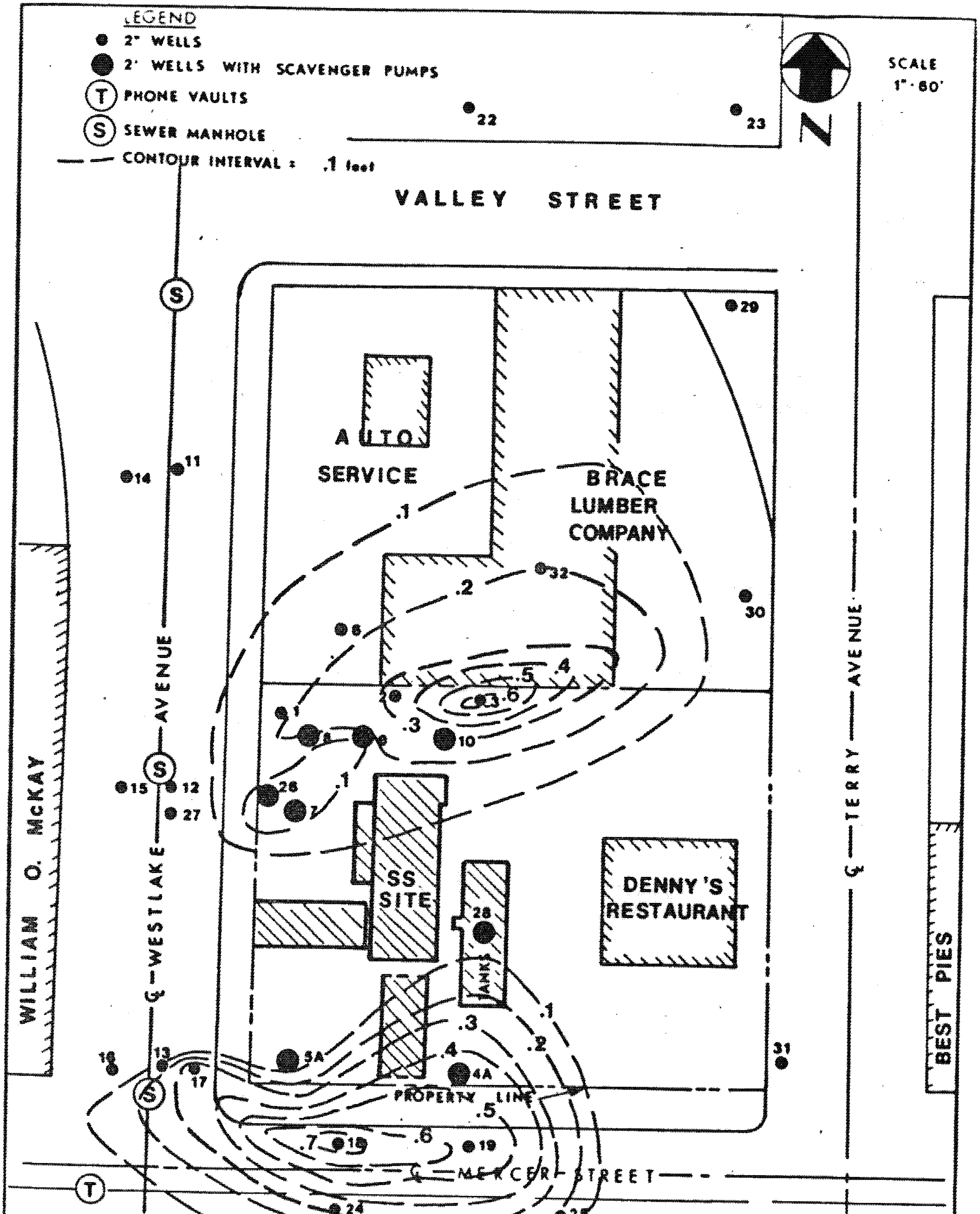


ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

PIEZOMETRIC ELEVATIONS
Union Oil Company 7-31-81
Seattle, Washington

PLATE
2

JOB NO 14.197.006.07 APPR [illegible] DATE 8/21/81



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

GASOLINE THICKNESSES
Union Oil Company 7-31-81
Seattle, Washington

PLATE
3

JTC copy

HARDING-LAWSON ASSOCIATES
ENGINEERS GEOLOGISTS AND GEOPHYSICISTS

BELLEVUE, WASHINGTON 98009 206 453-8383

September 3, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report #19
Monitoring & Recovery Operations
West Lake & Mercer
Gasoline Spills
Seattle, Washington

This letter reports on the recovery and monitoring operations for the period between August 1 and August 21, 1981. Piezometric levels and gasoline thicknesses recorded at the site on August 21, 1981 have not changed appreciably from those recorded on July 31, 1981. Except for one well, explosimeter readings at the 4-foot and 8-foot levels have remained within 15% of those recorded on July 31.

Gasoline Recovery

Between August 1 and August 21 there was no gasoline removed from the site. The total volume of gasoline recovery, therefore, remains at 36,538 gallons

Piezometric Elevations

Piezometric elevations recorded on August 21, 1981 are shown on Plate 1. There has been a slight rise of approximately .4 foot in the vicinity of Well 2. Other than this minor variation, the piezometric surface has remained essentially stable throughout the past three-week period. Currently, there are approximately two feet of relief in the piezometric surface throughout the site.

Gasoline Thickness

Gasoline thicknesses recorded on August 21, 1981 are presented on Plate 2. Except for an approximate one inch decrease in the vicinity of Well 3 and an approximate one inch increase in the vicinity of Well 18 and 19, there has been essentially no change in the gasoline thicknesses recorded at the site. The fluid gasoline is still concentrated in two areas;one in the middle portion of the block and the other at the southern end. The recent trend of increasing gasoline thickness appears to have stopped. Throughout the most recent three-week period maximum recorded gasoline thicknesses of ten inches occurred in Wells 18 and 19.

Explosimeter Readings

Explosimeter readings have remained essentially stable since July 31, 1981. Except for Well 22, all readings have varied less than 15% since those reported previously. Explosimeter readings at the 8-foot level in Well 22 have dropped from approximately 100% to 75% over the three-week period.

It appears that the readings for Wells 22, 25, and 26 are correct as they have remained consistent since their sudden variations which were first recorded on July 17, 1981 in which explosimeter readings in Well 22 increased from 0% to 60% and 100%, at the 4-foot and 8-foot levels, respectively, and Well 26 decreased from 100% to 10% and 60%, at the 4-foot and 8-foot levels. In addition, readings in Well 25 decreased from 60% to 0% at the 8-foot level and did not vary at the 4-foot level. It may be that groundwater flushing from the south and west of the site has cleansed the contaminated soil in the midportions of the site to lower the gasoline vapor levels, while contaminated water being carried toward Lake Union to the north has increased the vapor readings in Well 22; however, Well 22 still shows no measurable fluid gasoline.

Yours very truly,

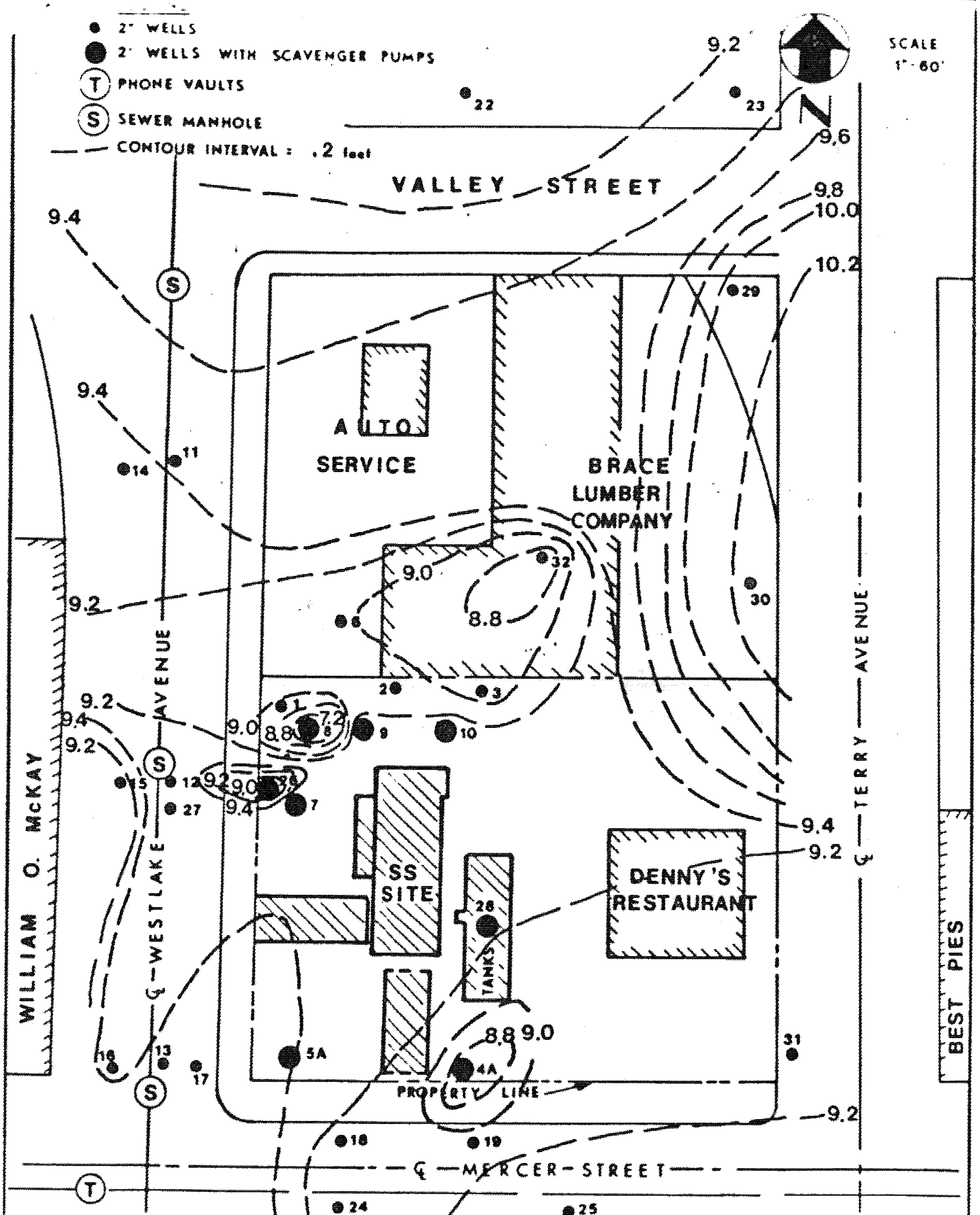
HARDING-LAWSON ASSOCIATES

James T. Cameron

James T. Cameron
Project Manager

JTC/mbd

cc: Jim Miller
Ed Ingham



ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

14,197,006.07 9/3/81

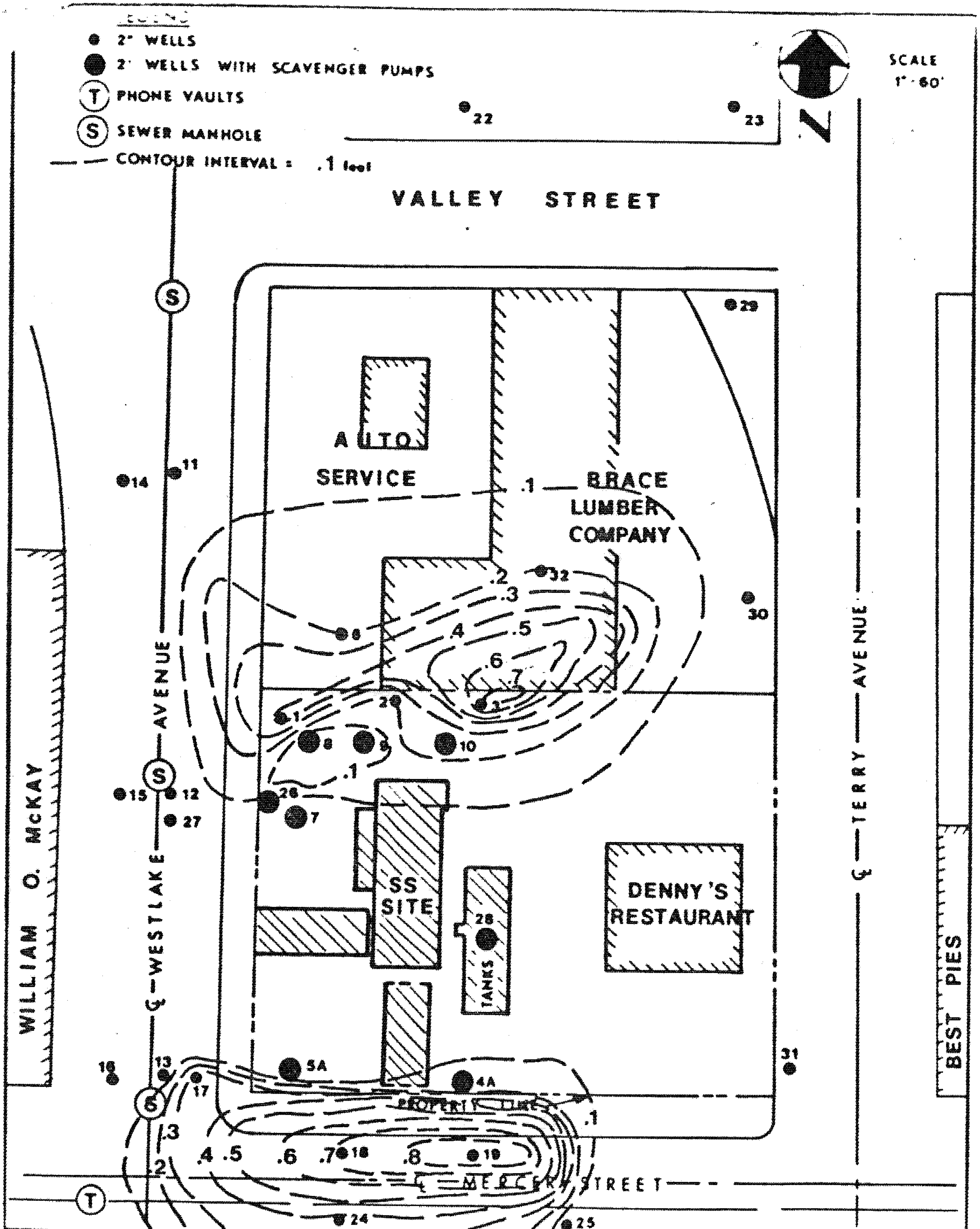
PIEZOMETRIC ELEVATIONS

8/21/81

Union Oil Company
Seattle, Washington

PLATE

1



ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

GASOLINE THICKNESSES
8/21/81

Union Oil Company
Seattle, Washington

PLATE
2

14,197,006.07 APPR. JTC DATE 9/3/81

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PO BOX 3885
BELLEVUE, WASHINGTON 98009 206/453-8383

COPY

September 22, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report #20
Monitoring & Recovery Operations
Westlake and Mercer
Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between August 21, 1981 and August 28, 1981.

Gasoline Recovery

No gasoline has been removed from the site since July 24, 1981. The total volume of gasoline recovered, therefore, remains at 36,538 gallons.

As discussed in previous progress reports (see Progress Report Number 17), the relationship between total gasoline recovered and the logarithm of the number of days since pumping began has been and continues to be linear except during periods when pumps were turned off or more pumps added. Another way to describe this relationship is to say that with time, the rate of gasoline recovery is declining logarithmically. Plate 1 shows the amount of gasoline recovered in successive 25-day intervals versus real time since pumping began.

As can be seen, the rate of gasoline recovery dropped sharply in the first 100 to 200 days of pumping and has since declined more slowly. As theory would indicate, the amount of recovery will continue to diminish until a negligible rate of return is reached. This minimal rate should be established based on the efficiency of the recovery operation and the tolerable gasoline liquid and vapor levels. This rate has not yet been established.

Piezometric Elevations

Piezometric elevations recorded on August 28, 1981 are shown on Plate 2. Other than a few minor variations, the piezometric surface has remained essentially stable for the past four weeks. Currently, there is a crude trough-like configuration to the piezometric surface with the trough axis centered north-south across the site and dipping slightly to the north.

Gasoline Thickness

Gasoline thicknesses recorded on August 28, 1981 are presented on Plate 3. Except for an approximate 0.1 foot decrease in the vicinity of Wells 8 and 9, there has been essentially no change in the recorded gasoline thicknesses, since August 21, 1981. The fluid gasoline is still concentrated in the middle portion and at the southern edge of the site centered around Wells 3 and 18, respectively. We understand that the drawdown pumps will be moved from Wells 4A and 8 to Wells 5A and 10, in an effort to increase gasoline recovery.

Explosimeter Readings

Explosimeter readings have remained essentially stable since July 31, 1981. Comparison of explosimeter readings taken on August 28, 1981 with those early in the recovery effort, on March 8, 1981 indicate that there has been some significant change over the long term. (The changes were discussed briefly in our last progress report). Contours of explosimeter readings at the 4-foot depth on these two days are shown on Plates 4 and 5. The plots indicate that there has been some extension of gasoline vapors to the north toward Valley Street and also across the center line of Westlake Avenue towards the southwest. Accompanying this has been a small reduction in gasoline vapor readings near the middle of the site along Westlake Avenue. The reason for the change in Well 22 is not clear, but as discussed in our previous progress report, it may be that contaminated groundwater has been slowly moving northward and is now near enough to the well to produce vapor. The reason for vapor increases in Wells 14 and 16 is less clear. Possibly, contaminated groundwater previously prevented from moving westward by the storm drain trench has somehow breached the trench. It is, however, reassuring to note that the core area of readings greater than 60% has not increased significantly.

As we discussed, we are currently in the process of preparing a proposal for evaluation of state-of-the-art gasoline recovery methods. We expect the proposal to be completed within the next week.

Yours very truly,

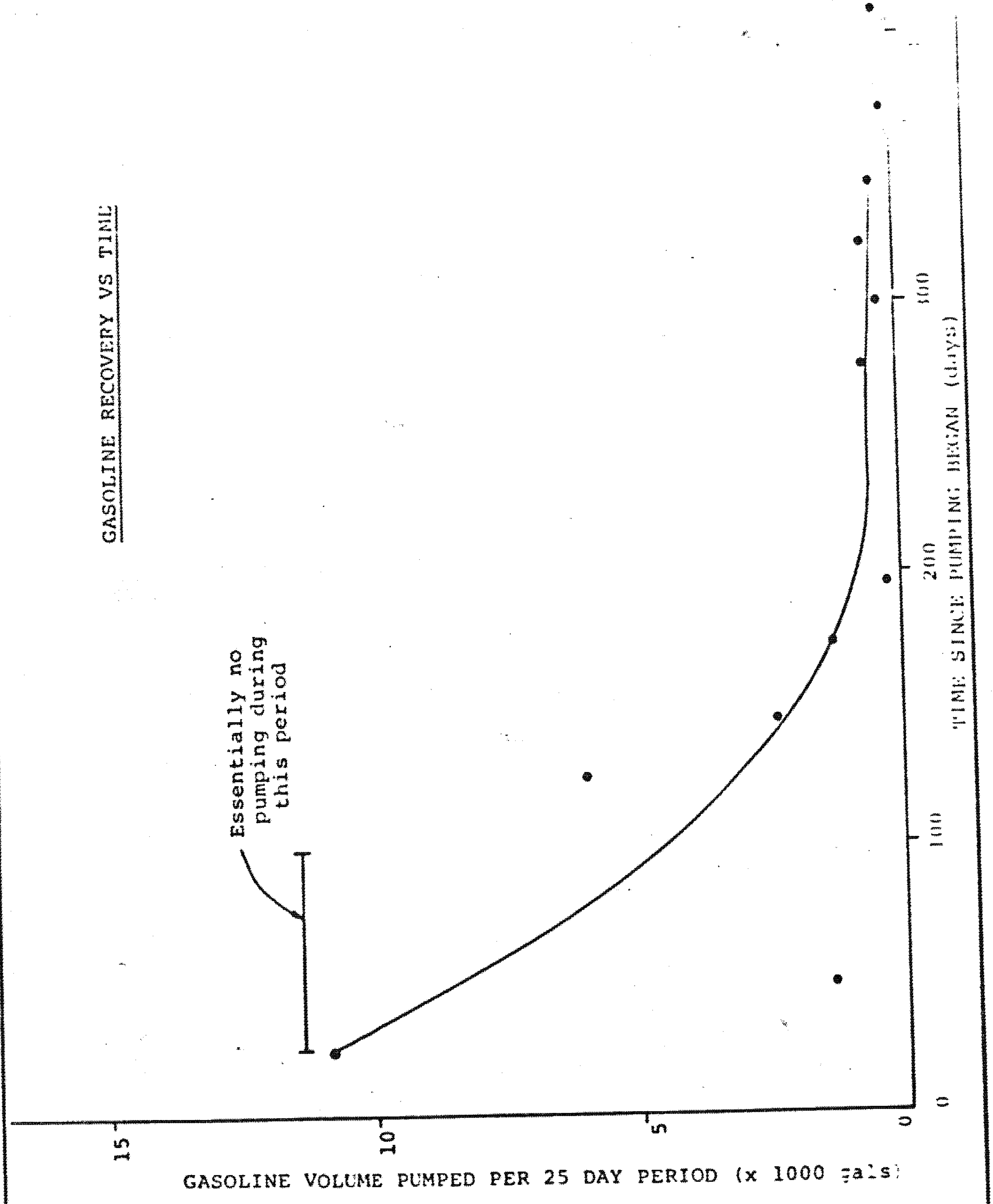
HARDING-LAWSON ASSOCIATES

James T. Cameron by MAA

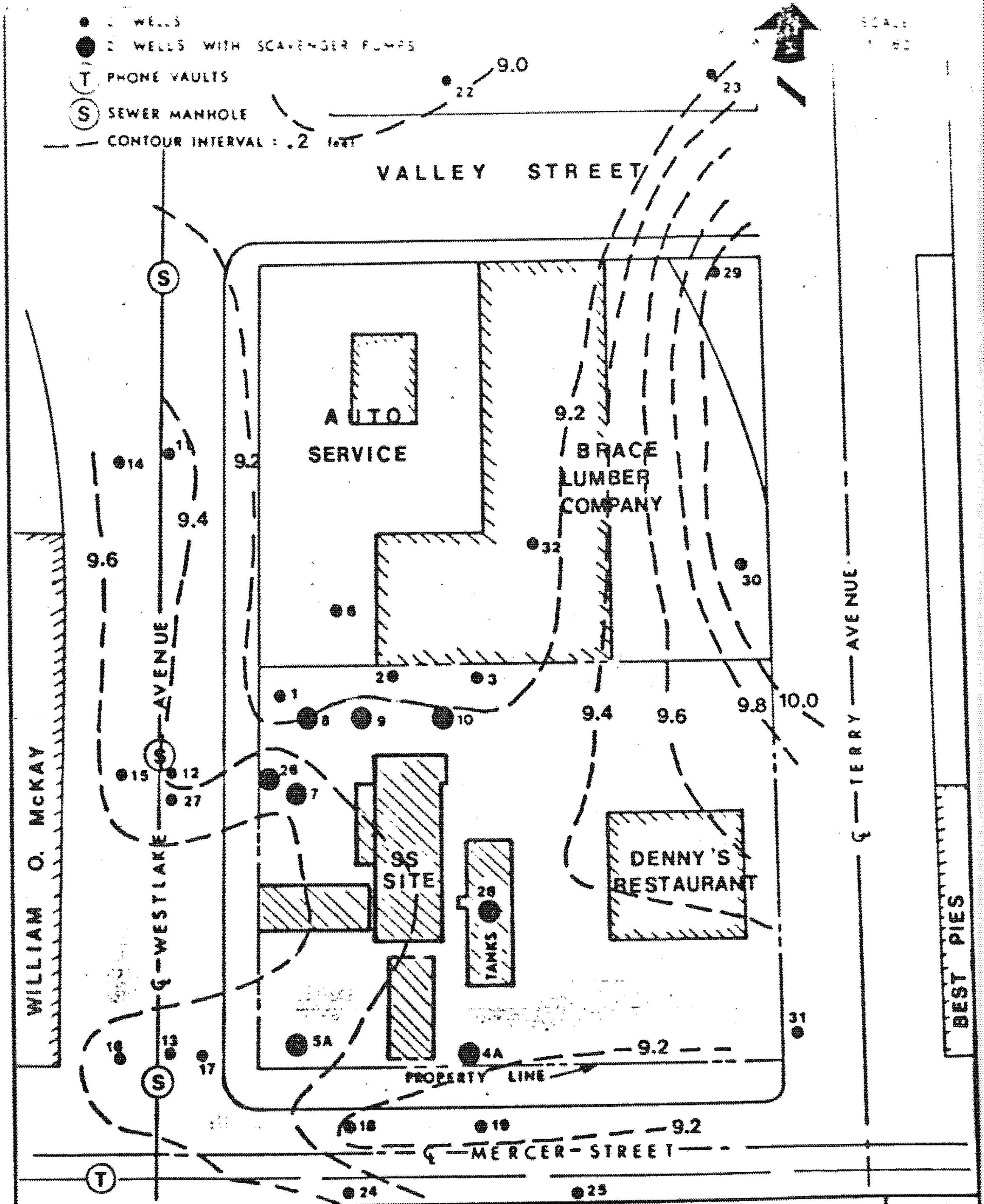
James T. Cameron
Project Manager

JTC/mbd

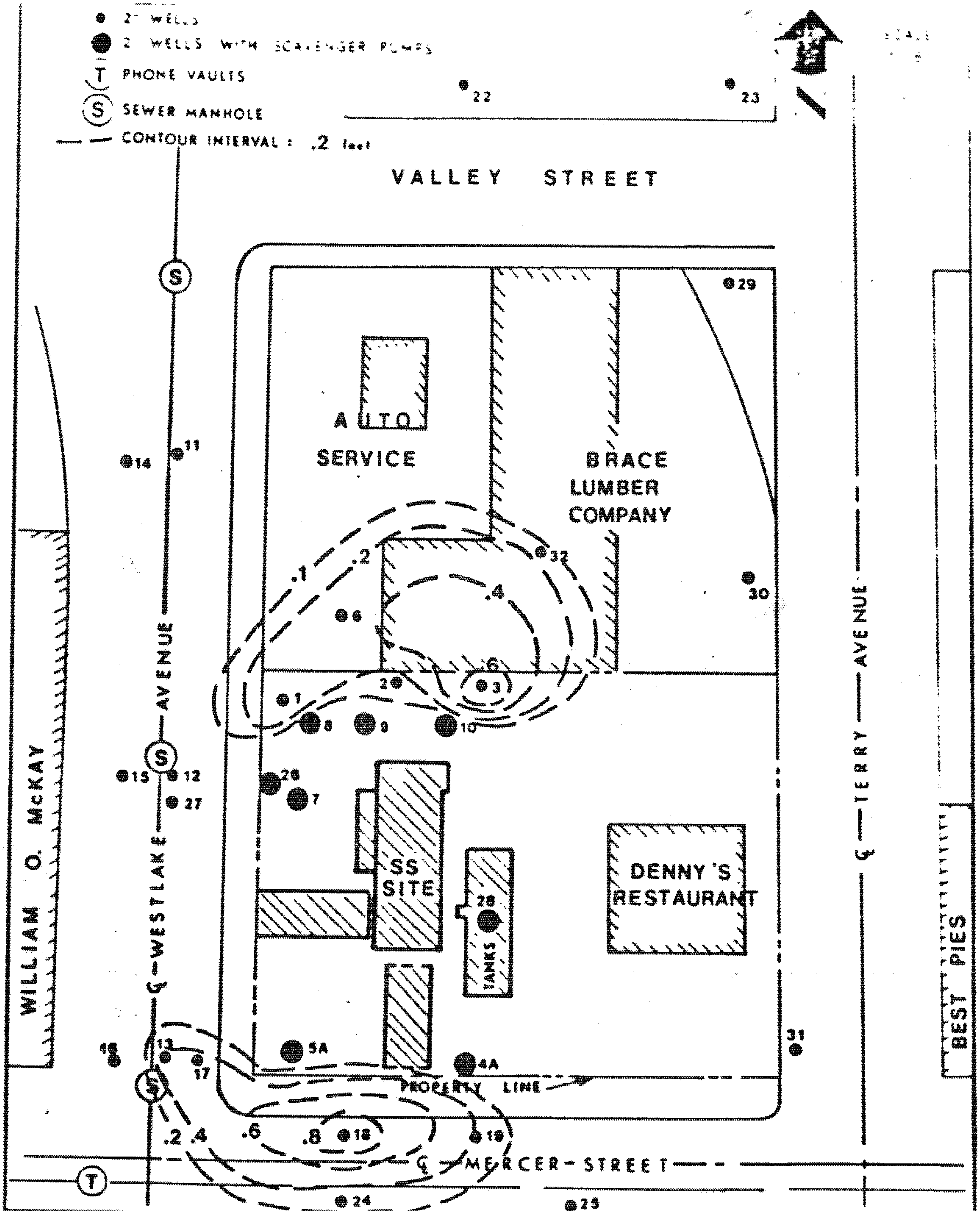
copies to: Jim Miller
Ed Ingham



ROGER LOWE ASSOCIATES A Division of **HARDING-LAWSON ASSOCIATES** *Engineers, Geologists and Geophysicists*	GASOLINE RECOVERY RATE	PLATE
JOB NO 14,197,006.07 APPR MAA DATE 9/21/81	Union Oil Company Seattle, Washington	**1**



ROGER LOWE ASSOCIATES A Division of HARDING-LAWSON ASSOCIATES *Engineers, Geologists and Geophysicists*	PIEZOMETRIC ELEVATIONS 8/28/81	PLATE **2**
JOB NO 14,197,006.07 APPR MAA DATE 9/21/81	Union Oil Company Seattle, Washington	



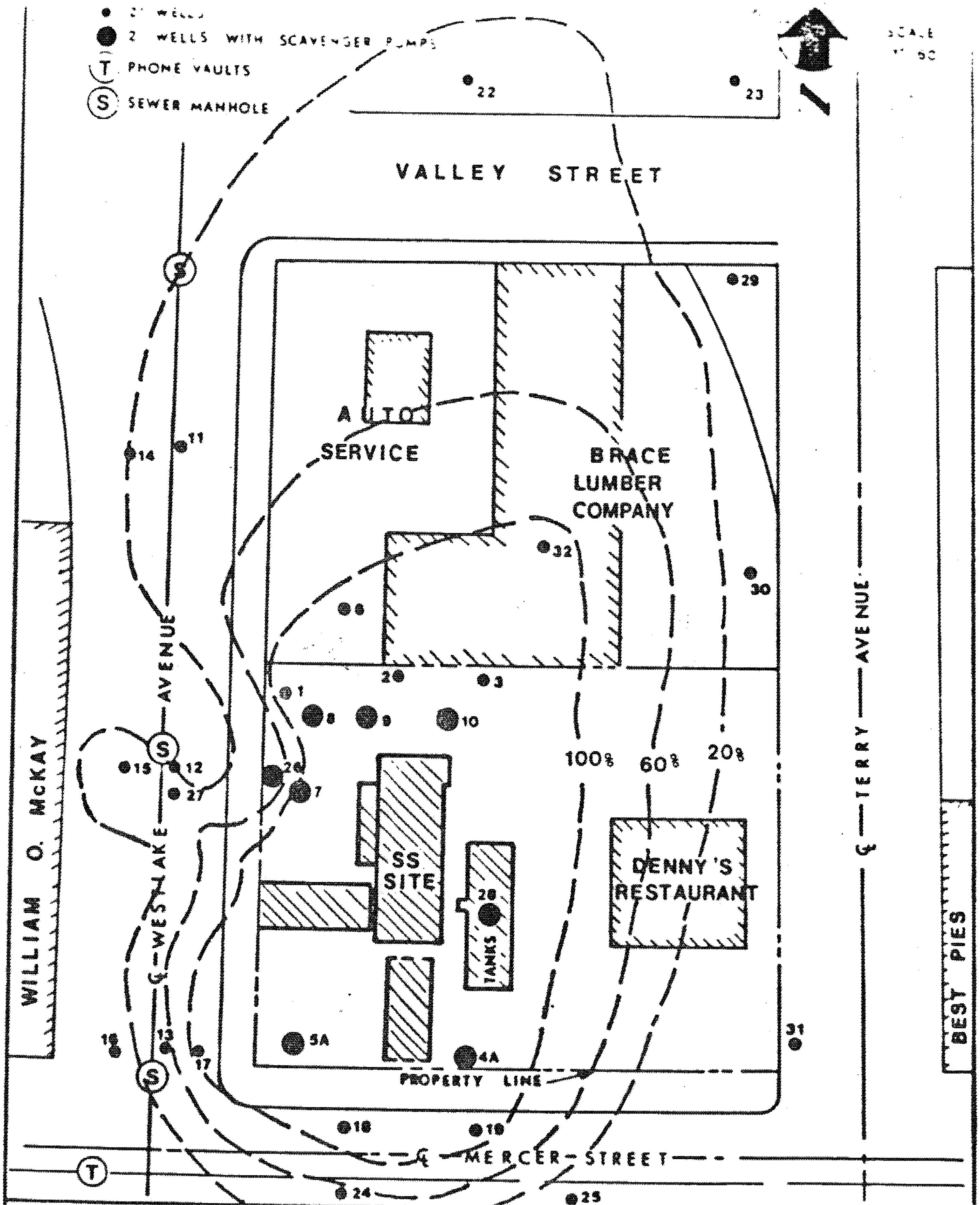
ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

JOB NO 14,197,006.07 APPR HAA DATE 9-01-81

GASOLINE THICKNESSES
8/28/81

Union Oil Company
Seattle, Washington

PLATE
3



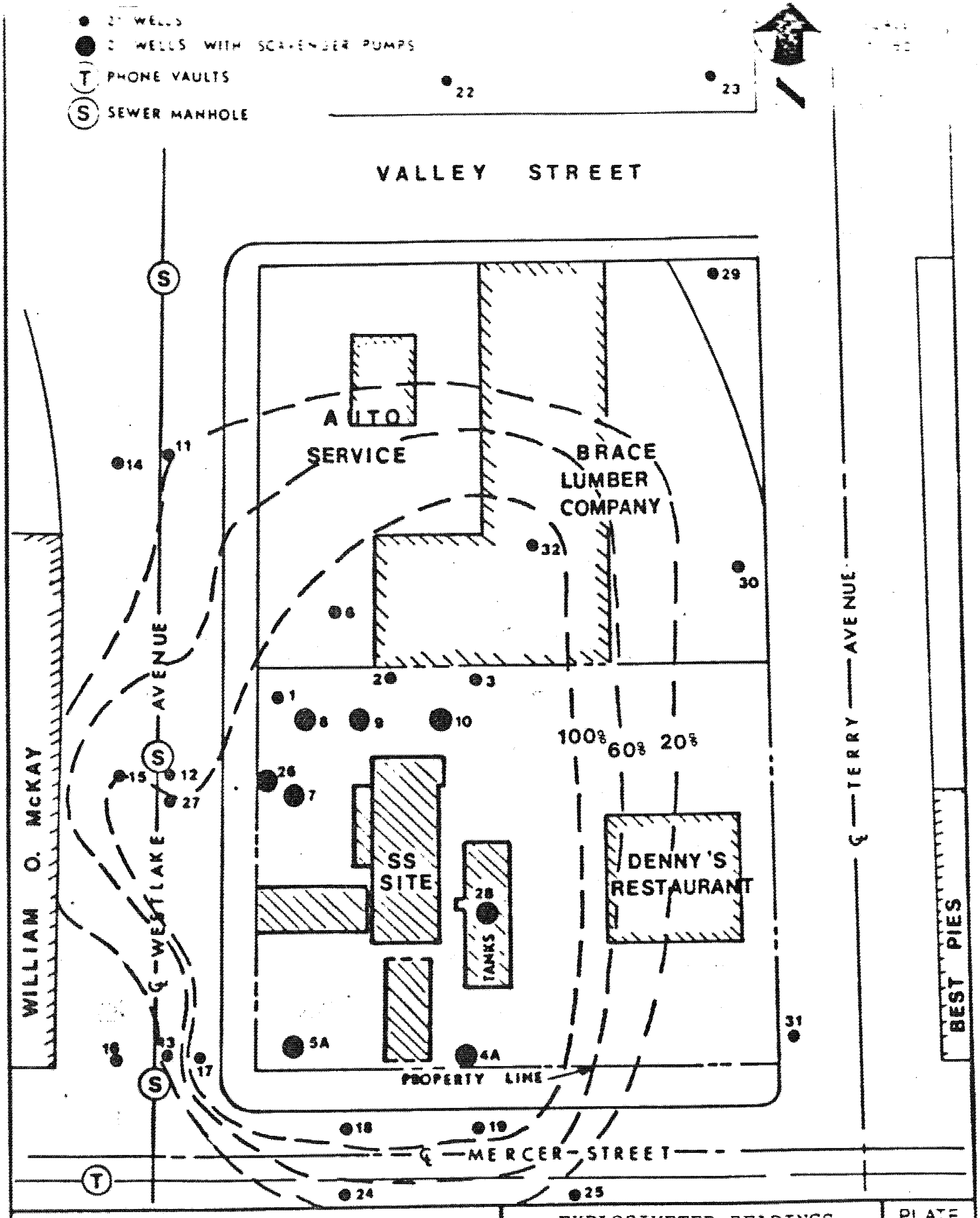
ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

JOB NO 14,197,006.07 APPR MAA DATE 9/21/81

EXPLOSIMETER READINGS
4-FOOT DEPTH 8/28/81

Union Oil Company
Seattle, Washington

PLATE
4



ROGER LOWE ASSOCIATES A Division of HARDING-LAWSON ASSOCIATES *Engineers, Geologists and Geophysicists*	EXPLOSIMETER READINGS 4-FOOT DEPTH 3/8/81	PLATE
JOB NO 14,197,006.07 APPR MAA DATE 9/21/81	Union Oil Company Seattle, Washington	**5**

Harding Lawson Associates

HLA

October 2, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report #21
Monitoring & Recovery Operations
Westlake and Mercer
Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between August 28, 1981 and September 11, 1981. No additional gasoline was recovered during this period. Piezometric elevations reflect a continuing decline in groundwater levels which we believe is related to the lowering of Lake Union and the low precipitation levels through the beginning of September. Gasoline thickness has not changed, other than some shifting of location. Gasoline vapor readings continue to increase, possibly due to warming of the ground or a delayed effect of the lowering groundwater. However, the diminished amounts of gasoline available for migration and the extremely slow rate of apparent migration mitigates any undue concern.

Gasoline Recovery

No gasoline has been removed from the site since July 24, 1981. The total volume of gasoline recovered, therefore, remains at 36,538 gallons.

According to Frank Pinney of Pacific Testing Lab, the skimmer pump located in Brace Lumber Yard was shut off on September 10, 1981 due to electrical problems. The pump is expected to be reactivated as quickly as possible. We also understand that the planned pump relocation from Wells 4 to 5, and from 8 to 10 has not yet occurred.

Piezometric Elevations

Piezometric elevations recorded on September 11, 1981 are shown on Plate 1. Comparison of these elevations with those recorded on August 28, 1981 indicate that there has been an overall lowering of the piezometric surface at the site, and a deeping of the trough beneath the auto service yard and Brace Lumber Company. The drop is particularly noticeable in Well 6, which dropped from Elevation 9.1 to 8.8, in Well 22 which dropped from Elevation 8.9 to 8.8, and in Well 25 which dropped from Elevation 9.3 to 9.1. As an average, the piezometric surface across the site has lowered about .1 to .2 feet. It should be noted that Plate 2 (showing piezometric elevations) in our previous progress report should have shown a "dimple" in the piezometric surface amounting to .2 feet around Well 17 and .8 of a foot around Well 8. Plate 1 in this report shows these two "dimples."

Because of its close proximity, it has been assumed that changes in the level of Lake Union would have a significant effect on piezometric elevations at the site. In fact, it appears likely that only those wells at the extreme north end of the site, including Wells 22, 23, and perhaps 6 and 32, are so influenced. The other wells appear to have been influenced by other factors, which would include precipitation and pumping effects.

Plate 2 shows a plot of piezometric elevation for Wells 22 and 16 against time. Also plotted is the elevation of Lake Union as recorded by the U.S. Army Corp of Engineers. Well 16 was chosen to be plotted because we felt it would be least likely to be influenced by the lake or by pumping activities. At the opposite end of the scale, Well 22 is closest to the lake and, therefore, should be most responsive to changes in lake level. The plot shows a correlation between the lake and Well 22, but not between the lake and Well 16. To evaluate to what degree the water level variation in Well 16 is influenced by rainfall, we are obtaining precipitation data to add to the plot on Plate 2.

Gasoline Thickness

Gasoline thicknesses recorded on September 11, 1981 are presented on Plate 3. As can be seen, fluid gasoline is still concentrated in two zones, one at the north end of the station site and one at the south end. However, there has been a marked shift in gasoline thickness within the northerly zone away from Well 3 and towards Well 8. Since August 28, fluid gasoline in Well 8 has increased from less than .1 feet to .9 feet.

Despite these changes, there has been little overall increase in recorded gasoline thicknesses at the site, since the large increase between June 28 and July 24, 1981 and the subsequent gradual increase until August 21st (gasoline thicknesses have remained approximately constant since August 21st). The only significant change for the period between August 28 and September 11, 1981 has been the appearance of gasoline in Well 28 for the first time since May, 1981 and the occasional presence of gasoline in Well 25. Gasoline was never recorded in this latter well until August 21, 1981. The reason for gasoline in this well is not clear, but is probably related to declining water levels in this area (declining since June) and a reduction in the gradient between Wells 25 and 19. Currently, there is a difference in water levels of only .1 feet between Wells 25 and 19. This could indicate that the depressed area which typically has been centered around Wells 18 and 19 is migrating towards the south.

Explosimeter Readings

Explosimeter readings taken at the 4-foot depth on September 11, 1981 are shown on Plate 4. A comparison of these readings with those on August 28, indicate that there has been a significant increase in the number of wells which show gasoline vapor. The increase has been particularly marked in Wells 23, 29, and 30, which until recently have shown no gasoline vapor.

Expansion of the area in which explosimeter readings of 100% are obtained at a 4-foot depth has also been marked. Currently, all wells on site except Wells 14, 22, 23, and 29 indicate 100% levels.

It is difficult to explain the sudden jump in explosimeter readings considering that there has been no apparent migration of the measurable liquid gasoline and that some of the wells showing gasoline vapor for the first time are up-gradient of the liquid gasoline zones. Two possible explanations for the marked increase are: 1) an increase in vapor pressure due to warming of the ground in the unusally warm months of July and August, and 2) a delayed effect of lowering groundwater levels and the related increase in gasoline thickness.

Wells 22 and 23 are located down-gradient from the Brace Lumber gasoline zone and directly in line with its hypothetical flow path. Considering that vapor has been detected in Well 22 since July 17 and that the most recent readings have been increased, we believe that contaminated groundwater may have moved close enough to the wells (22 and 23) to produce measurable gasoline vapor.

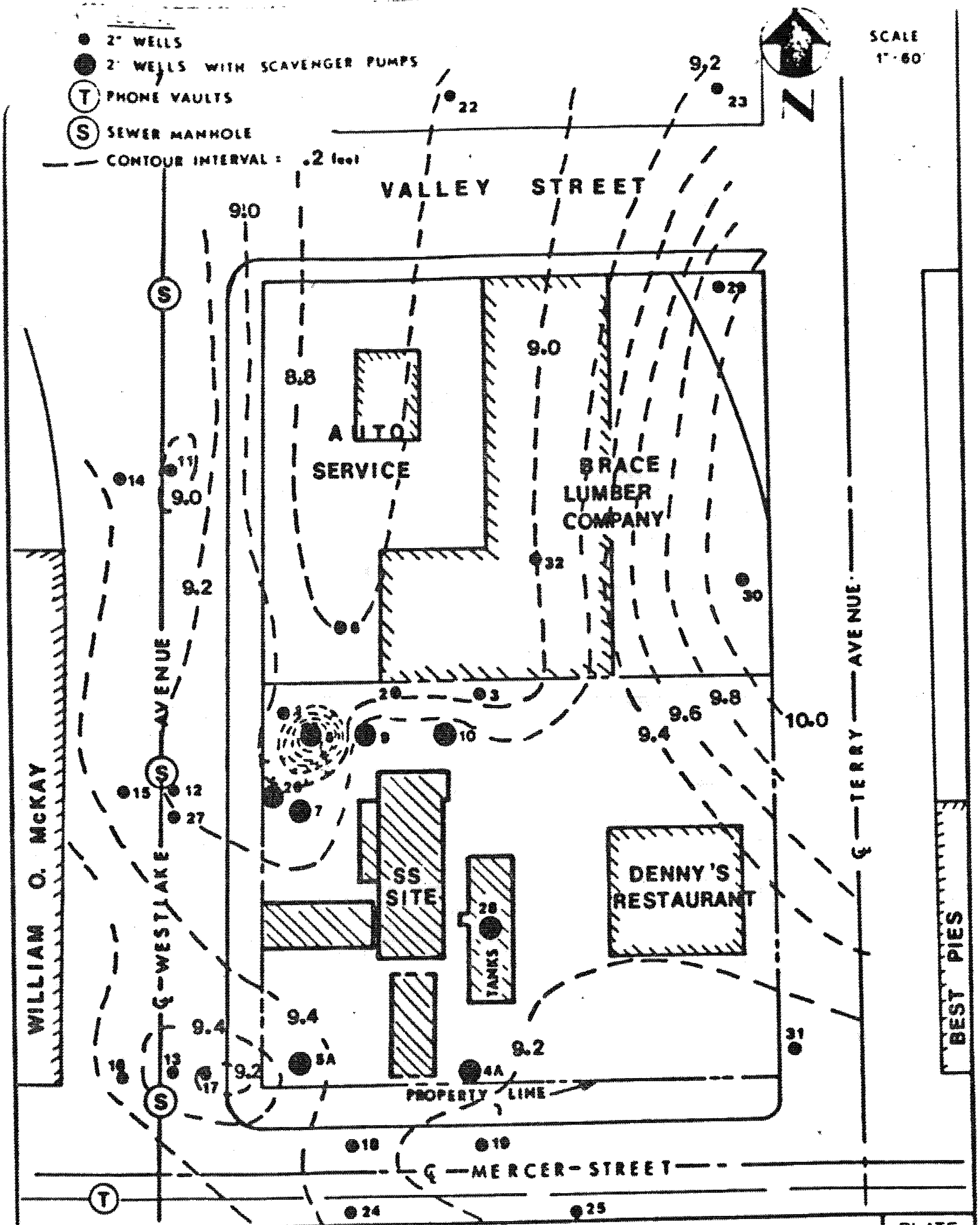
Yours very truly,

HARDING LAWSON ASSOCIATES

James T. Cameron
Project Manager

MAA/JTC/mbd

cc: Jim Miller
Ed Ingham



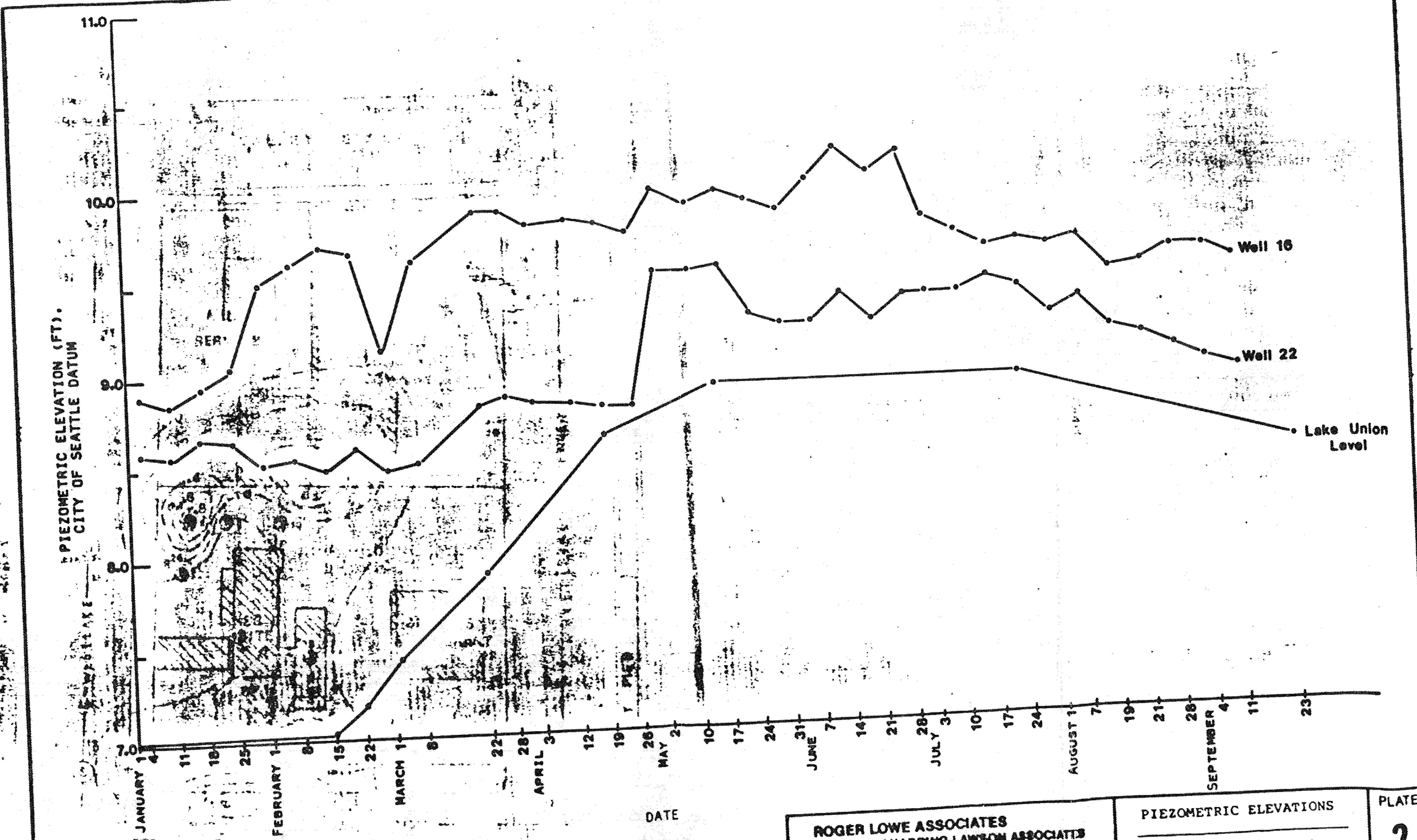
ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

JOB NO 14,197,006.07 APPR MAA DATE 9/23/81

PIEZOMETRIC ELEVATIONS
9/11/81

Union Oil Company
Seattle, Washington

PLATE
1

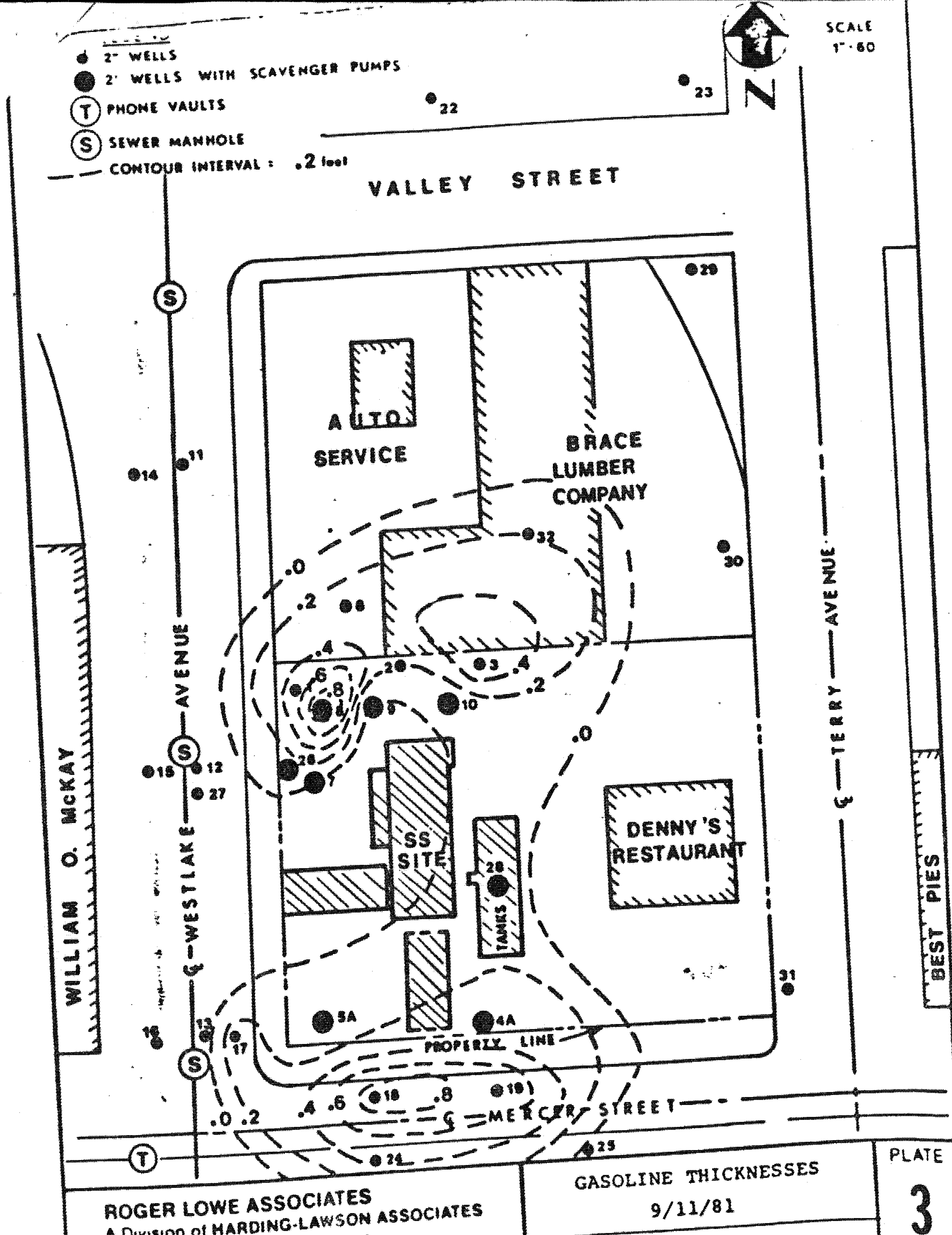


ROGER LOWE ASSOCIATES
A Division of HARDING-LAWSON ASSOCIATES
Engineers, Geologists and Geophysicists

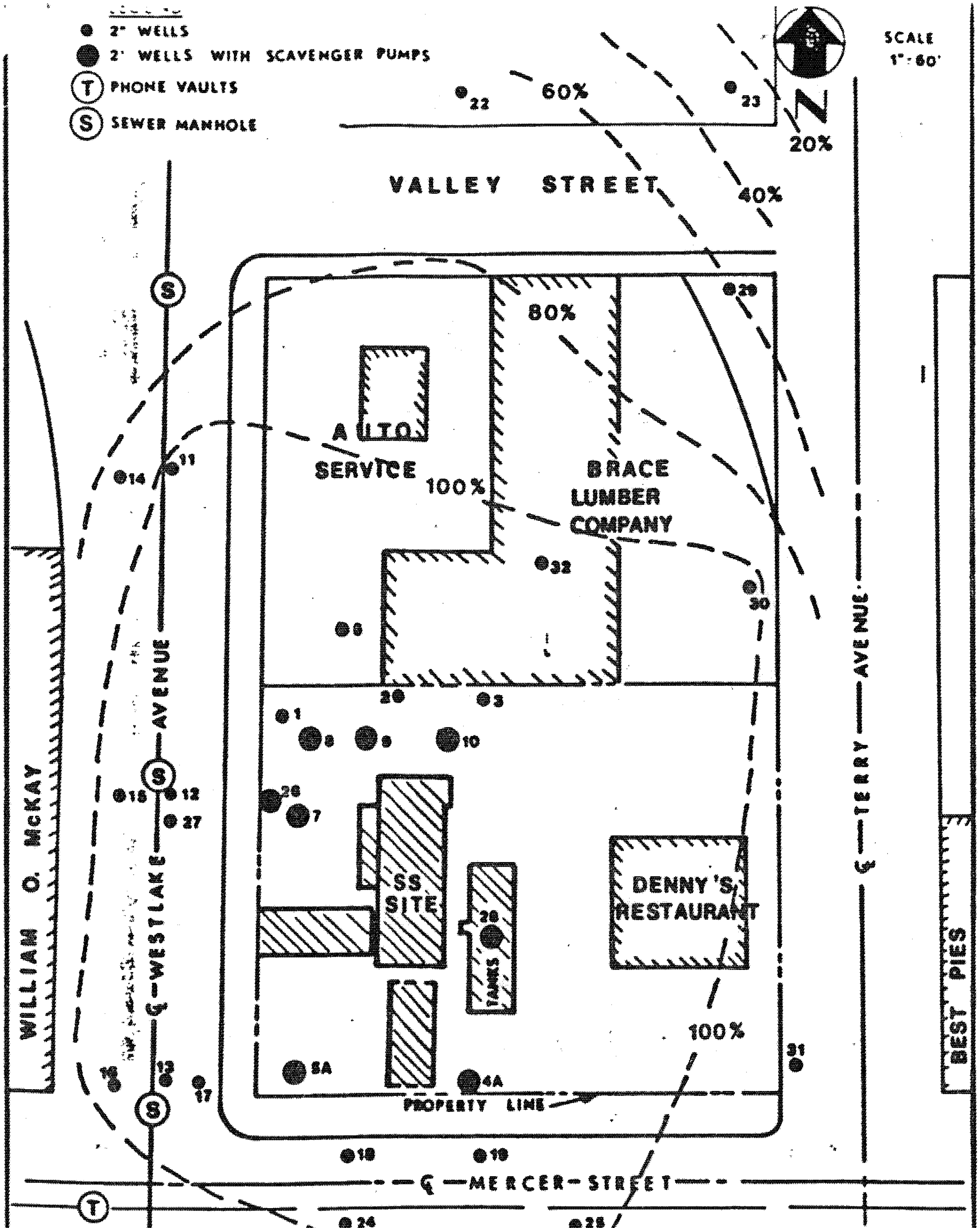
PIEZOMETRIC ELEVATIONS

Union Oil Company
Seattle, Washington

PLATE
2



ROGER LOWE ASSOCIATES A Division of HARDING-LAWSON ASSOCIATES *Engineers, Geologists and Geophysicists*	GASOLINE THICKNESSES 9/11/81	PLATE 3
JOB NO 14.197.006.07 APPR MAA DATE 9/23/81	Union Oil Company Seattle, Washington	



ROGER LOWE ASSOCIATES
A Division of **HARDING-LAWSON ASSOCIATES**
Engineers, Geologists and Geophysicists

JOB NO 14,197,006.07 APPR MAA DATE 9/23/81

EXPLOSIMETER READINGS
4-FOOT DEPTH 9/23/81

Union Oil Company
Seattle, Washington

PLATE
4

Harding Lawson Associates

HLA

October 16, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report #22
Monitoring & Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between September 11, 1981 and September 25, 1981.

Gasoline Recovery

On September 21, 118 gallons of gasoline were pumped from the Brace Lumber Yard tank, and on September 25, 448 gallons were pumped from the main holding tank. Of the 448 gallons, 347 were recovered between July 24th and September 2nd, and the remaining 101 were recovered between September 1st and September 25th. The total volume of gasoline recovered is currently 37,058 gallons.

The most recent gasoline recovery is slightly less than previous recoveries when considered on a monthly basis, indicating that the decline in the rate of recovery is continuing. Plate 1, a plot of total gasoline recovered against the log of the number of days since pumping began, shows this trend. The recovery data also indicates that there has been a departure from the original linear recovery trend. Previous data points were not sufficient to show the departure, but the new data shows a flattening in the slope of the plot after day 250 (February 22, 1981) indicating less gasoline recovery than would be predicted by well theory. The reason for this is not known but is probably related to modifications of the gasoline reservoir by several factors including lateral and vertical variation in soil conditions and fluctuations in groundwater levels.

According to Frank Pinney of Pacific Testing Laboratory, the depressant pump in Well 8 was relocated to Well 10 and activated on September 23, 1981. The other planned pump relocation from Well 4 to Well 5 has not occurred as of September 25th.

Piezometric Elevations

Piezometric elevations recorded on September 25, 1981 are shown on Plate 2. Comparison of these elevations with those recorded on September 11th indicate that there has been a continued lowering of the piezometric surface. With the exception of Wells 5, 11, 19, 22, and 32, a majority of the wells showed drops of between .05 and .2 feet, with a maximum decline of .43 feet recorded in Well 8. Other wells showing substantial declines include Wells 3 and 4 of .24 and .33 feet, respectively.

The shape of the piezometric surface has been changed slightly toward a more east-west trending trough beneath the Brace Lumber Yard. This shift was brought about principally by an abrupt 5- to 6-inch rise in the piezometric level in Wells 11 and 22. Considering that the water level in Well 22 was about 6 inches lower until just prior to September 25th, we believe the higher elevation may be erroneous and suspect that the trough actually still trends through Well 22 as it did on September 11th. The rebound in Well 11, however, is probably accurate since its piezometric level is now near previous levels.

With the exception of the trough reorientation, most areas of the piezometric surface have retained essentially the same shape. In particular, there are still depressions in the piezometric surface along Mercer Street and near Well 8.

We obtained precipitation data for the area to help evaluate the effect of rainfall on groundwater levels. The data is plotted on Plate 3, along with the elevation of Lake Union and the piezometric elevations in Wells 16 and 22. As can be seen, there is no clear correlation between rainfall levels and groundwater elevations in Wells 16 and 22. Normally, groundwater reaches its highest level some time after the yearly precipitation peak. Although there is a clear peak in groundwater levels after the period of maximum rainfall, it is not possible to correlate the peak exclusively with rainfall because of possible effects from changes in the level of Lake Union.

We believe that the continued decline in water levels at the site are related to the lowering of Lake Union and to low precipitation levels through the beginning of September.

Gasoline Thickness

Gasoline thickness recorded on September 25, 1981 are presented on Plate 4. The two zones of fluid gasoline present at the southern and northern sides of the Union Station have changed very little since September 11th except for a slight shift back to the east. As noted in our previous report, the gasoline concentrations appeared to move westward between August 28th and September 11th.

The shift is marked in the northerly concentration by a decrease in gasoline thickness of .6 feet in Well 8 and an increase of .2 and .1 feet in Wells 3 and 10 respectively. Similarly, for the southerly concentration, there has been a decrease of .09 and .29 feet in Wells 17 and 18, respectively, and an increase of .41 feet and .08 feet in Wells 4 and 19, respectively. The shift on the north side of the station may be related to the transferral of the drawdown pump from Well 8 to Well 10. The reason for a corresponding shift at the south end of the site is not known.

In addition to these changes, there appears to be a slight decrease in the area encompassed by gasoline thicknesses in excess of .2 feet.

Explosimeter Readings

Explosimeter readings at the 4- and 8-foot depth were essentially the same on September 25, 1981 as they were on September 11,

1981. The only exceptions are a decrease in Wells 11, 14, 22, and 30 at the 4-foot depth and a slight increase in Well 29 at the 4-foot depth.

Yours very truly,

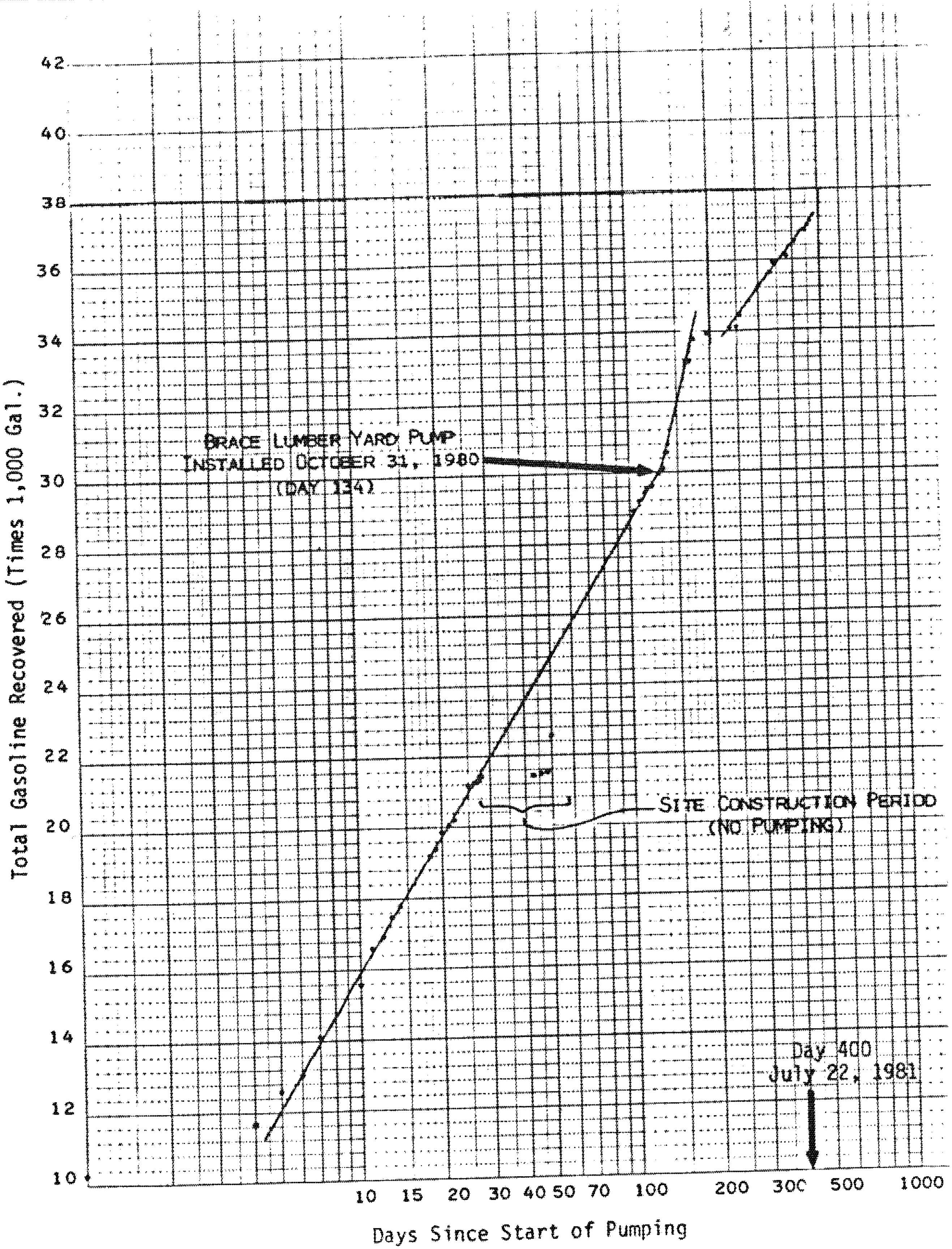
HARDING LAWSON ASSOCIATES

James T Cameron
BY MAA

James T. Cameron
Project Manager

MAA/JTC/mbd

cc: Jim Miller
Ed Ingham



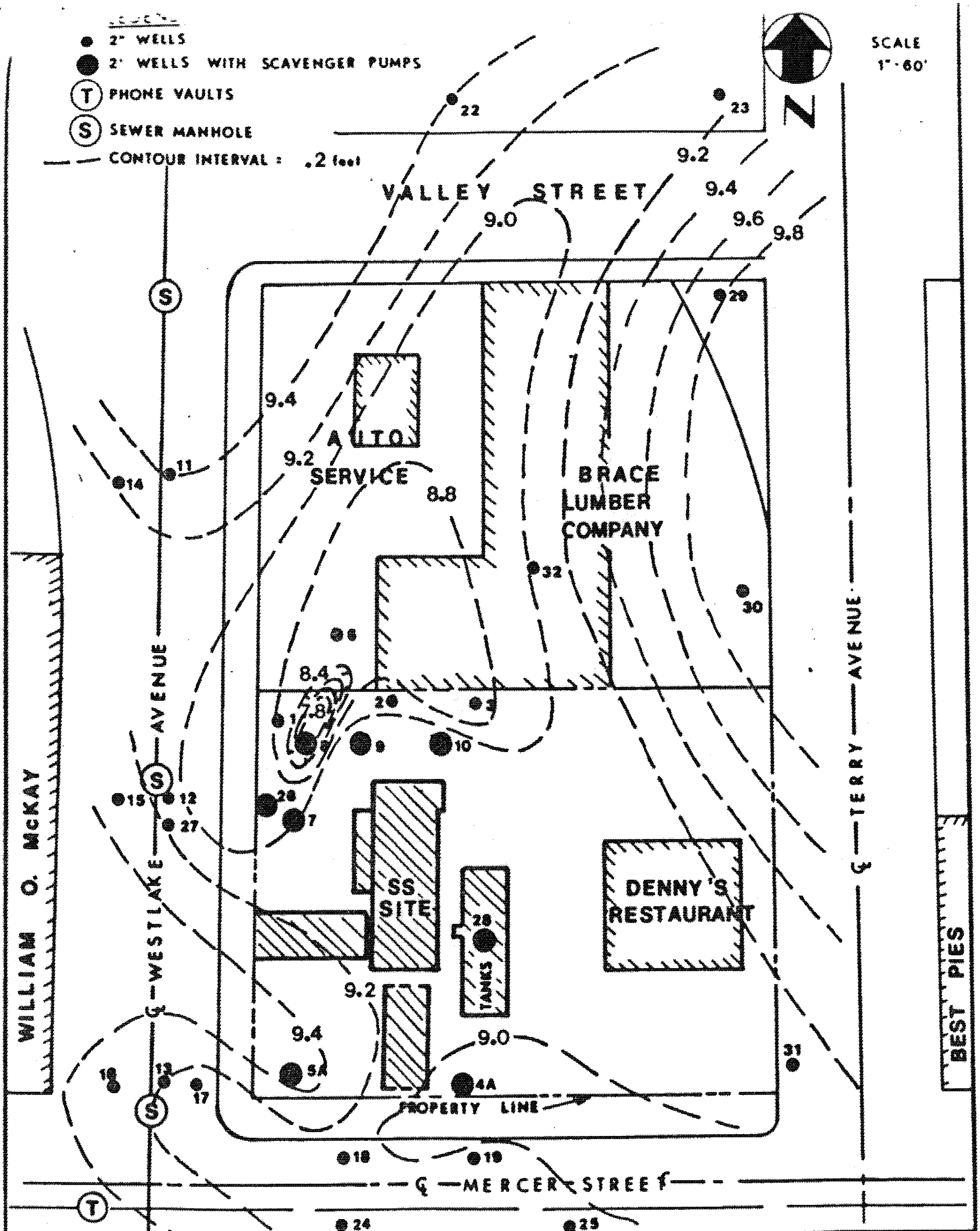
Note: Start of Pumping on June 19, 1980

Harding Lawson Associates
Engineers Geologists
& Geophysicists

Total Gasoline Recovery
Union Oil Company
Seattle, Washington

PLATE **1**

BT	14,197,006.07	MKP	10-16-81	REVISED	DATE

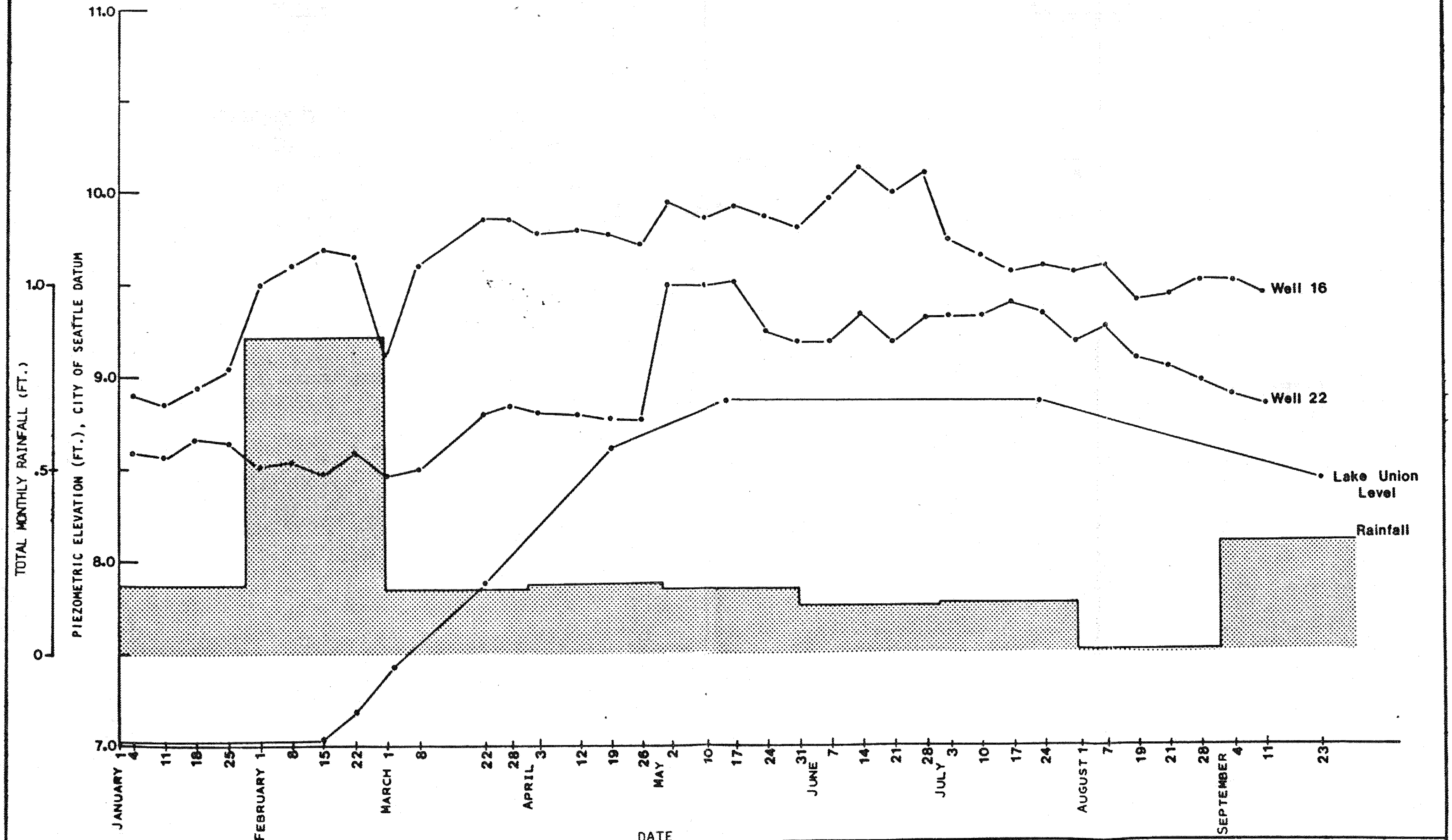


Harding Lawson Associates
Engineers Geologists
& Geophysicists

Piezometric Elevations 9/25/81
Union Oil Company
Seattle, Washington

PLATE
2

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BT	14,197,006.07	MAA	10/16/81		

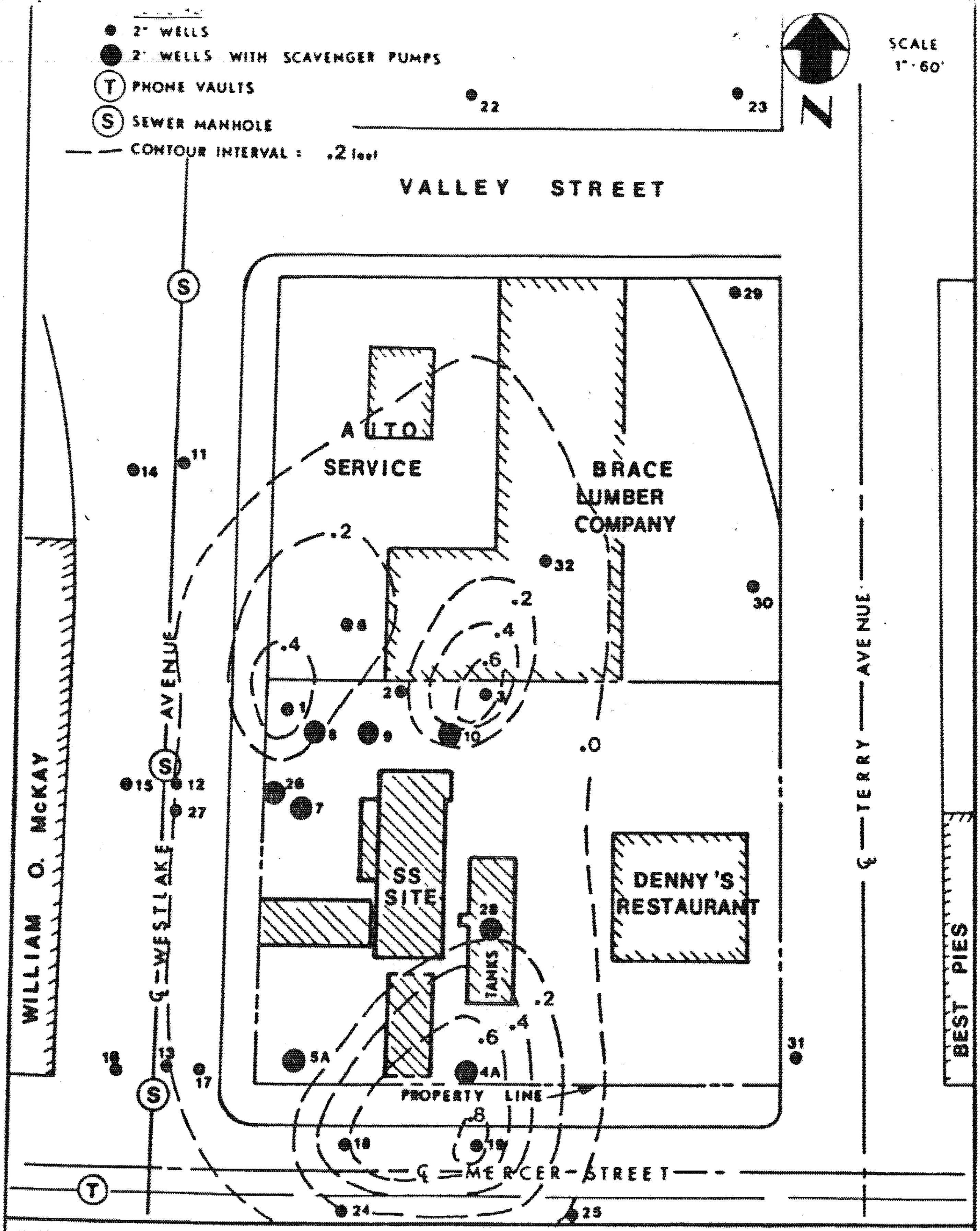


Harding Lawson Associates
Engineers, Geologists & Geophysicists

Piezometric Elevations
Union Oil Company
Seattle, Washington

PLATE **3**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BT	14,197,006.07	MAH	10-16-81		



Harding Lawson Associates
Engineers, Geologists & Geophysicists

Gasoline Thickness 9/25/81
Union Oil Company
Seattle, Washington

PLATE **4**

BT	14,197,006.07	MAA	10/16/81		

November 3, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 23
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between September 25 and October 16, 1981.

GASOLINE RECOVERY

Gasoline recovery increased markedly at the site between September 25 and October 16 in conjunction with a period of intense rainfall. In addition, a pronounced upward and downward movement of the groundwater table occurred. Because of the rise in groundwater levels, the main holding tank filled much faster than usual requiring repeated pumping. On several occasions no gasoline was recovered when the tank was pumped. Pumpings on October 5, 7, 9, 14, and 16 however, recovered 22, 41, 21, 41, and 555.5 gallons of gasoline, respectively. The total volume of gasoline recovered is currently 37,739 gallons.

According to Frank Pinney of Pacific Testing Laboratory the depressant pump in Well 4A was relocated to 5A and activated on October 7.

PIEZOMETRIC ELEVATIONS

During the three week period between September 25 and October 16, there was a dramatic fluctuation in piezometric elevations at the site. During the first week, groundwater levels rose between .03 and .40 feet in most wells except Wells 5, 7, 10, 18, and 22. In these wells, a drop of between .08 and .20 feet was recorded. Wells on the periphery of the site, including Wells 14, 15, 16, and 25, recorded the greatest rise in water levels, while those near the middle of the site (around the gas station) indicated only small rises. This pattern was reversed in the second week when interior wells recorded larger gains than peripheral wells. For example, in the first week, the piezometric levels rose .34 feet and .12 feet in Wells 15 and 26, respectively. In the second week, Well 15 continued to rise an additional .25 feet, but the groundwater level in Well 26 rose an even greater .46 feet. Overall, groundwater elevations across the site rose substantially during the second week.

A pronounced reversal in the trend occurred in the third week with almost all the wells showing decreases of between .15 and .55 feet.

For the entire three-week period, a comparison of piezometric levels on October 16 (see Plate 1) with those on September 16 indicate little overall change near the middle of the site but increases in piezometric elevation of .32 to .40 feet along the western and southern edges of the gasoline station block. Groundwater levels in Wells 22 and 23 at the north end of the site had a net drop of .94 and .06 feet, respectively, during this same period.

The rapid rise and fall of piezometric levels recorded during the three weeks correlates with unusually heavy rainfall through October 6 and appears to reflect the passage of a groundwater "wave" across the site. The "wave" was first noted in peripheral wells and subsequently in interior wells suggesting that its movement was to the north or northeast from the south and west. After the "wave" passed, groundwater levels around the site remained higher than previous levels while those near the middle of the site returned to about their previous levels. There are a few exceptions, including Well 3 (up .39 feet), Well 4 (up .34 feet), and Well 18 (up .46 feet).

The shape of the piezometric surface is still very similar to that on September 25 except that the trough beneath

Brace Lumber Yard has shifted westward back toward Well 22 as expected (and as discussed in the last progress report).

We were advised that all depth-to-water measurements prior to October 2, 1981, are in error by 4 inches. The true depths to water can be obtained by adding 4 inches to the recorded depths.

No ∴ 4 in rise in all wells after Oct 2 due to measurement only

GASOLINE THICKNESSES

Gasoline thicknesses recorded on October 16, 1981, are shown on Plate 2. As can be seen, the distribution of liquid gasoline has not changed significantly since September 25 except for a stronger bifurcation of the gasoline concentration at the north end of the gasoline station. However, amongst those wells not influenced by skimmer or depressant pumps, and which traditionally contain some fluid gasoline, three indicated marked increases in gasoline thicknesses, two indicated decreased thicknesses, and one remained the same. The three wells measuring substantial increases, Wells 1, 2, and 6, are adjacent to one another, suggesting that some mechanism has concentrated gasoline in that area. The gasoline thickness also increased substantially in Well 10 probably as a result of the recent installation of a depressant pump. Similarily, the .45 feet decrease in gasoline thickness in Well 18 is probably related to the installation of a depressant pump in the nearby Well 5A. Elsewhere at the site, gasoline thicknesses remained about the same as that on September 25 although the thicknesses fluctuated excessively during the three week period ending October 16.

The fluctuations in gasoline thickness and the recent increase in gasoline thickness in Wells 1, 2, and 6 are difficult to explain. Although they are probably related in part to perturbations in the groundwater table and effects of changes in pump rate and position, the overall impression of a thickening in the layer of gasoline available for recovery seems to suggest addition from a new source. Such an addition, whether by flushing from a hitherto untapped gasoline concentration or leakage from a new source, should be reflected by an increase in the rate of gasoline recovery. There was in fact, more gasoline pumped during this period than usual, but only after repeated changes in pump positioning. So, the evidence is inconclusive at this time.

EXPLOSIMETER READINGS

Explosimeter readings at the 8-foot depth were essentially the same on October 16 as on September 25, 1981, except for a decrease from 70% to 40% in Well 22 and from 100% to 55% in Well 25. At the 4-foot depth, explosimeter readings were also the same except for decreases in Wells 13, 16, 22, 25, and 29. A slight increase was also registered in Well 11. The majority of explosimeter readings at both the 4-foot and 8-foot depths are at or near 100%.

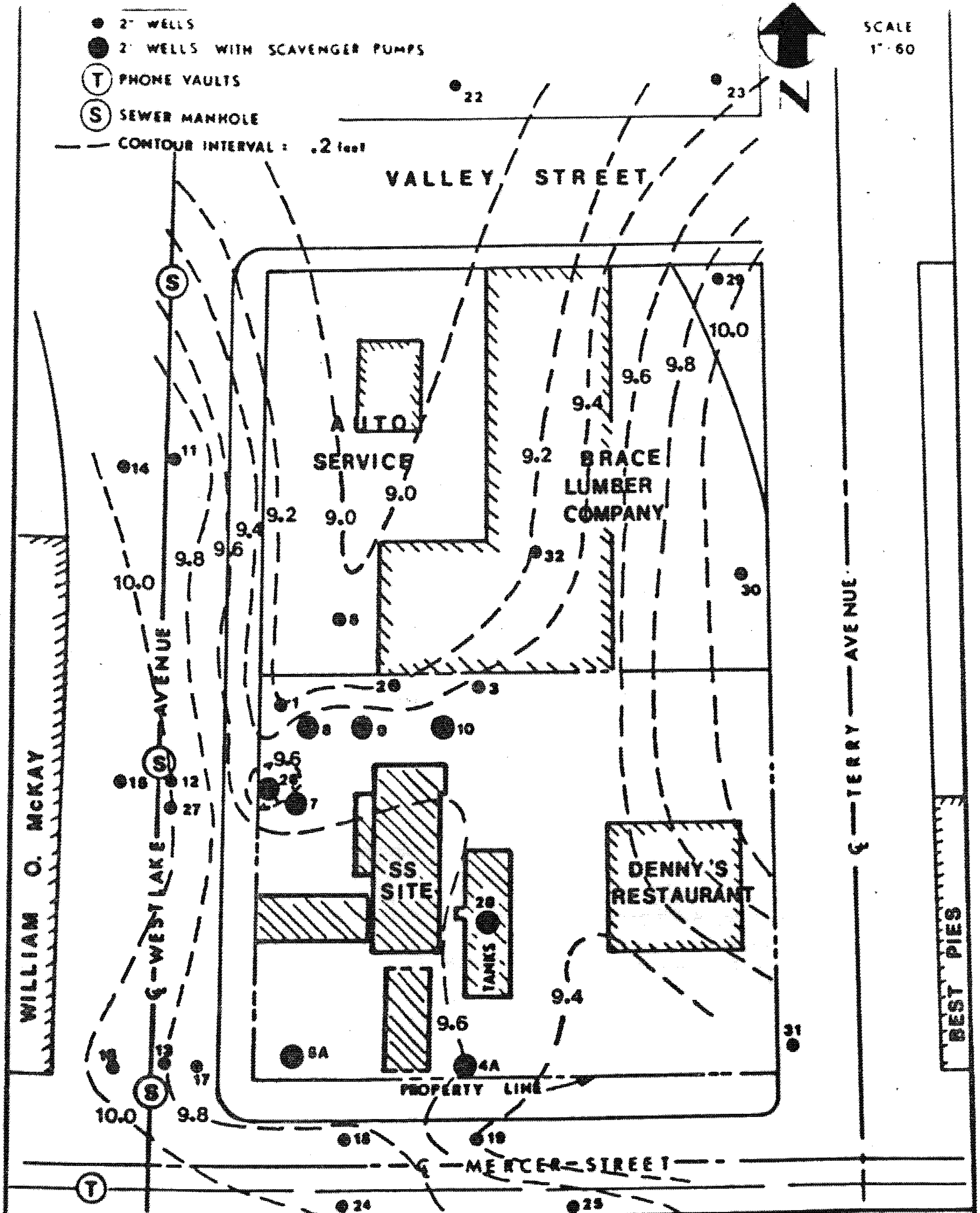
Yours very truly,

HARDING LAWSON ASSOCIATES

James T. Cameron
BY MAA

James T. Cameron
Project Manager

MAA/JTC/cag

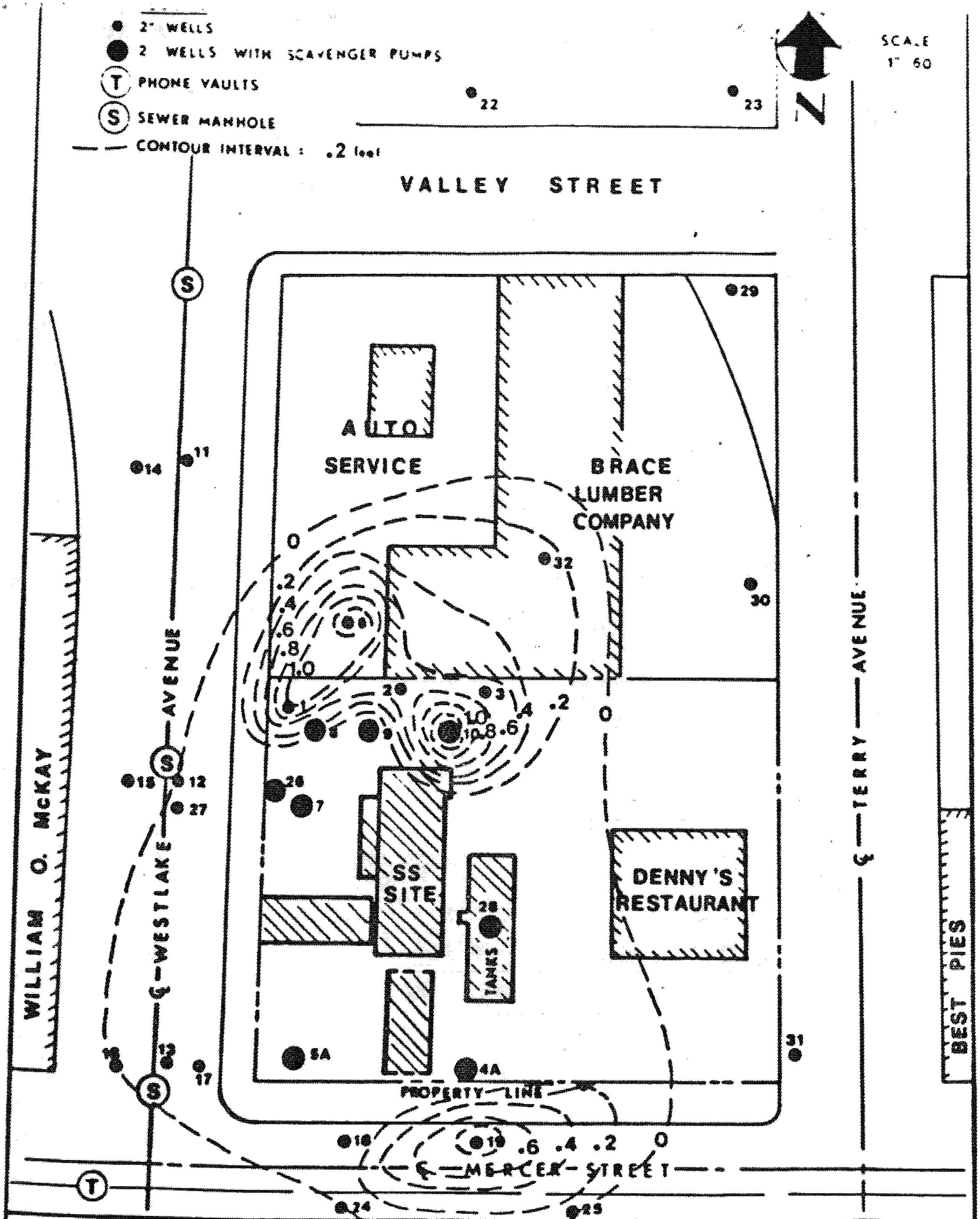


Harding Lawson Associates
Engineers Geologists
& Geophysicists

PIEZOMETRIC ELEVATIONS 10/16/81
UNION OIL COMPANY
SEATTLE, WASHINGTON

PLATE
1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BT	14,197,006.07				



Harding Lawson Associates
Engineers Geologists & Geophysicists

GASOLINE THICKNESSES 10/16/81
UNION OIL COMPANY
SEATTLE, WASHINGTON

PLATE
2

BT 14,197,006.07

/MAA

Harding Lawson Associates

November 13, 1981

14,197,006.07

Union Oil of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 24
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between October 17 and October 28, 1981.

GASOLINE RECOVERY

The recent increased rate of gasoline recovery noted from September 25 to October 16, 1981, continued, with an additional 734 gallons of gasoline being pumped from the main holding tank between October 17 and October 28. The total volume of gasoline recovered to date is 38,473 gallons.

The Brace Lumber yard sump pump, which has not been operating since September 17, was reactivated on October 28.

PIEZOMETRIC ELEVATIONS

Piezometric levels across the site continued to decline in the aftermath of the recent storm and groundwater "wave". All wells, except Well 12, recorded piezometric declines of between .08 and 1.89 feet, with the majority between .15 and .77 feet. The largest decline (1.89 feet in Well 8) appears to be a temporary aberration since groundwater levels were approximately 1.25 feet higher in measurements taken 2 to 5 days prior and since there is no longer a drawdown pump in Well 8.

Although there currently is not a well defined drawdown cone associated with the drawdown pumps in Wells 5A and 10, the gasoline station site as a whole is depressed relative to peripheral areas. This is marked by pronounced piezometric slopes towards the site from both the west along Westlake Avenue and from the east along Terry Avenue. Overall, there is a flat-bottomed valley-like configuration to the piezometric surface in the gasoline station area. Northward, the "valley" narrows and assumes a more trough-like appearance as it drops towards Lake Union.

GASOLINE THICKNESSES

Gasoline thicknesses recorded on October 28, 1981, are shown on Plate 2. As can be seen, the concentration pattern of liquid gasoline has not changed significantly since October 16 and is about the same as it has been for the last six months. In the northerly gasoline concentration (beneath Brace Lumber yard), most wells indicated either no change in gasoline thickness or a net reduction of between .37 and .50 feet. In particular, the three wells which showed substantial increases between October 16 and September 25 - Wells 1, 2, and 6 - all decreased in recorded gasoline thickness.

Two wells at the site did, however, show substantial increases in the gasoline thicknesses. These are Wells 18 and 19 which showed increases of .38 and 1.02 feet, respectively. The dramatic increase in Well 19 is difficult to explain but may be due to a delayed reaction to the recent groundwater "wave". If this is so, then the gasoline thickness in this well should decline in the next few weeks.

EXPLOSIMETER READINGS

Explosimeter readings at both the 8-foot and the 4-foot depth remained about the same in most wells on site. The majority of readings are currently at or near 100%.

Yours very truly,

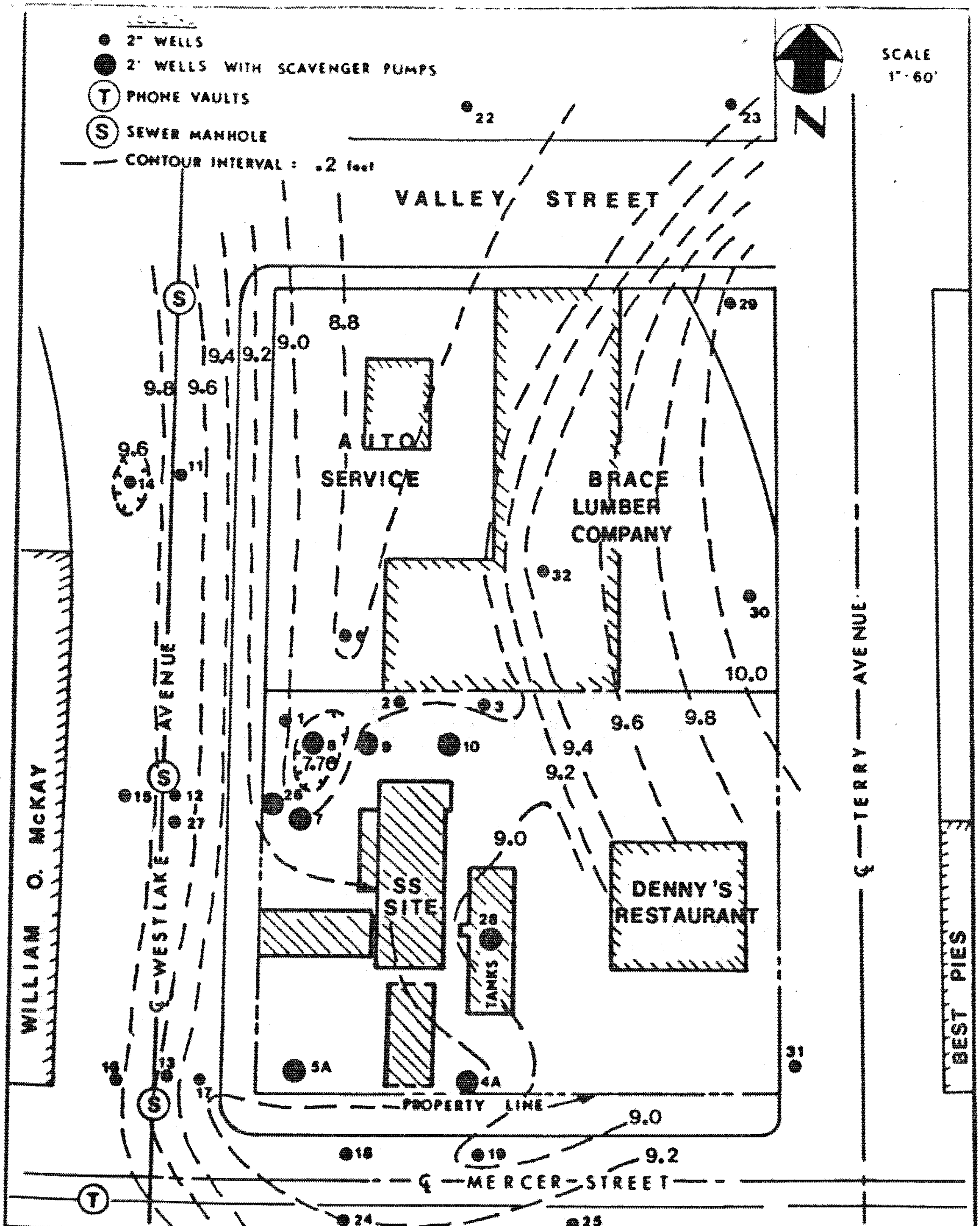
HARDING LAWSON ASSOCIATES

James T. Cameron
BY MAA

James T. Cameron
Project Manager

MAA/JTC/cag

Attachment

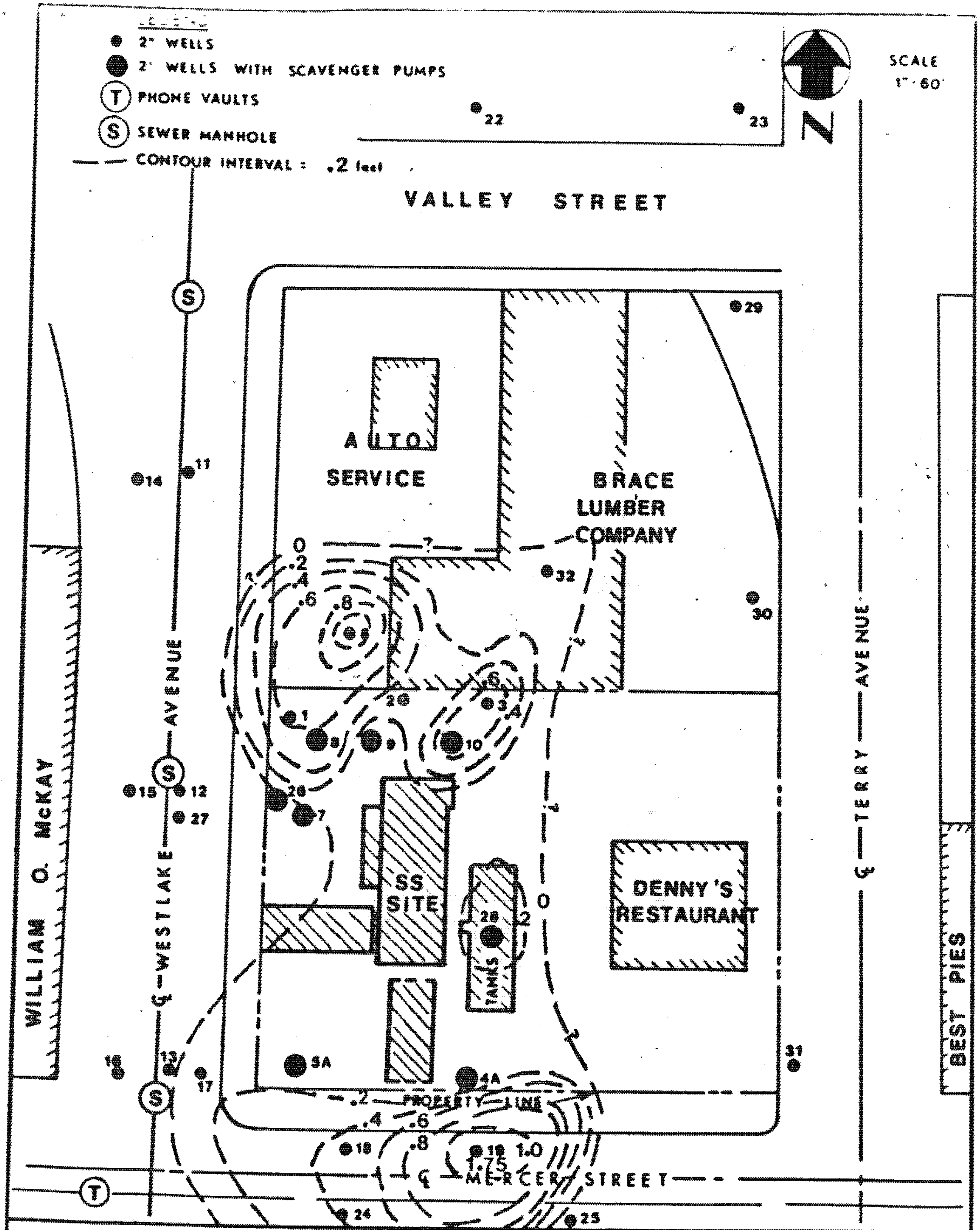


Harding Lawson Associates
Engineers Geologists
& Geophysicists

PIEZOMETRIC ELEVATIONS 10/28/81
Union Oil Company
Seattle, Washington

PLATE
1

BJT	14,197.006.07	MAA	11/13/81	REVISED	DATE



Harding Lawson Associates
Engineers, Geologists & Geophysicists

GASOLINE THICKNESS 10/28/81
Union Oil Company
Seattle, Washington

PLATE **2**

BJT | 14,197,006.07 | MAA | 11/13/81

December 4, 1981

14,197,006.07

Union Oil of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 25
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between October 29 and November 6, 1981.

GASOLINE RECOVERY

The rate of gasoline recovery has declined markedly since the last monitoring period. Between October 29 and November 6, 154 additional gallons of gasoline were pumped from the main holding tank. The effects of the recent heavy rain storm seem to be diminishing. The total volume of gasoline recovered to date is 38,627 gallons.

No gasoline was recovered from the Brace Lumber Yard holding tank.

PIEZOMETRIC ELEVATIONS

Piezometric elevations on November 6, 1981, are shown on Plate 1. In general, piezometric levels across the site continued to decline in the last monitoring period. Only Wells 4, 7, 8, 9, 14, 18, and 19 exhibited increases, which were between .02 and 1.29 feet. The largest increase was in Well 8, and was expected given the abnormally large decline in the piezometric level in this well on October 16. Wells 4, 18, and 19 are near the southern boundary of the site; increases in their piezometric levels are attributed to the influx of groundwater from the higher ground to the south. Fluctuations of the piezometric levels in Wells 7, 8 and 9 are common due to the well pumping in this area. The increase in Well 14 is small and probably related to local soil and groundwater conditions.

In the remainder of the wells, piezometric levels decreased between .05 and .84 feet. The largest increase in the piezometric level occurred in Well 10 and most likely results from pumping of that well. The shape of the piezometric surface has changed very little since October 28. There is a flat-bottomed "valley" in the piezometric surface in the vicinity of the gasoline station, which narrows and slopes downward to Lake Union to the north. The "valley" is bounded by distinct slopes in the piezometric surface on both the east and west sides along Terry Avenue and Westlake Avenue, respectively.

GAS THICKNESS

Gas thicknesses recorded on November 6, 1981, are shown on Plate 2. The concentration of gasoline has not changed significantly from that noted in our previous report. Wells 3, 5, 6, 13, 18 and 32 exhibited increases in gasoline thicknesses between .04 and .50 feet. The piezometric levels in all of these wells decreased, except for Well 18. It is possible that the increase in gasoline at Well 18 is due to an insurgence of groundwater which has spread out the previously high concentration of gasoline at Well 19 over a larger area.

The decreased gasoline thicknesses at Wells 8, 9, 10 and 28 of between .09 and .50 can be attributed to pumping in these areas.

EXPLOSIMETER READINGS

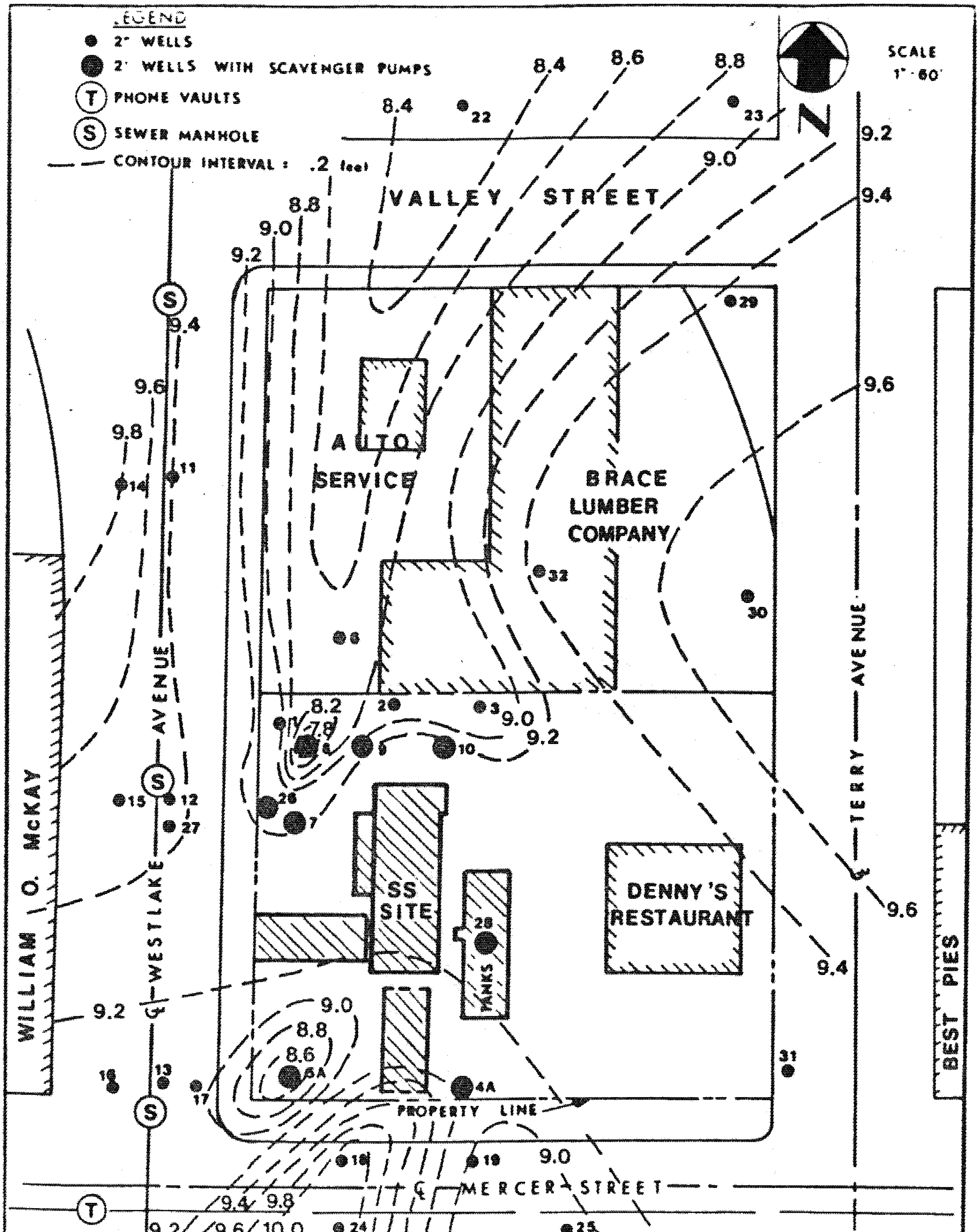
Explosimeter readings at both the 8-foot and 4-foot depths remained about the same in most of the wells, and are at or near 100%.

Yours very truly,

HARDING LAWSON ASSOCIATES

James T. Cameron

James T. Cameron
Project Manager

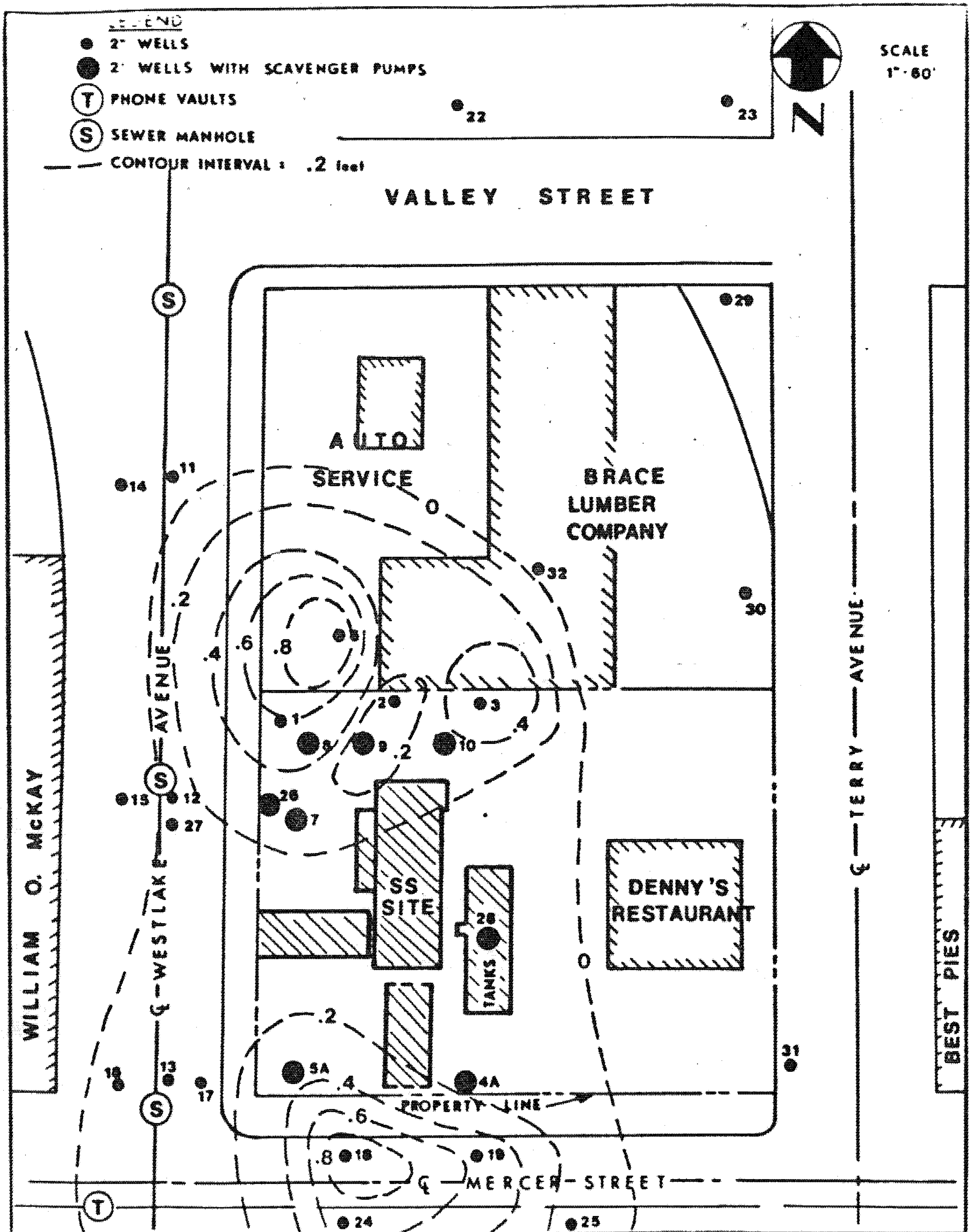


Harding Lawson Associates
Engineers Geologists
& Geophysicists

PIEZOMETRIC ELEVATIONS
Union Oil Company
Seattle, Washington

11/20/81

PLATE 1



Harding Lawson Associates
Engineers Geologists
& Geophysicists

GASOLINE THICKNESS 11/20/81
Union Oil Company
Seattle, Washington

PLATE
2

Harding Lawson Associates

HLA

December 14, 1981

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 26
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between November 7 and November 20, 1981.

GASOLINE RECOVERY

Gasoline recovery took a very sudden rise and appears to have resumed the same high rate of recovery as noted after the heavy rains which occurred in the early part of October. Between November 7 and November 20, 1,340 additional gallons of gasoline were pumped from the main holding tank. The lower rate of recovery noted in our previous report of November 13 appears to have been the result of a faulty scavenger pump which was located in Well 9. In addition, the pump located in the Brace Lumber yard was operating inefficiently and was shut down in the early part of the current monitoring period. The total volume of gasoline recovered to date is 40,087 gallons.

Figure 1 presents a semi-logarithmic plot of the total gasoline recovery versus time. Based on theory the relationship should be linear for recovery from a single finite gasoline source; however, there have been three major places of deviation on this graph. The first occurred early in the pumping period when the pumps were shut down for construction. The second occurred when the Brace Lumber yard recovery pump was installed in the late part of October, 1980. And the third began in the beginning of October, 1981, at the onset of unusually heavy rainfall. In the first two instances the recovery-versus-time plots returned to the original linear relationship. Assuming a new gasoline source has not been introduced to the site and that the recent increased rate of recovery is due to a freed pocket of gasoline, we expect that the plot of gasoline-recovery-versus-time will return to the original linear relationship. The time required for this to occur will depend on the amount of gasoline released from the pocket.

No gasoline was recovered from the Brace Lumber yard holding tank between November 7 and November 20, 1981.

PIEZOMETRIC ELEVATIONS

Piezometric elevations on November 20, 1981, are shown on Plate 2. The general shape of the piezometric surface has not changed appreciably on the north half of the site. Elevations on the southern boundary of the site near Mercer Street have generally decreased on the order of .5 feet. The largest decrease, 1.34 feet, occurred at Well 8 and the largest increase, .95 feet, occurred at Well 18.

GASOLINE THICKNESS

Gasoline thicknesses recorded on November 20, 1981, are shown on Plate 3. In general, gasoline thicknesses appear to have declined from those readings taken in the previous monitoring period. Wells 1, 4, 8, 9, 12, 16, 25, and 28 exhibited increases. The largest increase, .21 feet, occurred at Well 28. The remaining wells showed decreases in gasoline thicknesses with the largest amount, .59 feet, occurring in Well 19. The general zones of gasoline concentration have not changed appreciably since the previous monitoring period.

EXPLOSIMETER READINGS

In the last few weeks, explosimeter readings have been varying by as much as 100 percent. However, except for Wells 22 and 23, explosimeter reading have generally remained near 100 percent at both the four and eight-foot levels. Wells 22 and 23 appear to be decreasing in vapor levels as indicated by their most recent respective readings of 25 and 0 percent at the eight-foot level.

Yours very truly,

HARDING LAWSON ASSOCIATES

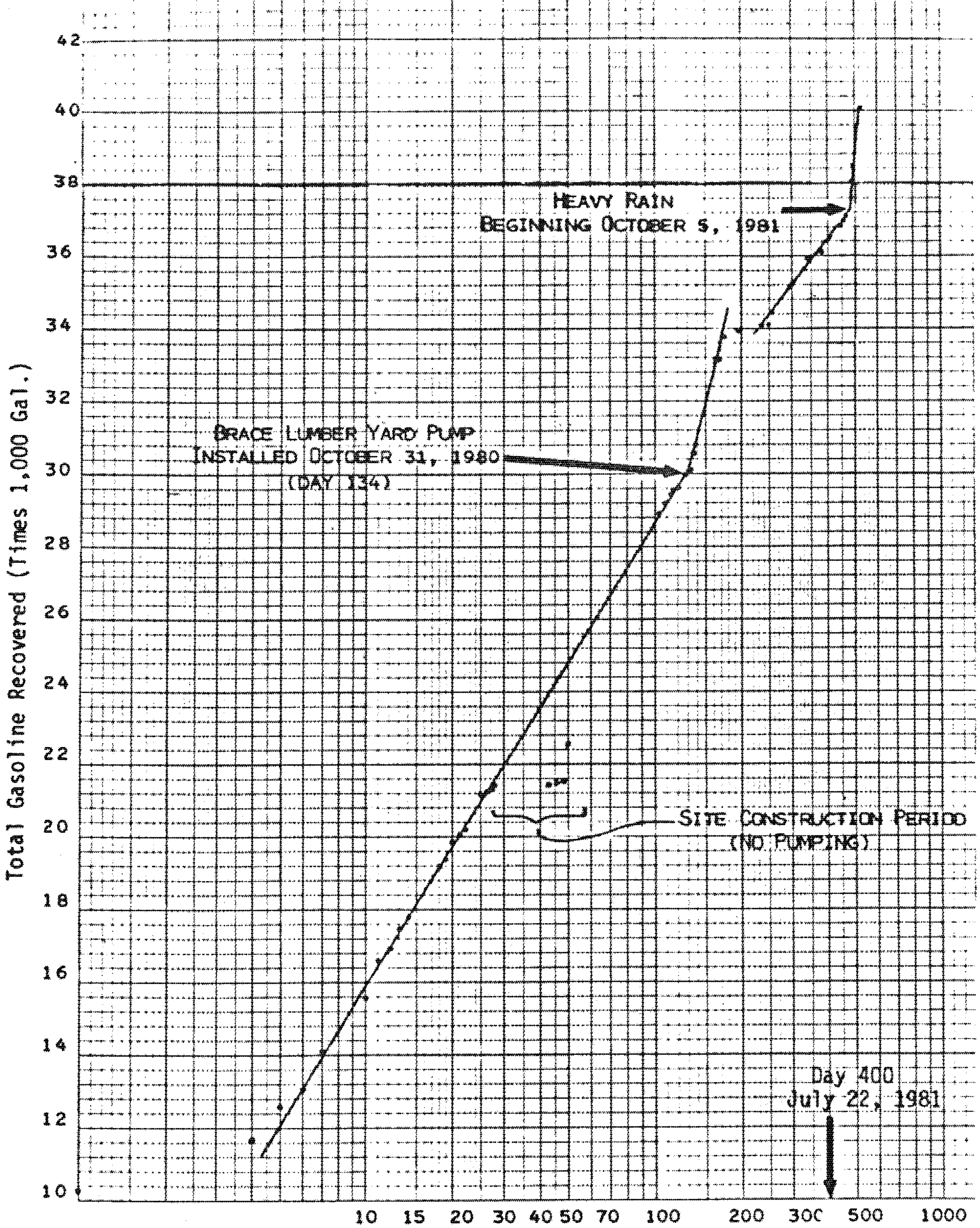
James T. Cameron

James T. Cameron
Project Manager

Attachments

cc: Jim Miller
Ed Ingram

JTC/cag



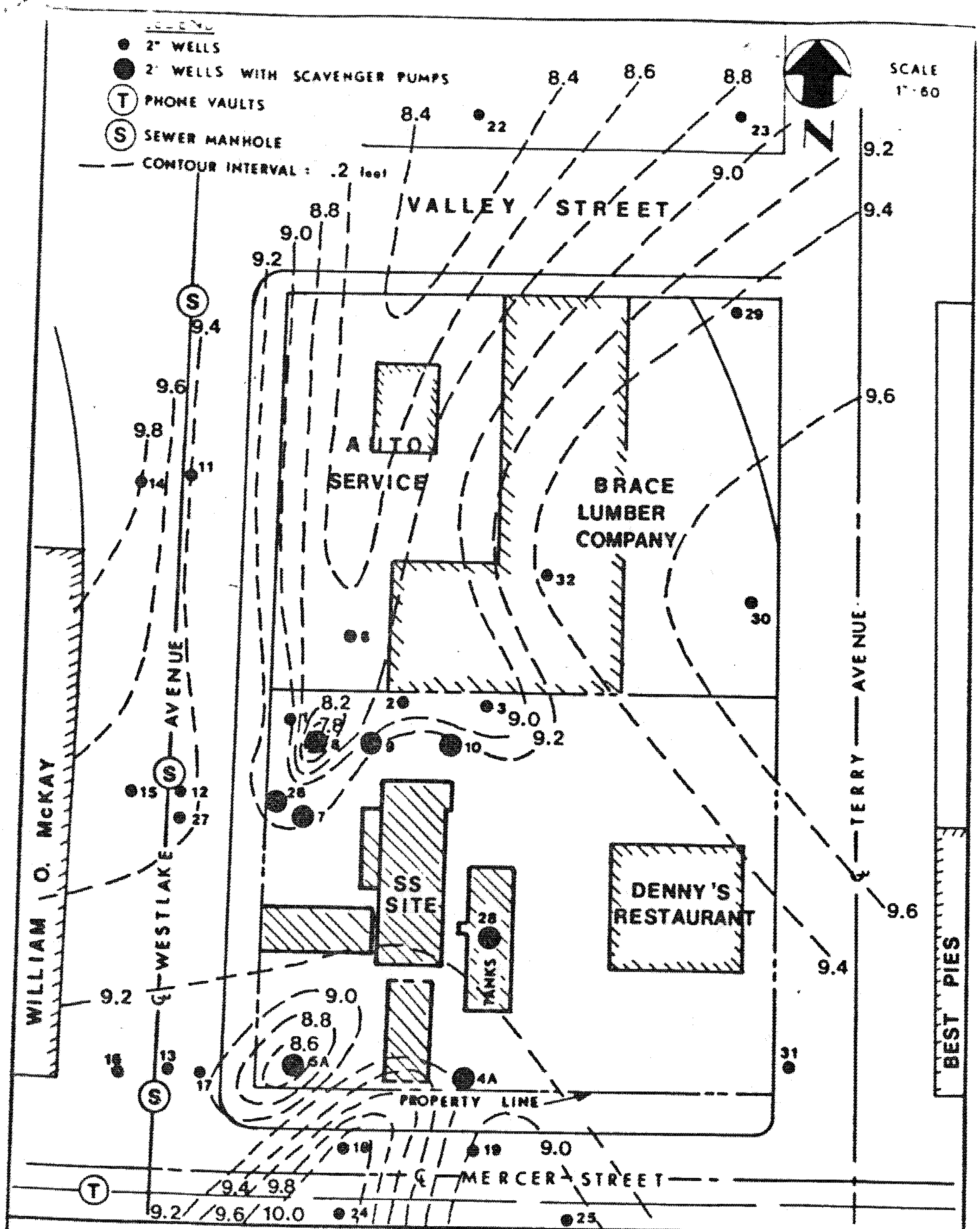
Note: Start of Pumping on June 19, 1980

Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Total Gasoline Recovery
Union Oil Company
Seattle, Washington

PLATE
1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BT	14,197,006.07	MAP	10-16-81		



Harding Lawson Associates
Engineers, Geologists & Geophysicists

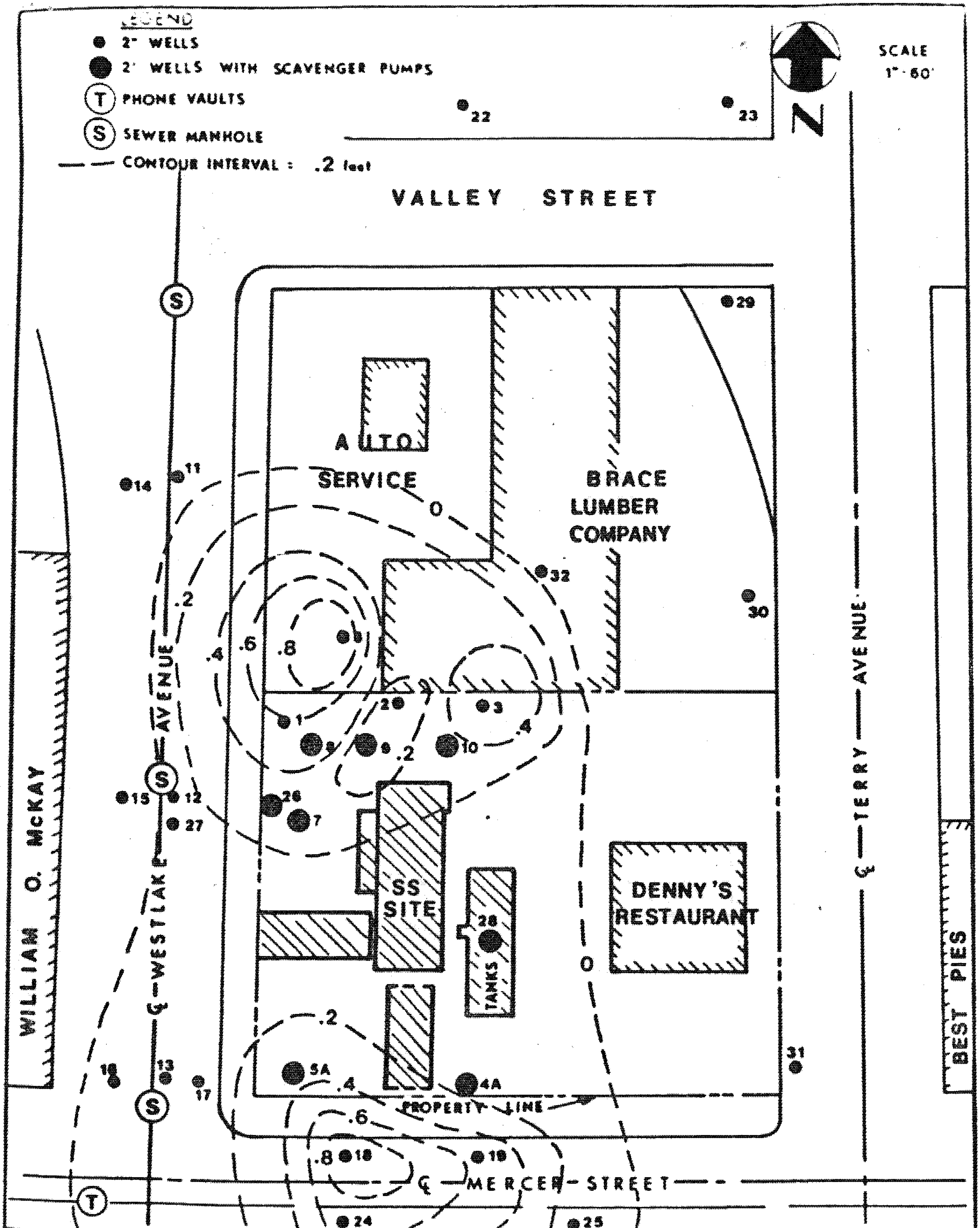
PIEZOMETRIC ELEVATIONS

Union Oil Company
Seattle, Washington

11/20/81

PLATE **2**

BJT 14,197,006.07



Harding Lawson Associates
Engineers Geologists
& Geophysicists

GASOLINE THICKNESS 11/20/81
Union Oil Company
Seattle, Washington

PLATE
3

BJT 14,197,006.07

JTC

Harding Lawson Associates

December 30, 1981

14,197,006.07

Union Oil of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 27
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between November 21 and December 18, 1981.

GASOLINE RECOVERY

Gasoline recovery rates continue to remain relatively high. During this period, approximately 574 gallons of gasoline were pumped from the main holding tank. The average recovery rate since the middle of September 1981, has been approximately 250 gallons per week. Prior to the middle of September, the gasoline recovery rate was approximately 250 gallons per month. The total volume of gasoline recovered to date is 40,541 gallons.

No gasoline was recovered from the Brace Lumber yard holding tank.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on December 18, 1981, are shown on Plate 1. It appears that the piezometric surface has risen .2 to .4 feet over the entire site. However, the general shape of the piezometric surface has not changed appreciably since that recorded on November 20, 1981. A number of wells could not be read on December 18 and therefore the piezometric surface could not be estimated as closely as previous sets of readings. However, the surface still declines gently from the south to the north with a shallow depression in a central part of the block. The total relief in piezometric levels across the site is approximately 1 foot.

GASOLINE THICKNESS

Gasoline thicknesses recorded on December 18, 1981, are shown on Plate 2. Gasoline thicknesses have dropped on the order of .2 to .8 feet throughout the site. At the southern end of the block the largest recorded gasoline thicknesses occurred in Wells 18 and 19; each measuring three inches of gasoline. In the middle portion of the block, the largest recorded thickness of 7.5 inches occurred in Well 3.

EXPLOSIMETER READINGS

Explosimeter readings continue to vary sporadically by as much as 100% in some wells. Wells 22 and 23 at the north end of the site record vapor readings between 50% and 100% in about one-half of their readings and no vapor in their other readings. The remaining wells record vapor readings at or near 100% at both the 4-foot and 8-foot levels. There appear to be no consistent changes in vapor levels across the site which would suggest gasoline movement or accumulation in new areas.

Yours very truly,

HARDING LAWSON ASSOCIATES

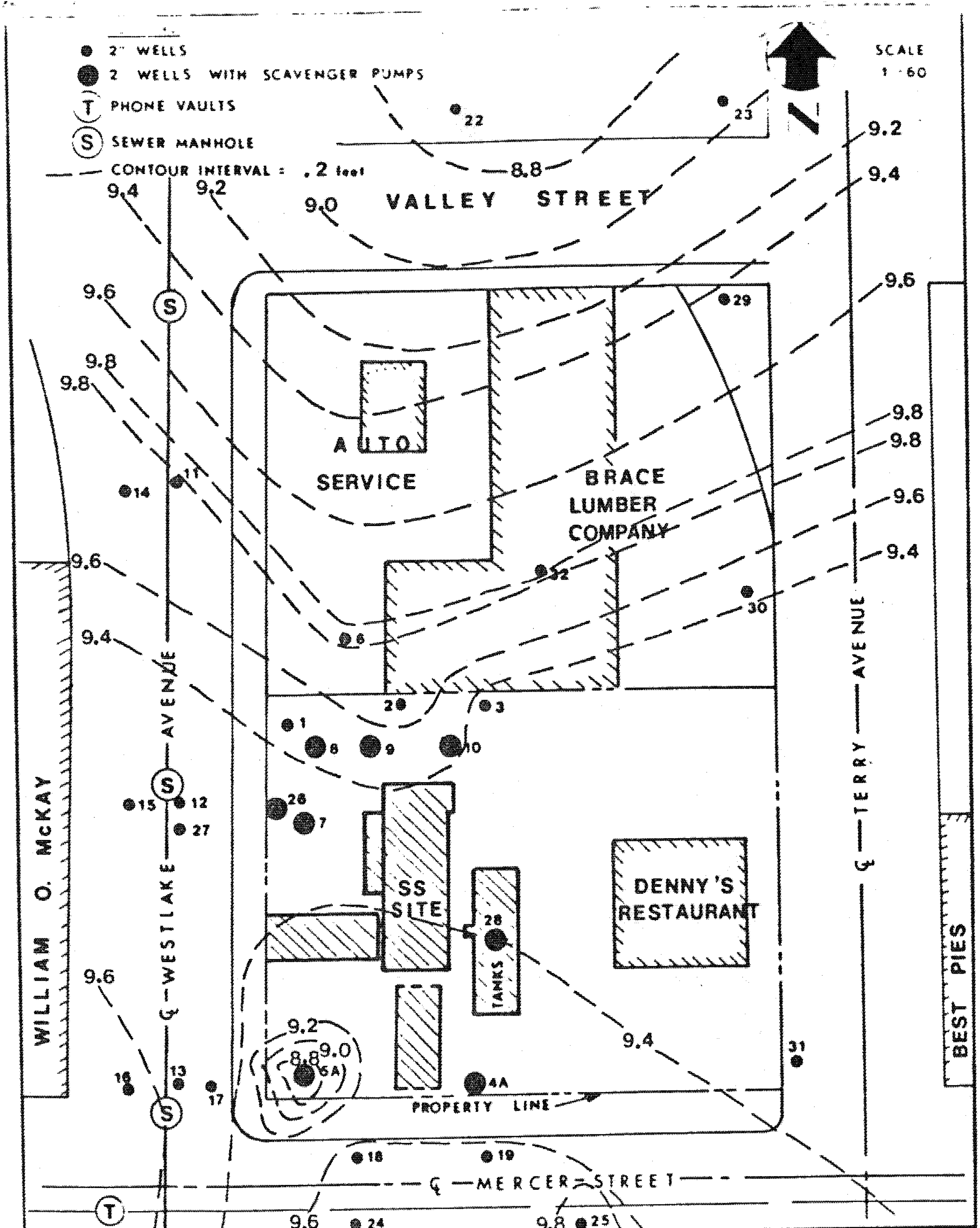
James T. Cameron

James T. Cameron, Project Manager

cc: Ed Ingham, Jim Miller

JTC/cag

Attachments



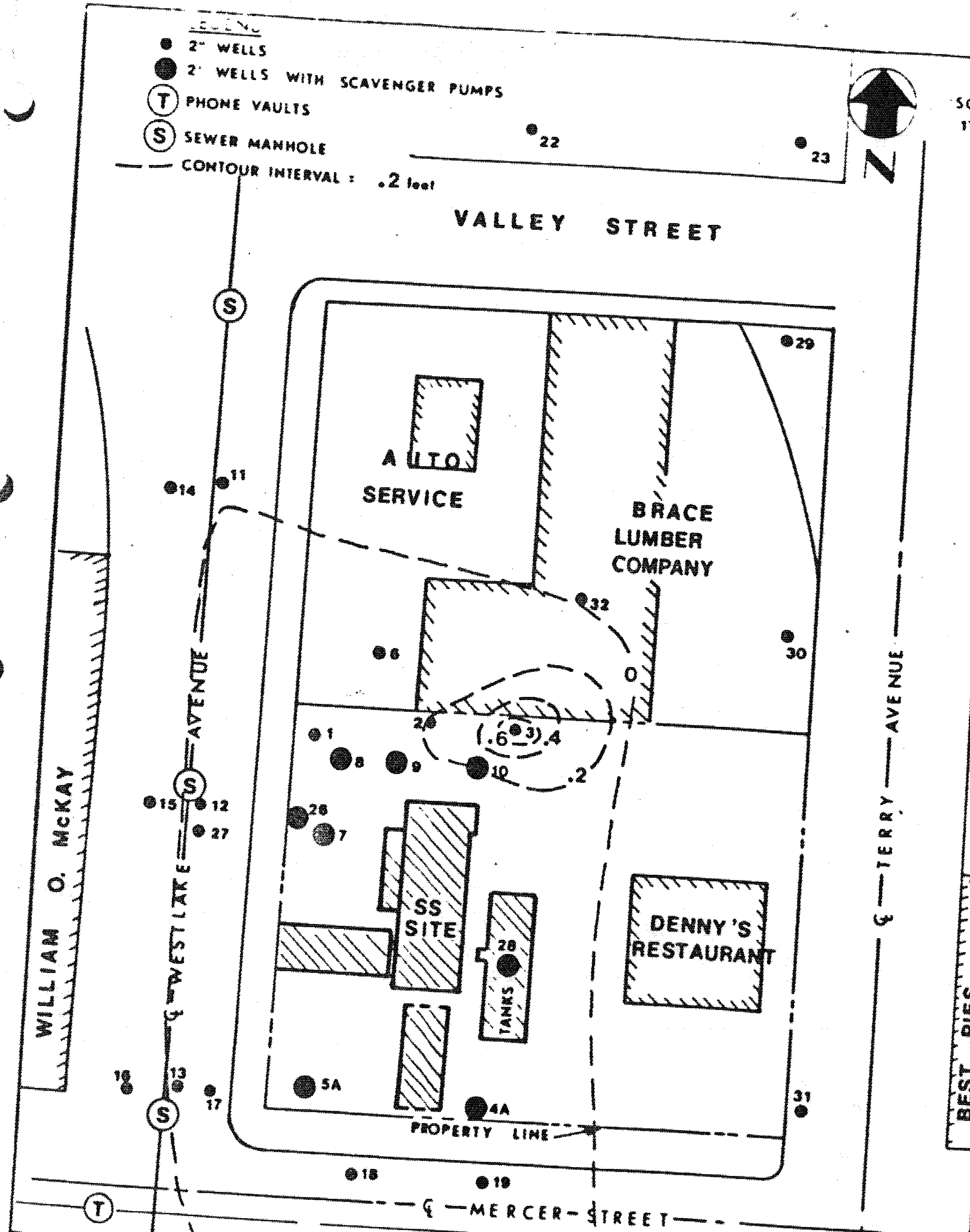
Harding Lawson Associates

PIEZOMETRIC ELEVATIONS

Union Oil Company 12-18-81

Seattle, Washington

1



Harding Lawson Associates

GASOLINE THICKNESS 12-18-81
Union Oil Company
Seattle, Washington

2

Harding Lawson Associates

January 15, 1982

14,197,006.07

Union Oil of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 28
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovering and monitoring operations for the period between December 19, 1981 and January 8, 1982.

GASOLINE RECOVERY

The gasoline recovery rate has dropped significantly since the last monitoring period. A total of 133 gallons of gasoline were pumped from the main holding tank. This is well below the average recovery rate since September 1981 (250 gallons per week). There were some problems with the pumps during this period which could account for the low recovery, or possibly, the new pocket of gasoline exposed by the October storm is diminishing. No gasoline was recovered from the Brace Lumber yard holding tank. To date, 40,674 gallons of gasoline have been recovered.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on January 8, 1982 are shown on Plate 1. The piezometric surface has dropped .2 to 1.3 feet over the entire site. Only Well 2 indicated a minor rise in the water level over the latest monitoring period.

The shape of the piezometric surface indicates a trough running north-south downward toward Lake Union. The lake is at its lowest level this time of year which may account for the recent low water level readings. Deeper depressions centered around Wells 5 and 9 may be attributed to pumping effects.

GASOLINE THICKNESS

Gasoline thicknesses recorded on January 8, 1982, are shown on Plate 2. As has been the case for the past 4 months, gasoline thicknesses across the site continue to fluctuate. Measurements continue to be highest in the vicinity of Wells 18 and 19, where thicknesses of 2.4 and .8 feet were recorded, respectively. However, the very high reading in Well 18 is suspect since much lower thicknesses were measured only a few days prior.

EXPLOSIMETER READINGS

There were very few changes in the explosimeter readings during this monitoring period. Wells 22 and 23, which recently recorded sudden increases in explosimeter readings, still have little or no measurable gasoline in them. Otherwise, there is no pattern or trend to the changes that could indicate gasoline migration or accumulation into new areas.

Yours very truly,

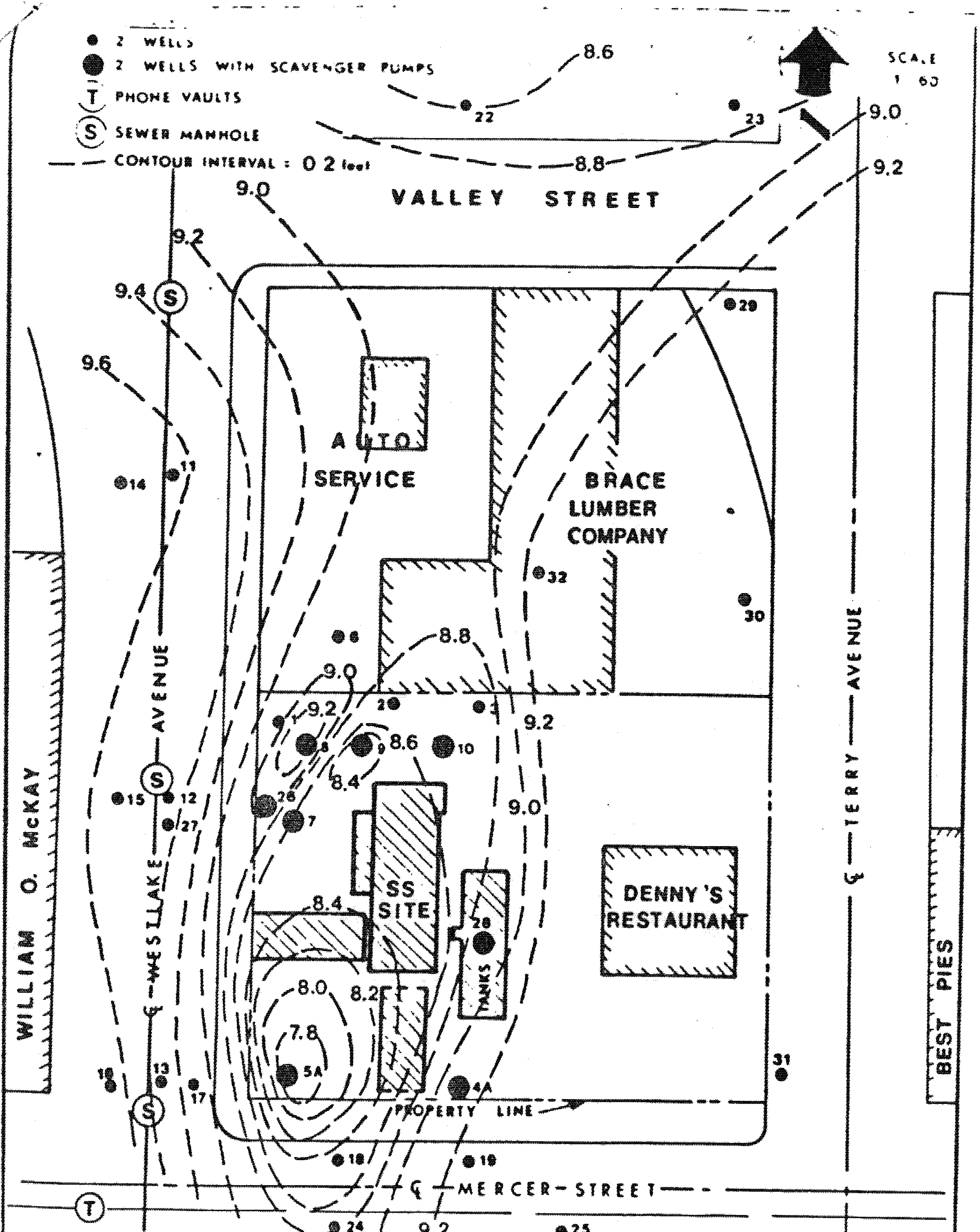
HARDING LAWSON ASSOCIATES

James T. Cameron

James T. Cameron
Project Manager

JTC/cag

cc: Ed Ingham, Jim Miller



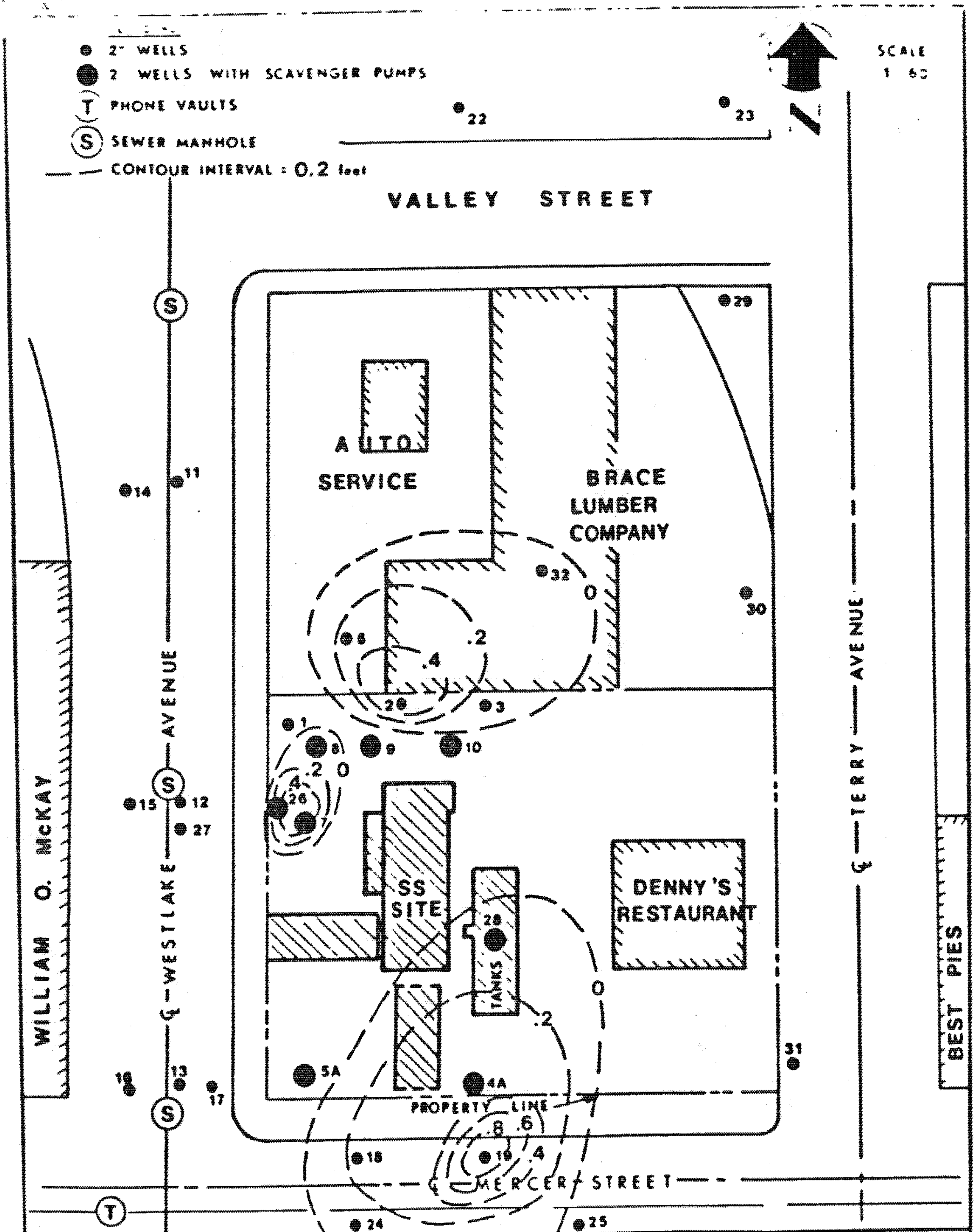
Harding Lawson Associates

PIEZOMETRIC ELEVATIONS 1-8-82

Union Oil Company

Seattle, Washington

1



Harding Lawson Associates

GASOLINE THICKNESS 1-8-82

Union Oil Company

Seattle, Washington

2

January 29, 1982

14,197,006.07

Union Oil of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 28 29
Monitoring and Recovery Operations
January 9 through January 20, 1982
Westlake and Mercer Gasoline Spill
Seattle, Washington

GASOLINE RECOVERY

The gasoline recovery rate continued its rapid decline with a total of only 97 gallons of gasoline recovered since our last progress report. This compares with 133 gallons and 574 gallons of gasoline recovered during the previous two monitoring periods. No gasoline was recovered from the Brace Lumber Yard tank. The total volume of gasoline recovered to date is 40,623 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on January 20, 1982, are shown on Plate 1. Except for Wells 5, 8, 14, 22, and 23, all wells showed a rise in the piezometric surface of between .8 and .1 feet. Most of them rose between .5 and .8 feet. This is a departure from the previous trend of lowered piezometric levels and is probably related to storm water infiltration. Although there is no clearly defined "wave" in the groundwater level, there is some suggestion for it in that both Well 22 and 23 have not yet shown increases and, in fact, declined.

A well defined drawdown cone is still being maintained around Well 5 and is present around Well 8. Although the drawdown cone around Well 5 is fairly consistent, the cone presently around Well 8 is inconsistent and varies in location depending on which well is being pumped. There is also a fairly well defined groundwater divide extending east-west across the site at the north edge of the gas station property. This divide has been in existence for the last several months, and separates a shallow basin to the south from a north trending and dipping trough to the north. The divide should help keep gasoline in the southern area from migrating toward the lake.

GASOLINE THICKNESS

Gasoline thicknesses recorded on January 20, 1982, are shown on Plate 2. With the exception of Wells 3, 7, 8, 9, 18, and 19, gasoline thicknesses across the site have remained essentially the same for the last two weeks. Wells 18 and 19 continue to show the greatest variation, with recorded thicknesses ranging from 0 to 9.5 inches in Well 18 and 6.5 to 20 inches in Well 19. There were also variations in gasoline thicknesses in Wells 3, 7, 8, and 9. We believe that these are probably due to variations in pump activity.

Despite the fact that at times there appears to be fairly significant thicknesses of gasoline in some wells on site, the overall decrease in gasoline thickness across the site and also the rapid decrease in recovery rate suggests that gasoline additions to the site after the October 6, 1981 storm are nearly depleted.

EXPLOSIMETER READINGS

Explosimeter readings at both the 4 foot and the 8 foot level remained about the same in all wells across the site. Most wells show a 100% reading at both the 4-foot and 8-foot depth. Lesser readings or zero readings at both depths were recorded in Wells 11, 12, 13, 15, 22 and 23. Gasoline vapor, at least in measurable quantities, seems to have disappeared from Well 23, as none has been detected since November 13, 1981. The adjacent Well 22 does show gasoline vapor but vapor levels have been generally declining since December, 1981.

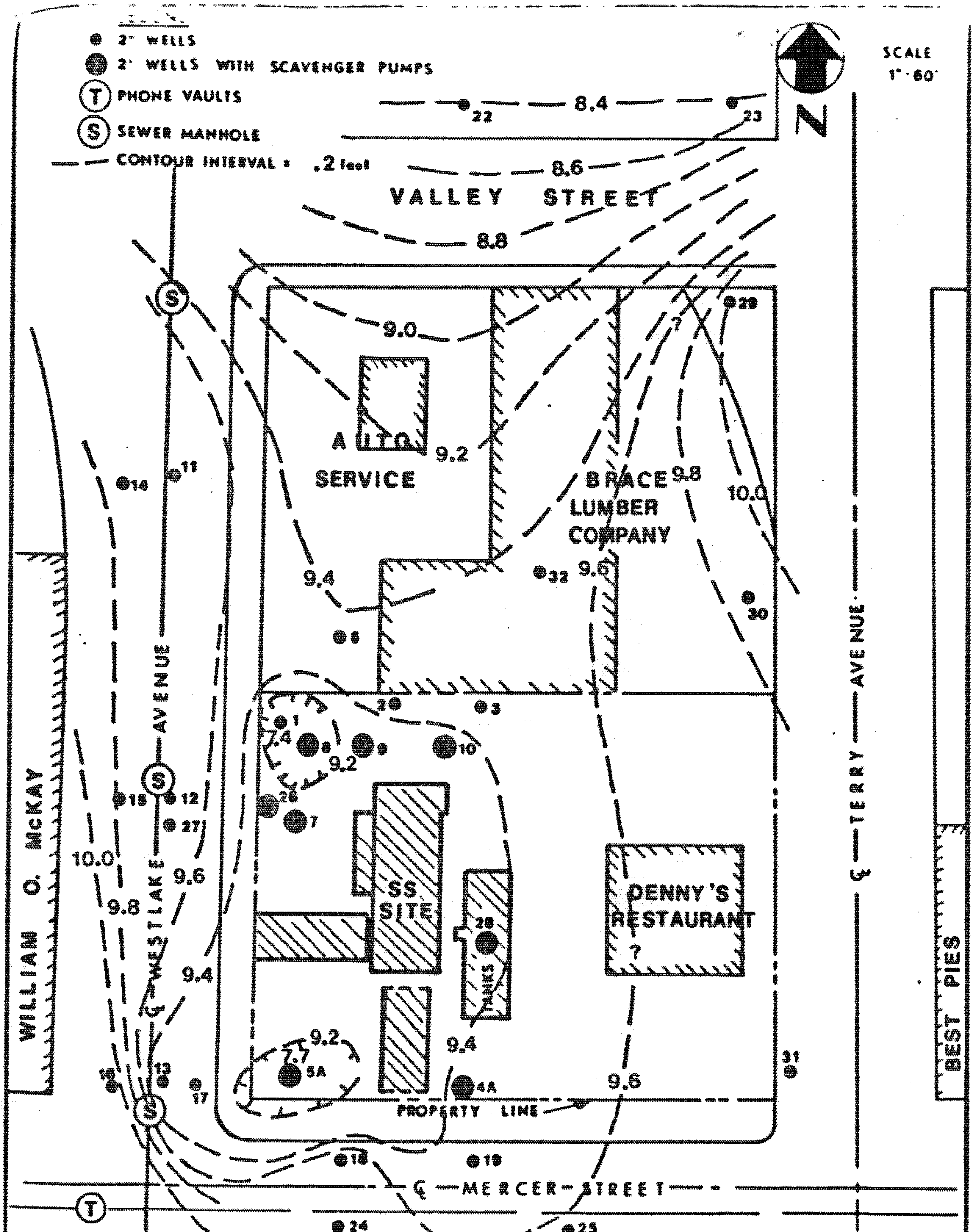
Yours very truly,

HARDING LAWSON ASSOCIATES

Mark A. Adams

Mark A. Adams
Geologist

MAA/cag
cc: Ed Ingham, Jim Miller



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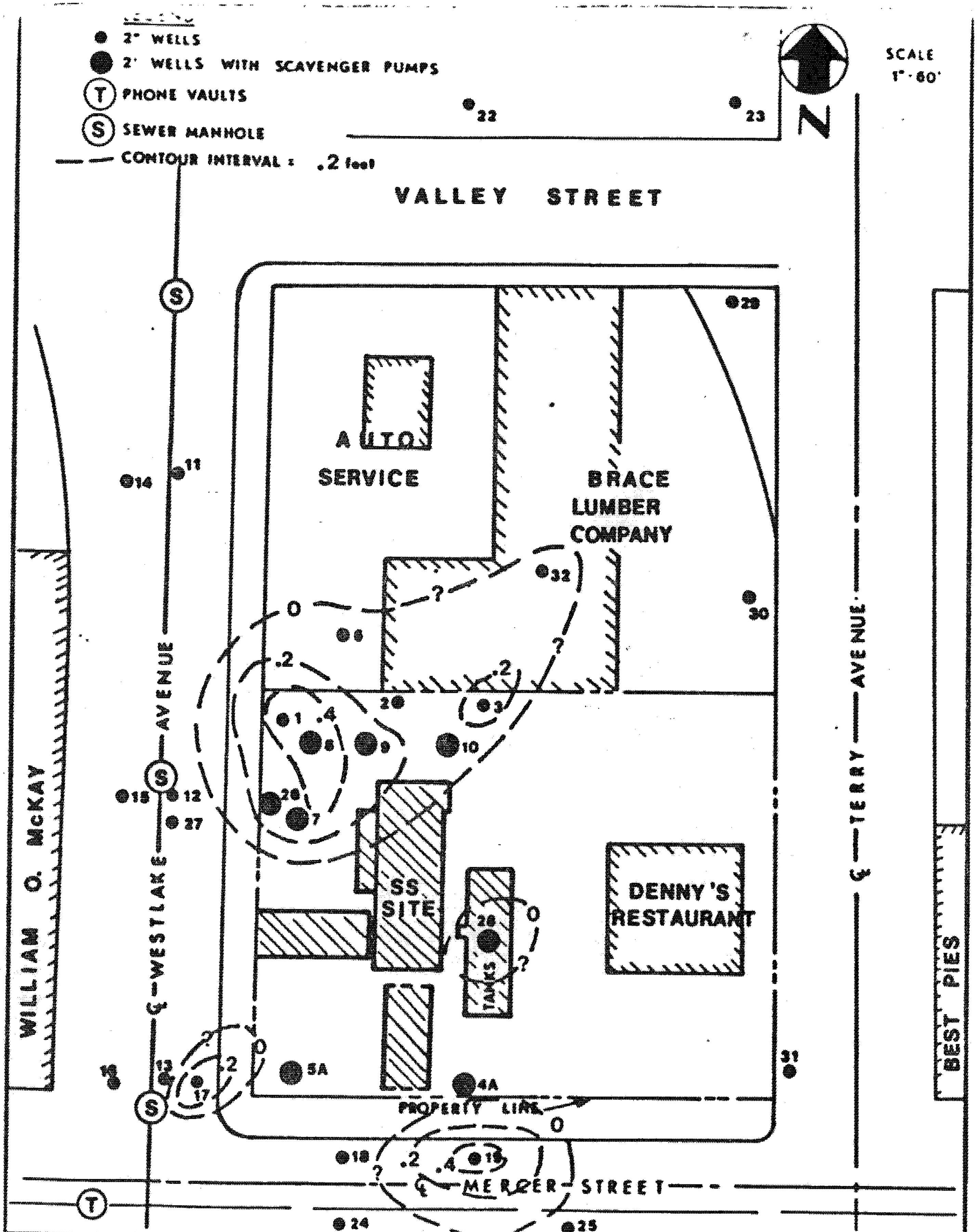
PIEZOMETRIC ELEVATIONS
Union Oil Company of California
Seattle, Washington 1-20-82

PLATE
1



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Engineers Geologists
& Geophysicists

GASOLINE THICKNESS

Union Oil Company of California
Seattle, Washington 1-20-82

PLATE
2

Harding Lawson Associates

February 12, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 30
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between January 21 and January 29, 1982. Our previous report had two errors in it which should be rectified to avoid confusion. The first was that it should have been numbered Progress Report No. 29 rather than No. 28. In addition, the total volume of gasoline recovered as of January 8, 1982, should have been 40,771 gallons.

GASOLINE RECOVERY

The gasoline recovery rate continued to decline with a total of only 26 gallons of gasoline recovered since our previous progress report. No gasoline was recovered from the Brace lumber yard tank. The total volume of gasoline recovered to date is 40,797 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on January 29, 1982, are shown on Plate 1. The piezometric surface has had very little variation since that recorded on January 20, 1982. Piezometric levels in Wells 22 and 23 on the north side of Valley Street have dropped approximately .2 to .4 feet since those levels reported previously. Piezometric levels

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California · Washington

in the vicinity of Wells 5 and 8 continue to fluctuate as depressant pumps and scavenger pumps are periodically relocated among the larger wells.

The recovery procedure still appears to be maintaining sufficient drawdown in the vicinity of the gasoline station to keep the gasoline from traveling off the site.

GASOLINE THICKNESS

Gasoline thicknesses recorded on January 29, 1982, are shown on Plate 2. There still appears to be two major areas of liquid gasoline concentration; one in the vicinity of Wells 3 and 8, in the middle portion of the block, and the other at the southern end of the block in the vicinity of Wells 18 and 19. Gasoline thicknesses remain essentially the same in the middle portion of the block and increased up to 1.2 feet in the southern end of the block. The most significant gasoline thickness increases of .4 and 1.2 feet occurred in Wells 19 and 18, respectively. Well 18 indicated no gasoline on January 20. These two wells have a long history of such sudden variations and we suspect that the variations are probably due to pump activity and represent only very limited local conditions.

EXPLOSIMETER READINGS

Explosimeter readings at the 8-foot level are generally around 100% except in Wells 22 and 23 which each recorded no gasoline vapor. Readings at the 4-foot level were also generally in the 100% range with the exception of Wells 22 and 23 which recorded no vapor and Wells 14, 15, 16, and 29 which recorded 35, 15, 15, and 30 percent, respectively.

Explosimeter readings were taken in the phone vaults and sewer holes in front of the Shell station on the adjacent block east of the Union Oil site. Readings indicated between 3 and 15 percent vapor levels at these locations. At this time the vapor levels are relatively insignificant and we do not feel that they pose enough of a threat to necessitate immediate action. The vapors may have originated from a newly released small pocket of gasoline washed into the vault or sewer line backfill by groundwater movement. Alternatively, the vapors may have originated from street washings containing gasoline or other volatile substances which have infiltrated to the vault and sewer line.

Yours very truly,

HARDING LAWSON ASSOCIATES

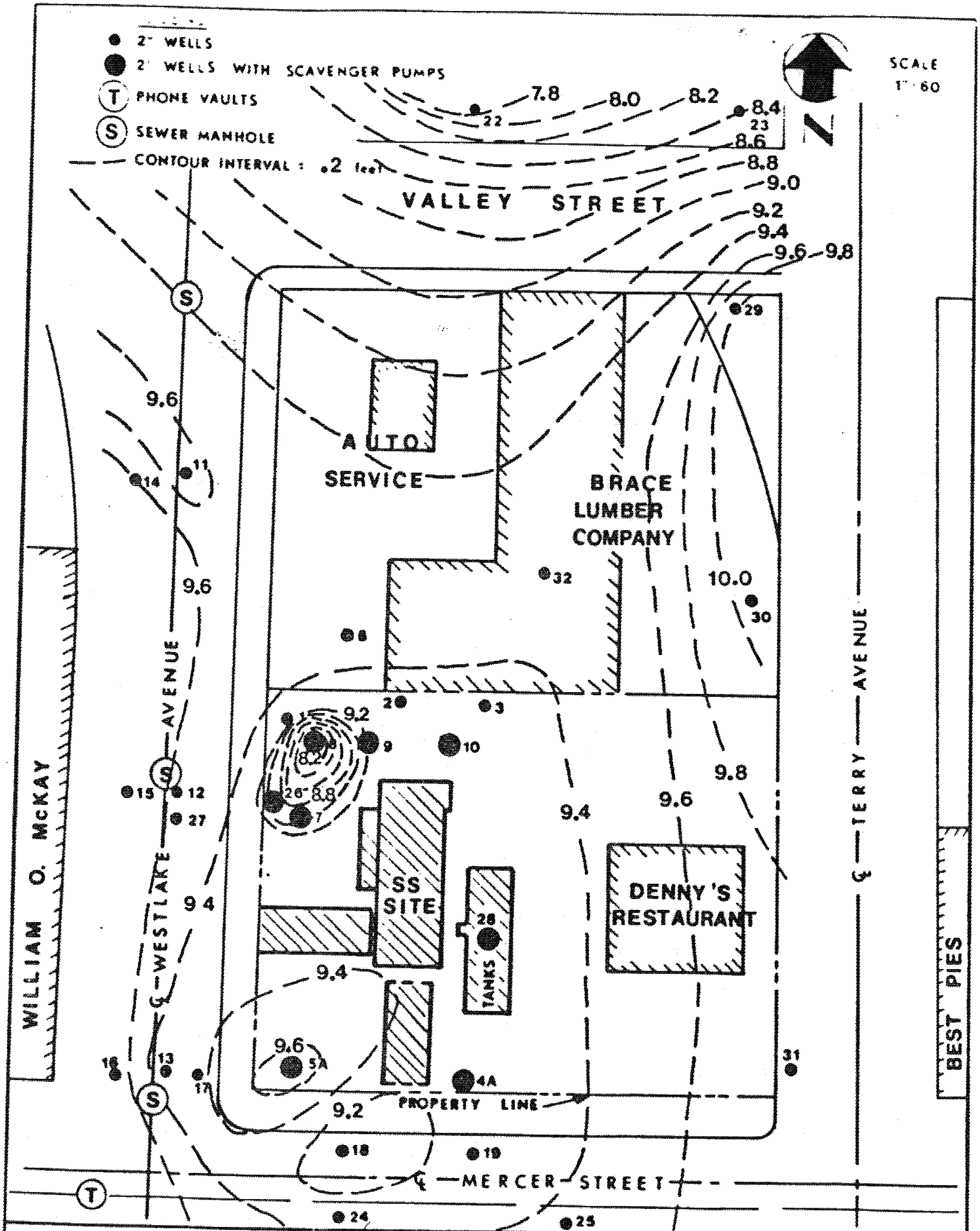
James T. Cameron

James T. Cameron
Project Manager

JTC/cag

Enclosures

cc: Ed Ingham, Jim Miller



Harding Lawson Associates

PIEZOMETRIC ELEVATIONS

Union Oil Company of California 1-29-82

Seattle, Washington

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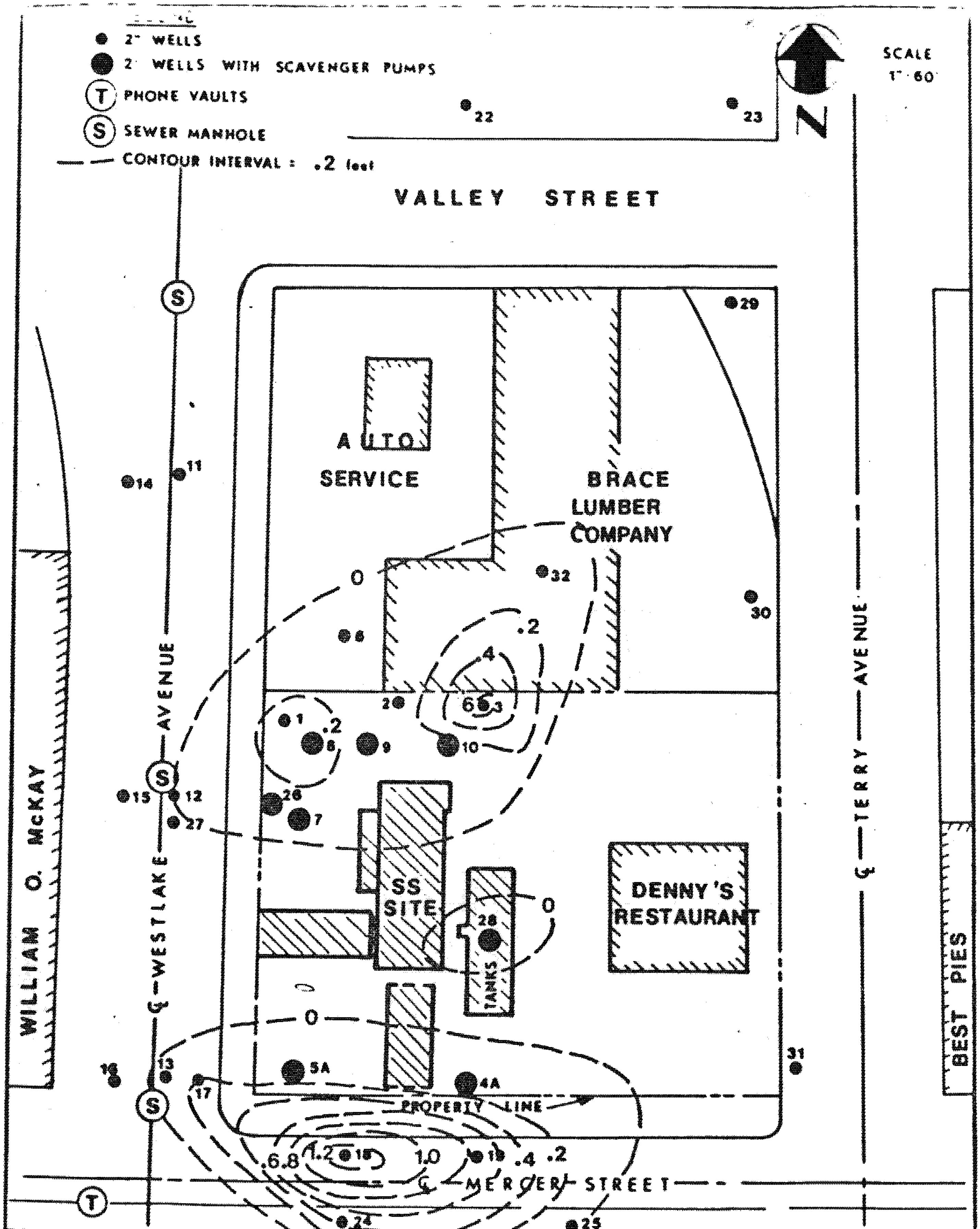


Harding Lawson Associates
Engineers, Geologists
& Geophysicists

GASOLINE THICKNESS

Union Oil Company of California 1-29-82

Seattle, Washington

PLATE

2

BJT

14,197,006,07

Harding Lawson Associates

HLA

February 26, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 31
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between January 30 and February 19, 1982.

GASOLINE RECOVERY

The gasoline recovery increased somewhat from the previous monitoring period. A total of 149 gallons of gasoline were recovered between January 30 and February 19, 1982. All of the recovered gasoline for this monitoring period was pumped from the main holding tank. No gasoline was recovered from the Brace Lumber yard tank. The total volume of gasoline recovered to date is 40,946 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on February 19, 1982, are shown on Plate 1. Except for Wells 22 and 23, the piezometric surface has generally risen about .2 to .4 feet across the site. Wells 22 and 23 on the north side of Valley Street, have risen between .8 and 1 foot. Based on the most recent readings, the piezometric surface is still generally depressed in the vicinity of the gasoline station indicating that the drawdown pumps are performing adequately in creating a cone of depression to prevent liquid gasoline from escaping off the site.

GASOLINE THICKNESS

Gasoline thicknesses recorded on February 19, 1982, are shown on Plate 2. Gasoline thicknesses in individual wells continue to fluctuate erratically, especially in Wells 18 and 19. On February 17, Well 19 recorded 24 inches of liquid gasoline. Two days later on the 19th, only four inches were recorded. In general, it appears that the overall thicknesses of recorded liquid gasoline are decreasing with still two major areas of concentration; 1) in the middle of the block in the vicinity of Wells 8, 9, and 10; and 2) the south end of the block in the vicinity of Wells 4 and 5.

EXPLOSIMETER READINGS

A number of wells have shown a marked decrease in explosimeter levels recently. Wells 6, 12, and 16, which have all been indicating explosimeter readings at the 100% level consistently over the last four to five months, have indicated much lower levels in the last two weeks. Readings of 45, 5, and 10% were recorded in Wells 6, 12, and 16, respectively, at the 8-foot level and 0, 0, and 5% at the 4-foot level. Except for Wells 22 and 23, the remaining wells in use at the site generally demonstrate 100% explosimeter readings at the 8-foot level and 50 to 100% at the 4-foot level. Well 23 has not indicated any explosive vapor since the middle of November, 1981. Explosimeter levels in Well 22 have a past history of erratic fluctuation with recent readings being in the range of 0 to 20% at the 8-foot level. However, on February 19, 1982, a 40% reading was indicated at the 8-foot level.

Explosimeter readings were also taken in the nearby manhole and telephone vaults throughout the last three weeks. There were no explosive vapor levels detected at any of these locations. It appears that the vapors detected during the previous monitoring period have dispersed.

Yours very truly,

HARDING LAWSON ASSOCIATES

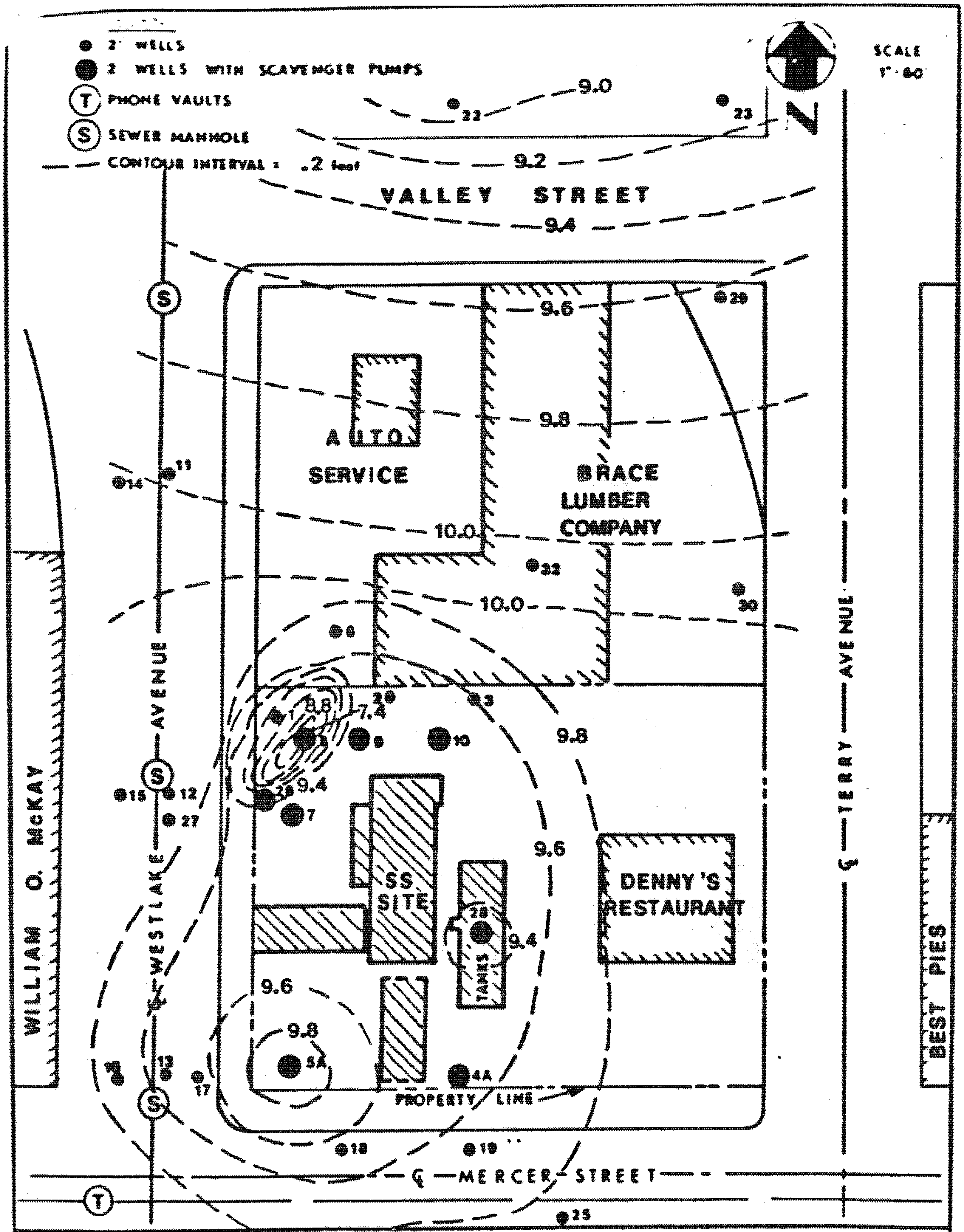
James T. Cameron

James T. Cameron
Project Manager

JTC/cag

Attachments

cc: Ed Ingham
Jim Miller



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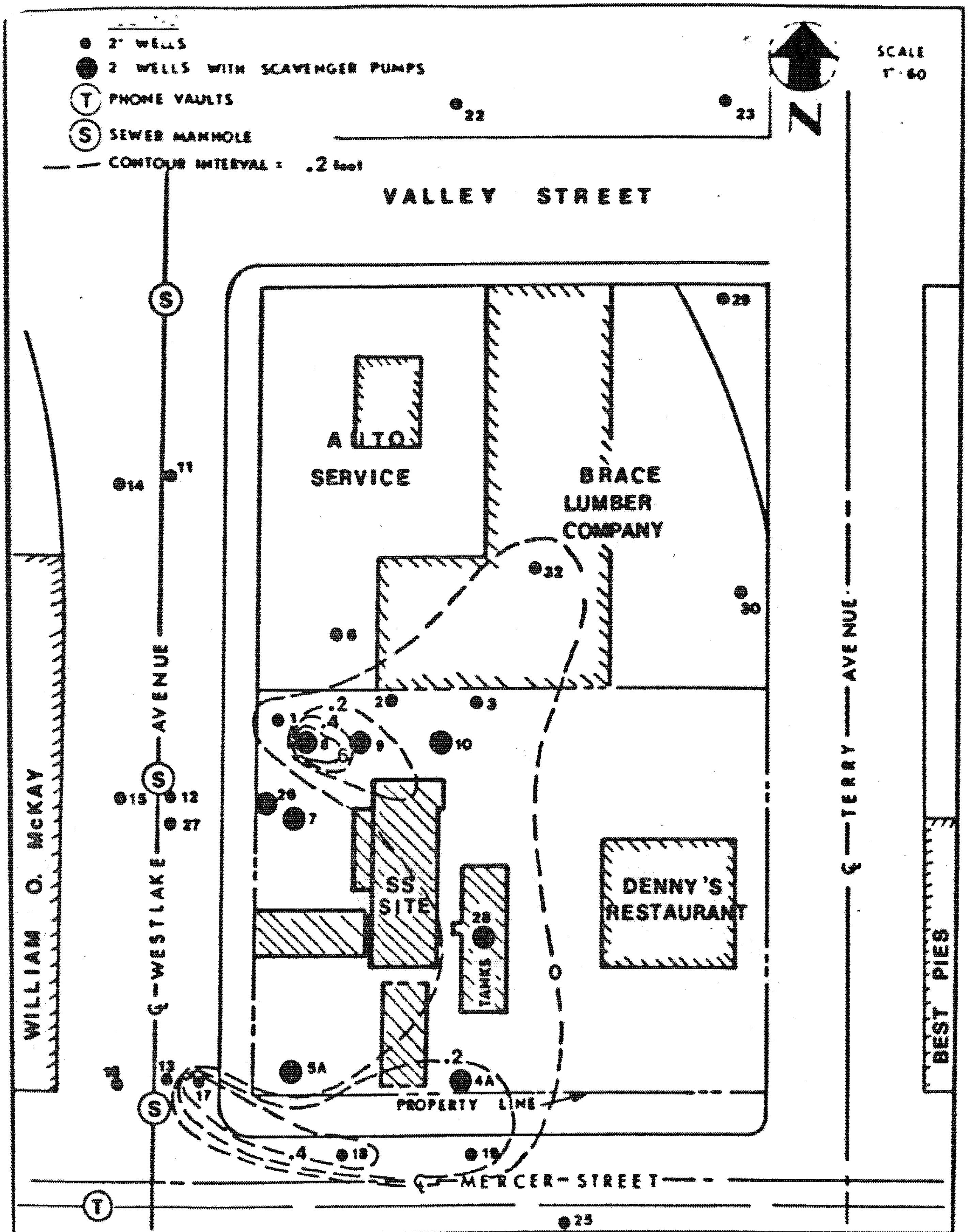
PIEZOMETRIC ELEVATIONS

Union Oil Company 2-19-82
Seattle, Washington

PLATE
1



Harding Lawson Associates
Engineers Geologists
& Geophysicists

GASOLINE THICKNESS
Union Oil Company 2-19-82
Seattle, Washington

PLATE
2

Harding Lawson Associates

March 12, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 32
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between February 20 and March 5, 1982.

SITE VISIT

On March 1, 1982, Steve Perrigo and Jim Cameron of our office visited the site to check on the measurement methods and recovery system as it is currently being employed at the site. At a number of the monitoring wells, the street surface is slightly depressed and surface runoff tends to collect and puddle around the monuments. This water either immediately enters into the monument or does so when the monument cover is removed. Inside the well the top of the piezometric tube has about 3 to 4 inches of extension and is uncapped. As the top of the casing chamber fills, water can freely flow into the piezometric tube. This can lead to two possible problems. One, unless sufficient time is allowed for any surface water inflow to dissipate into the surrounding groundwater, water level readings in these wells will be higher than the true groundwater levels. Two, the influx of surface water from the streets may carry silt, oils, and other substances which may plug the piezometric wells.

We recommend that all of the two inch piezometric wells which have indicated puddling in the past be capped and that care be taken to avoid allowing surface street flow to enter these wells by brushing away puddles, prior to opening the monuments, with a broom or other means and bailing out the top of the casing chamber prior to uncapping the piezometric tube. In wells where this is not possible, we recommend that measurements not be taken in the wells until the surrounding water dries up or is removed in some other fashion.

These measurements are important since accurate interpretation of piezometric levels and gasoline thicknesses at the site are dependent on accurate measurements.

We have discussed the situation with Pacific Testing Laboratories and they concur with our recommendations.

GASOLINE RECOVERY

Gasoline recovery remained at about the same level as during the previous monitoring period. A total of 122 gallons of gasoline was recovered from the main holding tank. No gasoline was recovered from the Brace Lumber yard tank. We have been informed that the Brace Lumber yard tank will not be used for recovery unless future monitoring of nearby wells indicates that gasoline levels in this area are increasing. The total volume of gasoline recovered to date is 41,068 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on March 5 are shown on Plate 1. The shape of the piezometric surface is essentially the same as that recorded on February 19. There still is a pronounced cone of depression around Well 18 and most of the site is encompassed by the 9.6 foot elevation contour. An apparent drawdown cone has also developed around Well 19.

GASOLINE THICKNESSES

Gasoline thicknesses recorded on March 5, 1982, are shown on Plate 2. Gasoline thicknesses in individual wells continue to fluctuate erratically, particularly in Wells 18 and 19. However, overall gasoline thicknesses remained nearly the same as previously recorded. In general, it appears that liquid gasoline is still concentrated in the area of Well 8 at the north end of the site and around Wells 17, 18, and 19 at the south end of the site.

EXPLOSIMETER READINGS

Explosimeter readings at both the 4-foot and the 8-foot levels remained nearly the same in all wells across the site. There was a slight increase in Wells 11, 12, and 13 at the 4-foot level, but the increase is well within the normal range of variation. The vapor readings in Well No. 22 which appeared to be declining for some time has now apparently reversed its trend and is increasing.

Yours very truly,

HARDING LAWSON ASSOCIATES

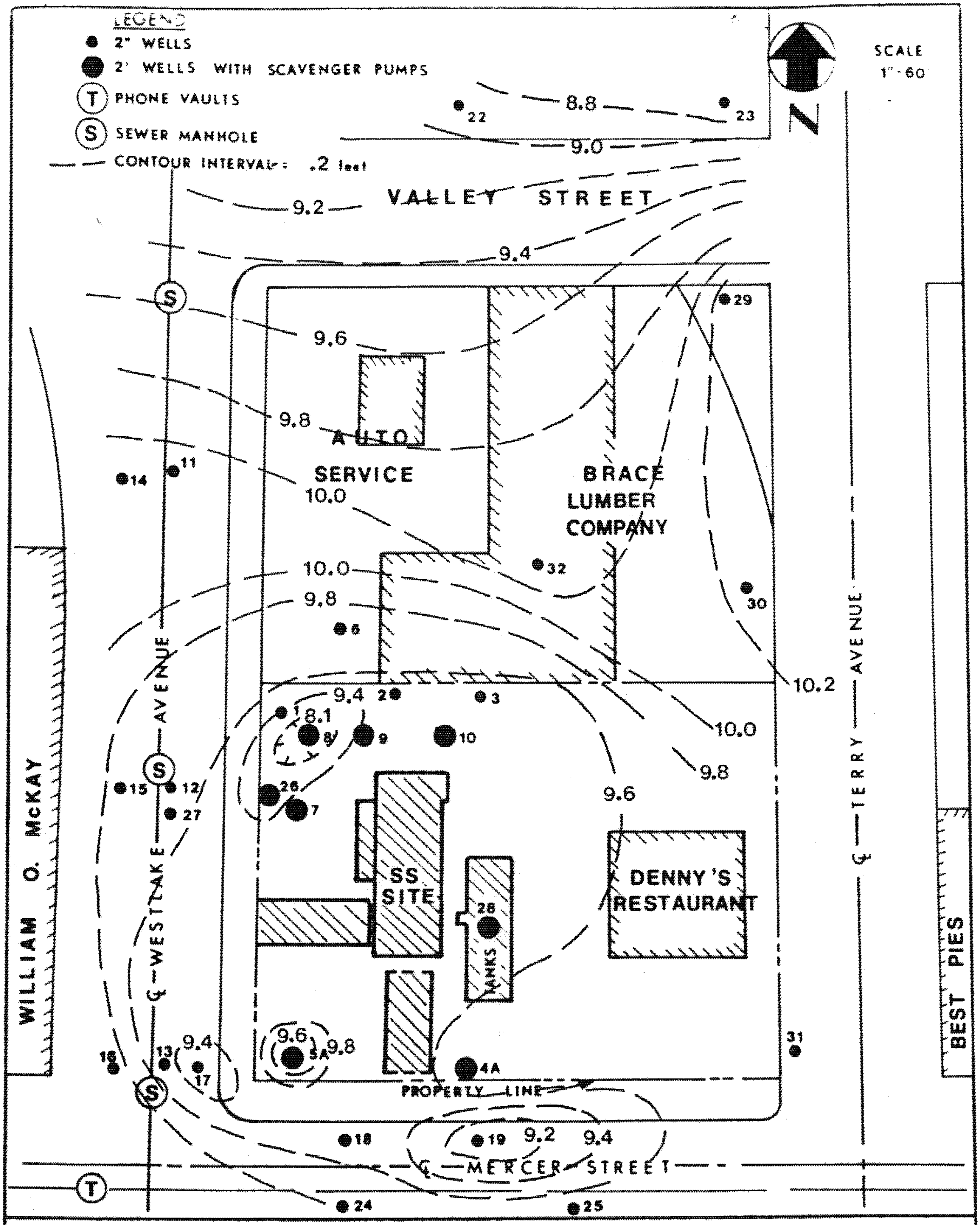
James T. Cameron

James T. Cameron
Project Manager

MAA/JTC/cag

Attachments

cc: Jim Miller
Ed Ingham



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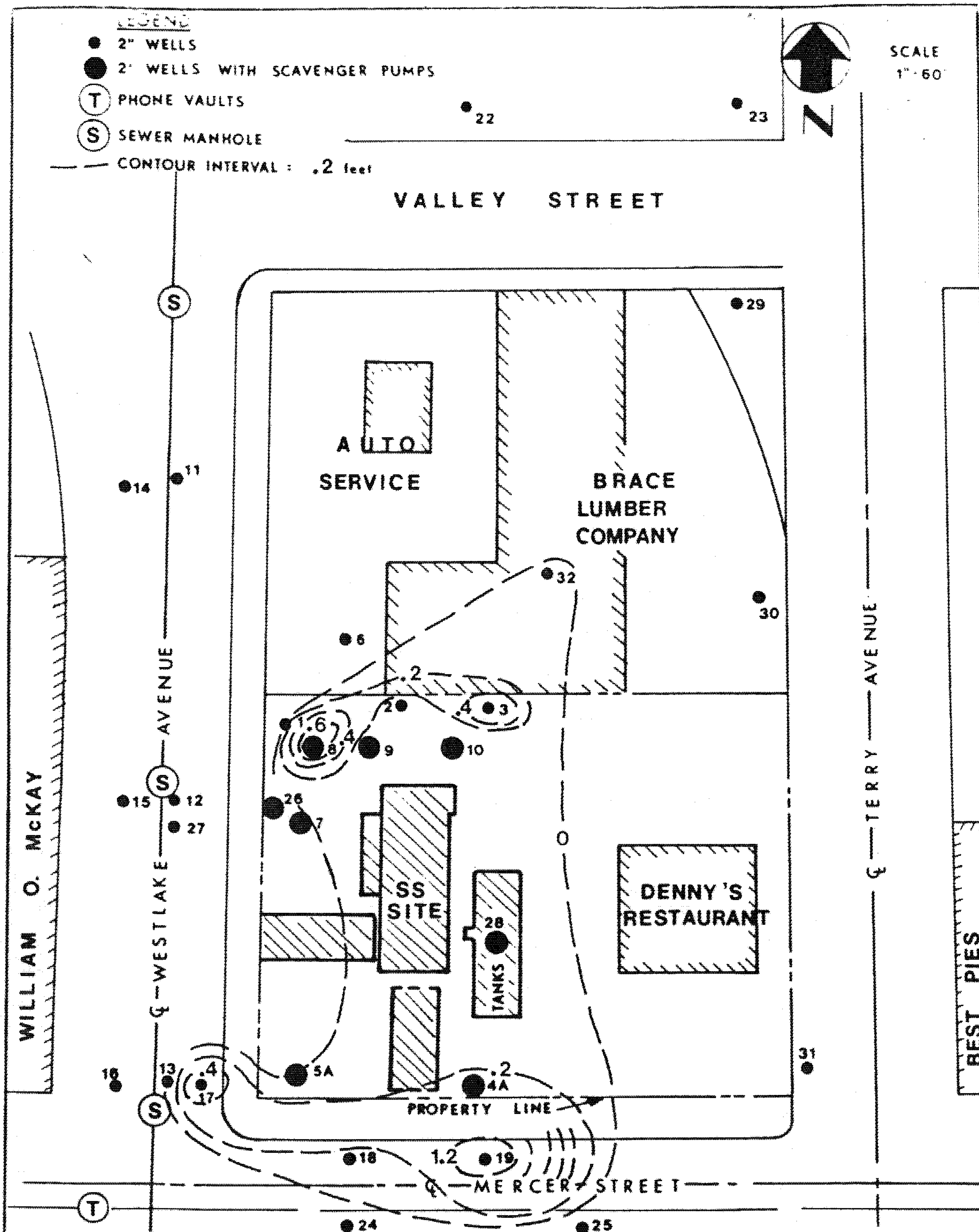
PIEZOMETRIC ELEVATIONS

Union Oil Company 3-5-82
Seattle, Washington

PLATE 1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07				



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GASOLINE THICKNESS
Union Oil Company
Seattle, Washington
3-5-82

PLATE
2

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07				

Jim

Harding Lawson Associates

March 26, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 33
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between March 6 and March 17, 1982.

GASOLINE RECOVERY

Gasoline recovery continues to be minimal. A total of 55 gallons of gasoline was recovered during this period. The total volume of gasoline recovered to date is 41,123 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on March 17 are shown on Plate 1. In general, it appears that water levels have risen slightly; on the order of .2 feet in the southern half of the block and up to .4 feet in the northern half. The drawdown pumps are still maintaining a slight depression in the southern half of the block which will tend to deter free gasoline from escaping northward toward the lake.

GASOLINE THICKNESS

Gasoline thicknesses recorded on March 17, 1982, are shown on Plate 2. Gasoline readings could not be taken in Wells 1, 7, and 26 on this date and the contours shown for the middle portion of the block reflect only those readings

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which were actually taken. There appears to be generally three local areas of gasoline concentration; one in the middle portion of the block in the vicinity of Wells 2 and 3. The other two are at the southern end of the block; one in the vicinity of Well 17 and the other in the vicinity of Well 19. The maximum gasoline thickness recorded on this date was 8 inches which occurred in Well 19. Interim gasoline thickness readings taken between March 5 and March 17 indicate that levels are still varying erratically. On March 12, Well No. 3 indicated 19.5 inches of free gasoline but only 4 inches on March 15. Similarily, Well No. 19 measured 4½ inches of free gasoline on March 8, 13 inches on March 12, and 8 inches on March 17. However, in a general sense, recent readings appear to indicate that free gasoline levels are dropping.

EXPLOSIMETER READINGS

Explosimeter readings remained nearly the same in all wells across the site. Since March 1, Well 22 which had previously indicated no vapor level has indicated explosimeter levels between 15 and 100%. Well 16 which measured a 30% explosimeter level on February 5 has dropped steadily in subsequent readings and has indicated no explosimeter levels since March 1, 1982.

Yours very truly,

HARDING LAWSON ASSOCIATES

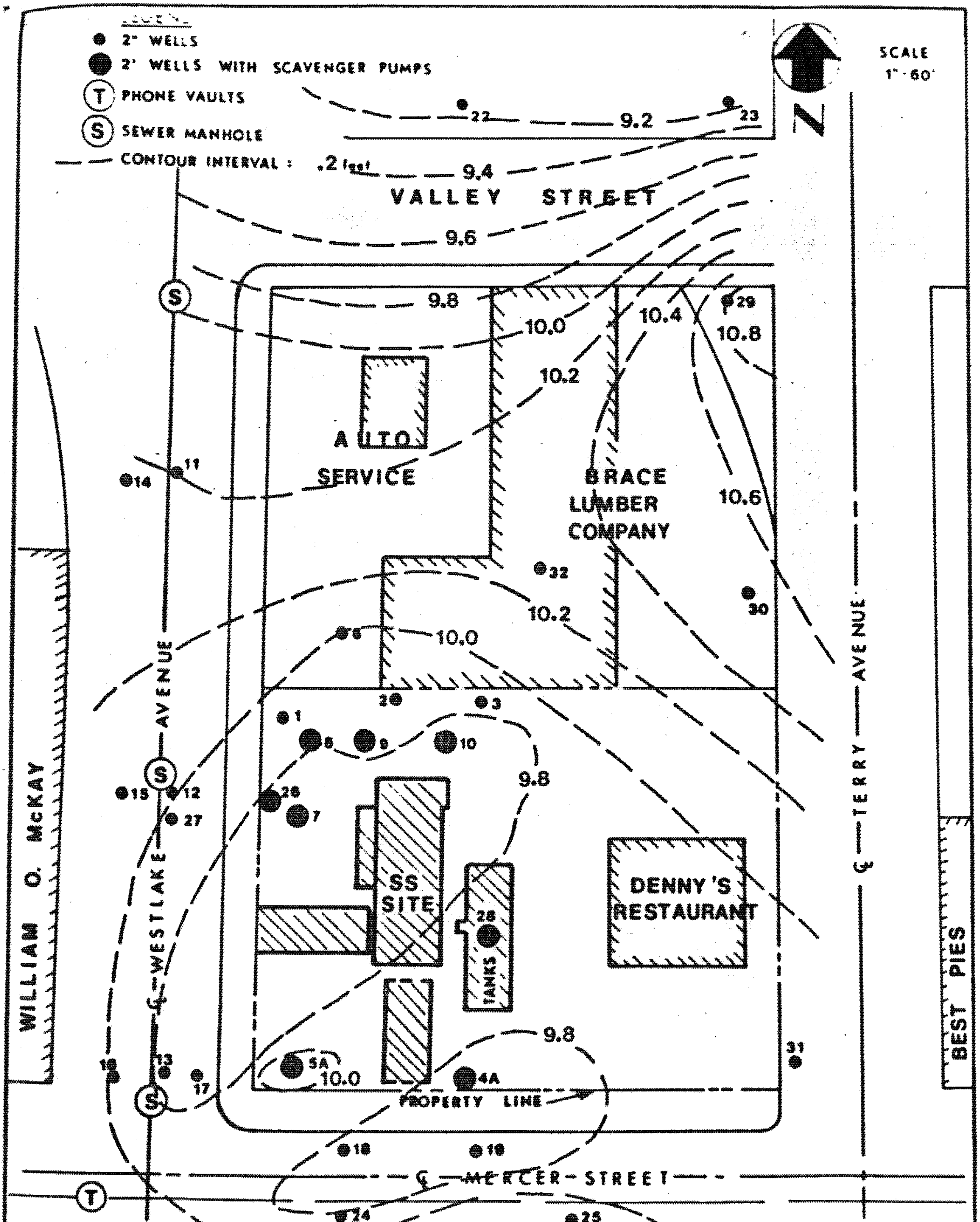
James T. Cameron

James T. Cameron
Project Manager

JTC/cag

Attachments

cc: Jim Miller
Ed Ingham



Harding Lawson Associates
Engineers, Geologists
& Geophysicists

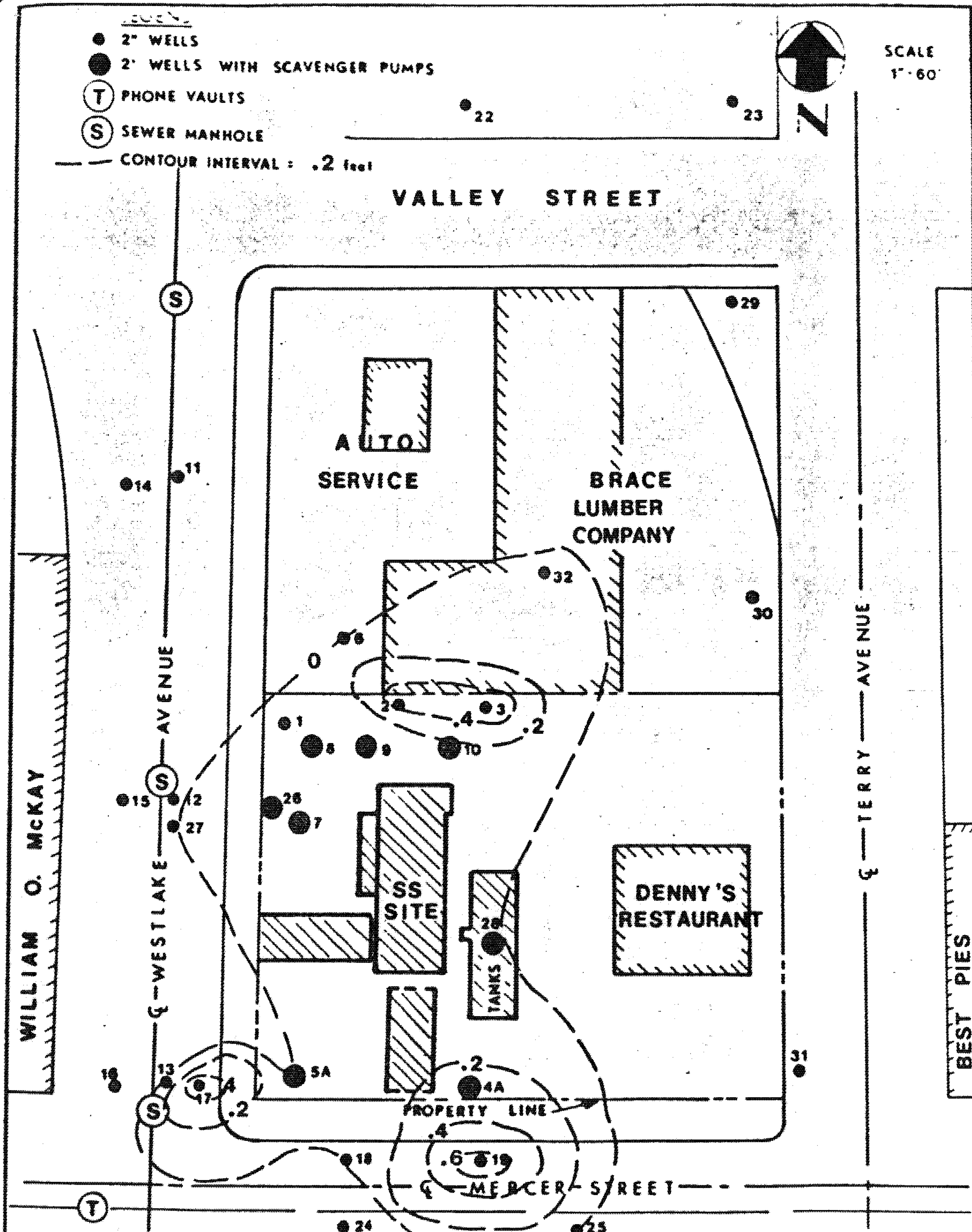
PIEZOMETRIC ELEVATIONS

Union Oil Company
Seattle, Washington

3-17-82

PLATE 1

BJT 14,197,006.07



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Engineers, Geologists
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GASOLINE THICKNESS
Union Oil Company 3-17-82
Seattle, Washington

PLATE
2

Harding Lawson Associates

April 9, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 34
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between March 18 and March 26, 1982.

GASOLINE RECOVERY

There was no gasoline recovered from the site during this time period. The total volume of gasoline to date remains at 41,123 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on March 26 are shown on Plate 1. Piezometric levels appear to have risen .2 to .4 feet on the south half of the block since those readings recorded in our previous progress report for March 17, 1982. Piezometric levels in the north half of the site appear to have deviated very little in this timespan. Recent readings indicate a .4 feet downhill gradient from the south half of the site to the middle portion. It appears that the drawdown pumps are still maintaining a sufficient drawdown to contain the free gasoline.

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GASOLINE THICKNESS

Gasoline thicknesses recorded on March 26, 1982, are shown on Plate 2. Gasoline thicknesses appear to have dropped on the order of .2 feet for both the middle and southern portions of the site where the two areas of the free gasoline concentration have historically resided. The maximum gasoline thickness recorded on this date was 7 inches which occurred in Wells 18 and 19. However, on March 22, these wells recorded 14 inches and 5 inches, respectively, As noted in our previous report, gasoline levels still appear to be dropping.

EXPLOSIMETER READINGS

Except for Wells 14, 22 and 30, explosimeter levels were essentially the same as those recorded on March 17, 1982. Well 14, at the 4-foot level, dropped from 30% on March 17 to 20% on March 24. Well 22, at the 4-foot level, indicated 15% on March 17 and increased to 95% on March 24. Well 30, which indicated 100% level on March 1, measured only 25% on March 24.

Yours very truly,

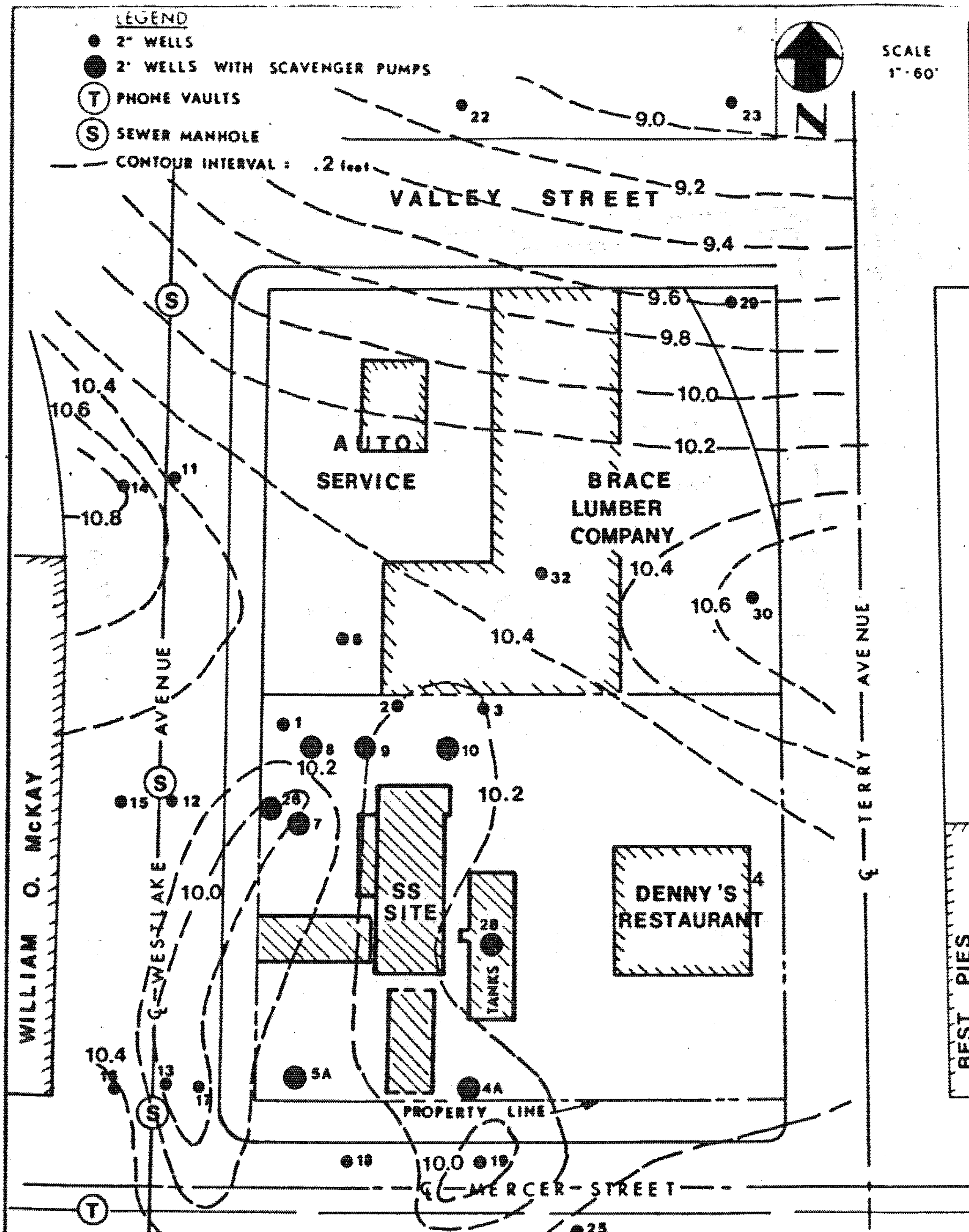
HARDING LAWSON ASSOCIATES

James T. Cameron

James T. Cameron
Project Manager

JTC/cag

cc: Jim Miller, GeoEngineers
Ed Ingham, Ryan & Haworth



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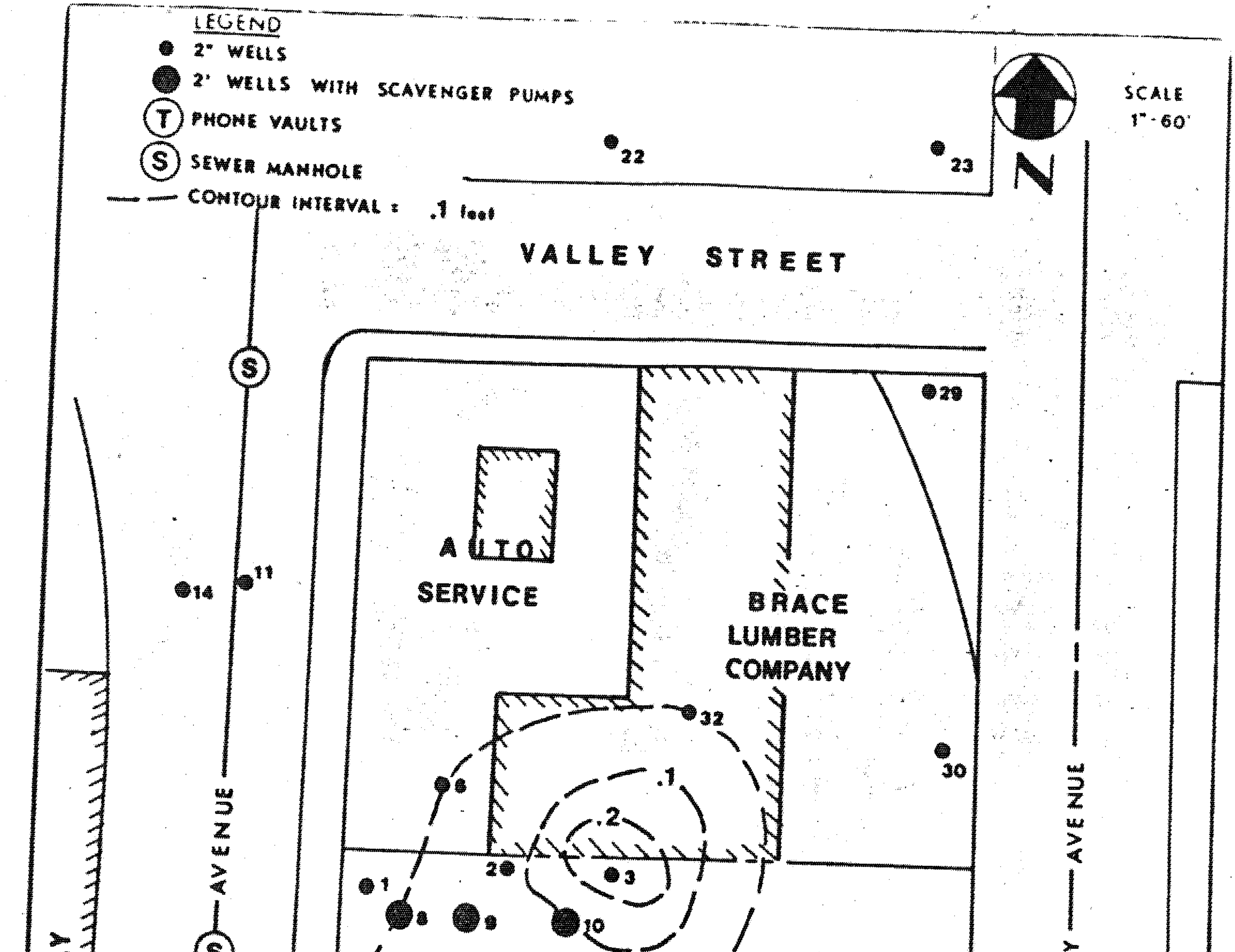
Engineers Geologists
& Geophysicists

PIEZOMETRIC ELEVATIONS
Union Oil Company
Seattle, Washington

3-26-82

1



Harding Lawson Associates
Engineers Geologists
& Geophysicists

GASOLINE THICKNESS

Union Oil Company
Seattle, Washington

3-26-82

PLATE **2**

April 23, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 35
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between March 27 and April 9, 1982.

GASOLINE RECOVERY

A total of 63 gallons of gasoline were recovered during this period. The total volume of gasoline recovered to date is 41,186 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on April 9 are shown on Plate 1. Piezometric levels have dropped an average of .2 feet across the southern and middle portions of the site since March 26. A shallow depression in the piezometric surface in this area is still indicated by the well readings.

The piezometric levels across the north end of the site rose an average of .2 feet. It's likely that these increases reflect the rise in Lake Union's water level. We expect that the piezometric surface across the north portion of the site will continue upward through the summer as the lake level increases. This rise in the piezometric surface, coupled with the shallow depression in the middle portion of the site, should help to continue to deter migration of gasoline northward to Lake Union.

GASOLINE THICKNESS

Gasoline thicknesses recorded on April 9 are shown on Plate 2. There are two main concentrations of free gasoline that are consistent with past observations. One is near the south end in the vicinity of Wells 4, 18, and 19; the other is at the middle of the site. Gasoline thicknesses in both areas rose .2 to .3 feet during this monitoring period. The draw down pumps appear to be maintaining a sufficient depression in the piezometric surface to contain the free gasoline. The maximum gasoline thickness of 1.5 feet was measured at Well 18, which is consistent with its history of rapid and unpredictable fluctuations.

EXPLOSIMETER READINGS

Consistent decreases in the explosimeter readings at both the 4 and 8 foot levels were observed in wells around the perimeter of the site during this monitoring period. It is not atypical for the explosimeter readings to vary in these wells. General trends are only observable after several monitoring periods.

Yours very truly,

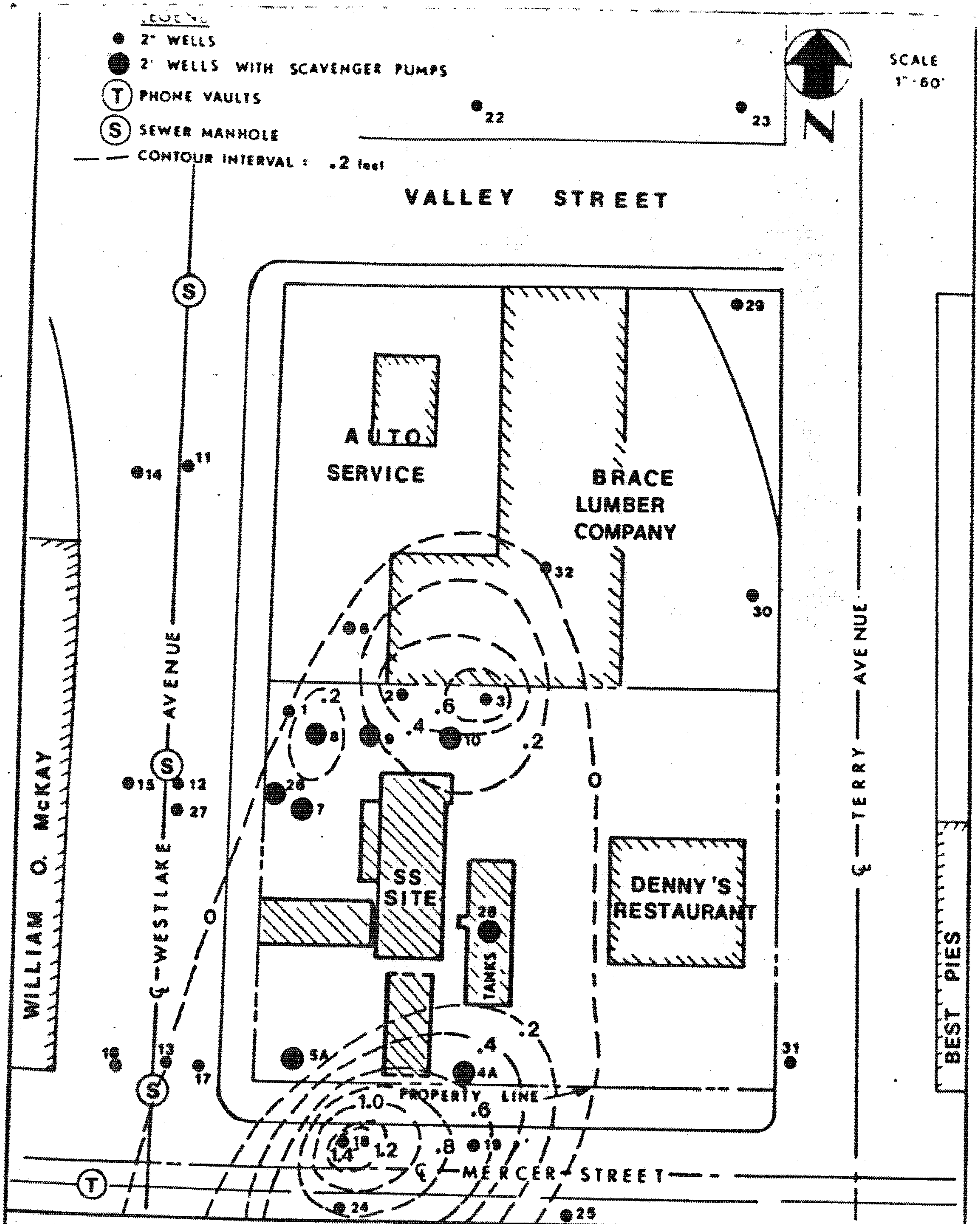
HARDING LAWSON ASSOCIATES

Mark A. Adams

Mark A. Adams
Geologist

VPL/MAA/cag

cc: Mr. Jim Miller, GeoEngineers
Mr. Ed Ingham, Ryan and Haworth



Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Gasoline Thickness 4/9/82
Union Oil Company
Seattle, Washington

PLATE
2

BJT 14,197,006.07 MAO 4/23/82

Harding Lawson Associates

May 5, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 36
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period between April 10 and April ~~17~~ 23, 1982.

GASOLINE RECOVERY

A total of 80 gallons of gasoline were recovered during this period. The total volume of gasoline recovered to date is 41,282 gallons. The recovery rate has been constant for the last 4 monitoring periods.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on April 23 are shown on Plate 1. Piezometric levels increased across the entire site. The increases average around .2 feet for wells in the southern portion, .3 feet for wells near the middle portion, and .4 feet for wells in the northern portion of the site.

The piezometric level increases in the northern portion appear to coincide with the rise of Lake Union. The increases reinforce our opinion that the water levels in this area are directly affected by the water level in the lake.

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The water depressant pump in Well 8 was turned off for 24 hours between April 20 and 21. This appears to explain the observed increase in the water levels in the central portion of the site as the water levels measured on April 19 (before the shutdown) were almost equivalent to those measured on April 9. The observed increase in the water levels around the southern perimeter of the site may result from the decreased gradient towards the center of the site.

GASOLINE THICKNESSES

Gasoline thicknesses recorded on April 23 are shown on Plate 2. The two main concentrations of free gasoline observed near the south and central portions of the site are consistent with past observations. The only significant changes in the gasoline thicknesses were observed in wells near the central portion of the site, in the vicinity of the depressant well pump. An average decrease of approximately .1 feet was observed in Wells 2, 3, 4, 8, and 9.

There was very little change in the observed gasoline thicknesses in the wells in the southern portion of the site. However, the gasoline thickness in Well 18 (which has fluctuated greatly in the past), dropped over 1 foot during this monitoring period, restoring it to a level consistent with readings taken in March.

EXPLOSIMETER READINGS

Consistent increases in explosimeter readings at both the four and eight-foot levels were observed in wells around the perimeter of the site during this monitoring period. We commented in our last report that it wasn't unusual to observe rapid and erratic changes in the explosimeter readings in these wells. The decreases observed in the last monitoring period were offset by the increases measured during this period.

Yours very truly,

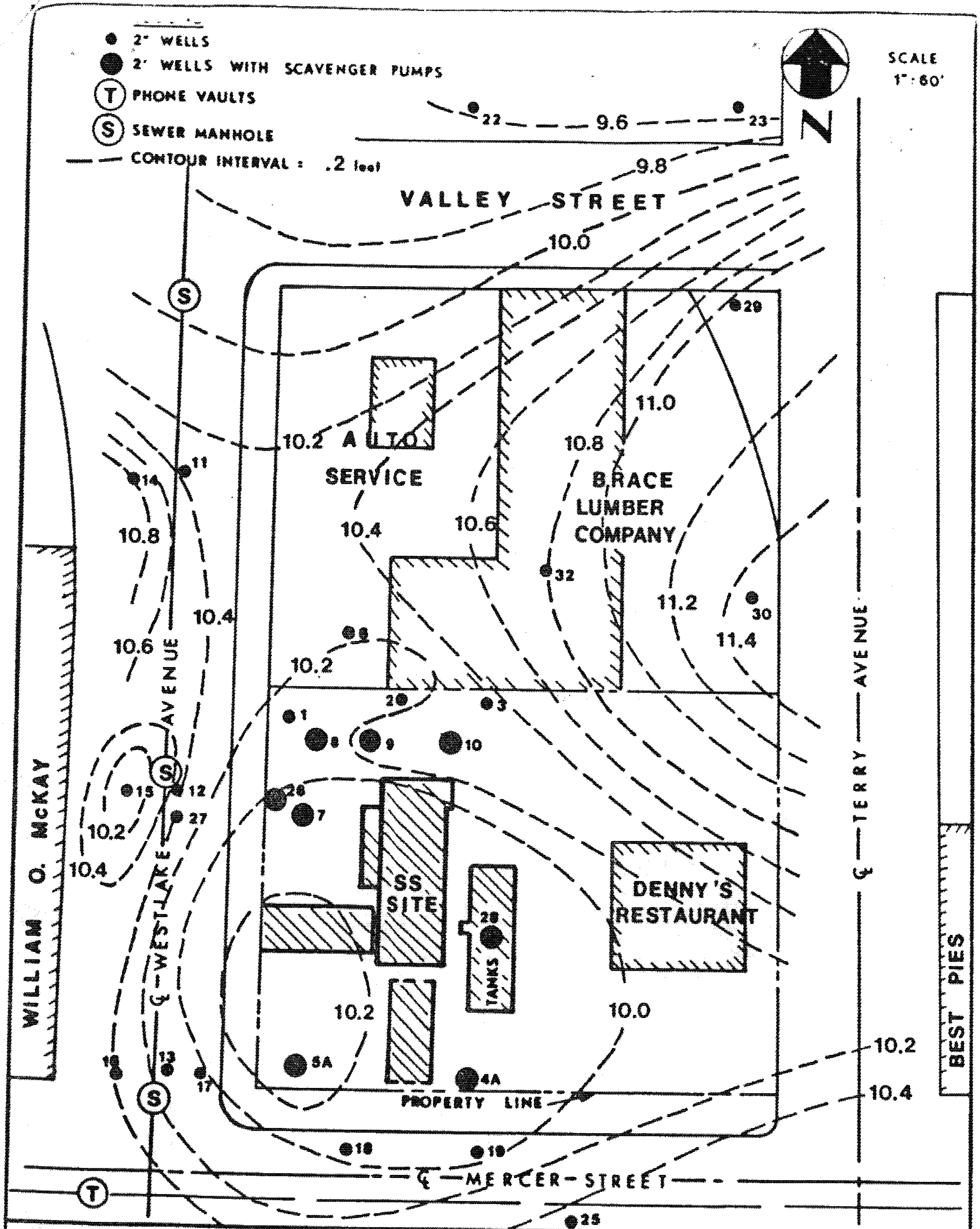
HARDING LAWSON ASSOCIATES

James T. Cameron

James T. Cameron
Project Manager

VPL/JTC/JEN/cag

cc: Jim Miller
Ed Ingham



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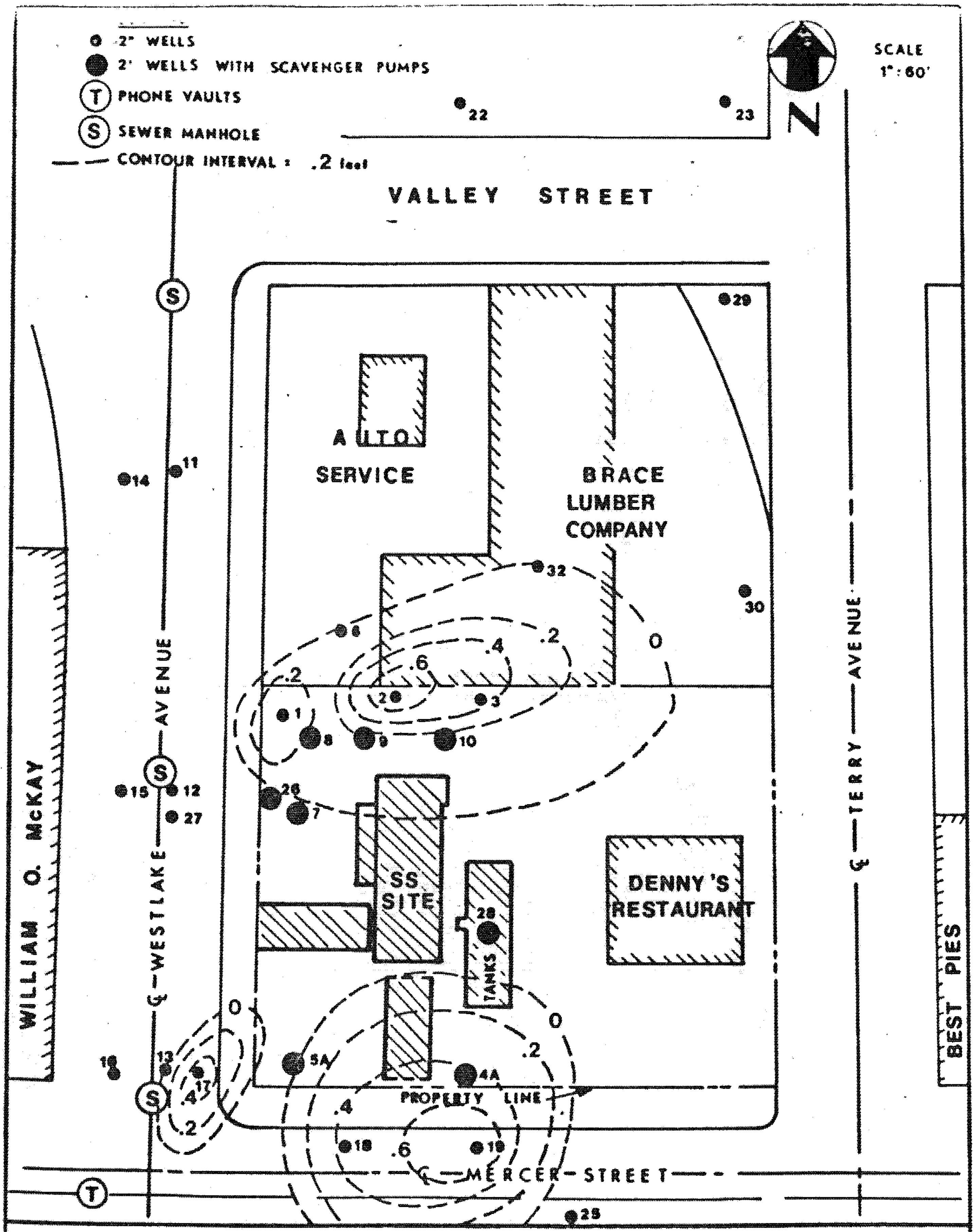
& Geophysicists

Piezometric Elevations 4/23/82
Union Oil Company
Seattle, Washington

PLATE **1**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	[illegible]	5/5/82		



Harding Lawson Associates
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Gasoline Thickness 4/23/82
Union Oil Company
Seattle, Washington

PLATE
2

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	[illegible signature]	5/5/82		

Jim

Harding Lawson Associates

May 19, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 37
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period of April 24 to May 14, 1982. Our previous report, No. 36, covered a monitoring period of April 10 to April 23, 1982 (incorrectly noted as April 10 to April 12).

GASOLINE RECOVERY

A total of 163 gallons of gasoline were recovered during this three weeks of monitoring. The average gasoline recovery rate during this monitoring period (57 gallons per week) was somewhat higher than for the previous four monitoring periods (33 gallons per week). The total volume of gasoline recovered to date is 41,423 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on May 14 are shown on Plate 1. Piezometric levels changed very little; on the average, we observed only a very slight decrease in the levels across the site of about 1 inch. We have been observing consistent rises in piezometric levels across the northern portion which appeared to coicide with the raising of Lake Union water

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levels. During this monitoring period, however, we observed a slight decrease in the piezometric levels in the northern wells.

GASOLINE THICKNESS

Gasoline thicknesses recorded on May 14 are shown on Plate 2. The two concentrations of free gasoline observed near the south and central portions are consistent with past observations, where average gasoline thicknesses have changed very little. There was a significant rise in the gasoline thickness in Well 3, of about .8 feet. This rise is likely related to a .33 foot decrease in this well's piezometric elevation.

EXPLOSIMETER READINGS

Explosimeter readings decreased in several of the wells around the perimeter of the site at both the 4 and 8-foot levels. The decreases offsets the increases observed during the last period. As we commented in our last report, the perimeter explosimeter readings have been erratic and have not indicated any consistent trends in the past several months.

Yours very truly,

HARDING LAWSON ASSOCIATES

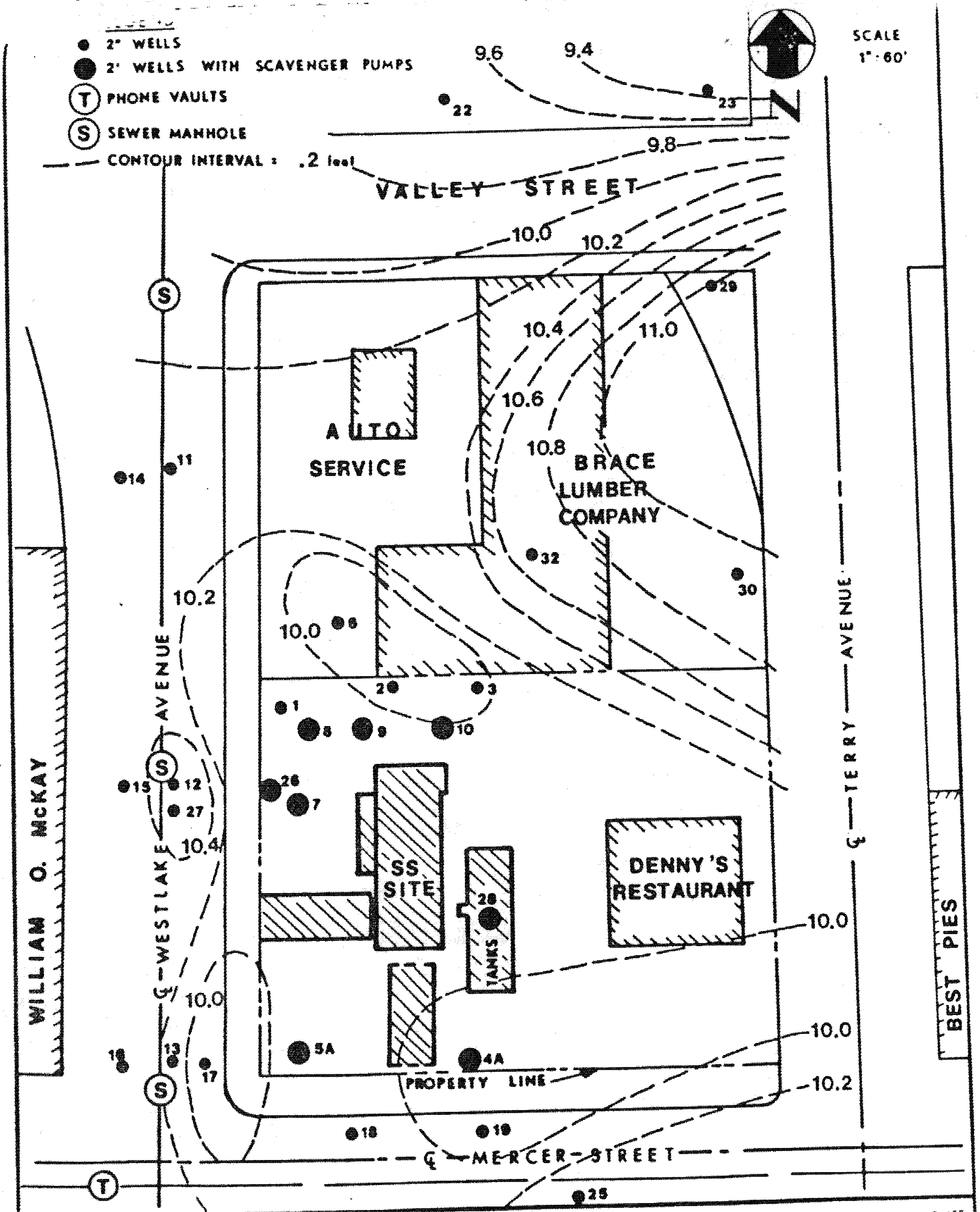
James T. Cameron

James T. Cameron
Project Engineer

VPL/JTC/cag

Attachments

cc: Jim Miller
Ed Ingham



Harding Lawson Associates
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Piezometric Elevation 5/14/82

Union Oil Company
Seattle, Washington

PLATE 1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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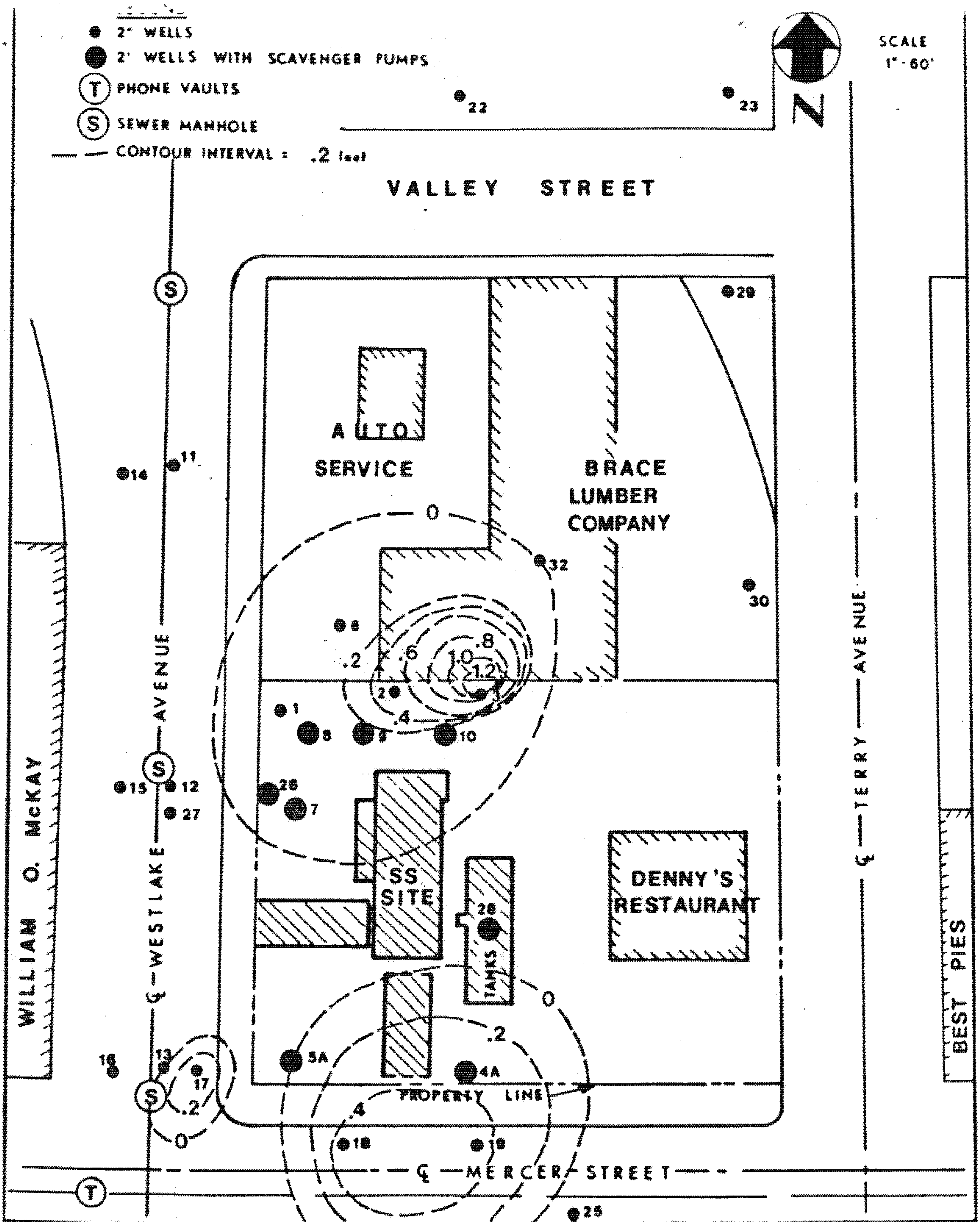

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Engineers, Geologists & Geophysicists

Gasoline Thickness 5/14/82

Union Oil Company
Seattle, Washington

PLATE **2**

14 197 006 07

5/14/82

JTC

Harding Lawson Associates

June 4, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 38
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period of May 15 through May 21, 1982.

GASOLINE RECOVERY

No gasoline was recovered during this time period. The total volume of gasoline recovered to date remains at 41,423 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on May 21 are shown on Plate 1. In general, piezometric levels have not varied significantly from those recorded in our previous report. Readings taken on the southern half of the block appear to have risen on the order of .2 feet from readings taken a week earlier. There appears to be a slight depression at the south end of the block in the vicinity of Wells 13, 17, 18, and 19, and another in the middle portion of the block in the vicinity of Wells 2, 3, 7, 8, and 9. Both are most likely due to pumping in nearby wells. It appears that the drawdown pumps are performing an adequate job maintaining a depression to keep the liquid gasoline localized in the southern half of the block.

GASOLINE THICKNESS

Gasoline thicknesses recorded on May 21 are shown on Plate 2. There are still two main concentrations of liquid gasoline. One, in the middle portion of the block in the vicinity of Wells 2 and 3, and the other at the southern end of the block in the vicinity of Wells 18 and 19. The thicknesses recorded in the middle portion of the block have dropped since the May 14 readings with maximum thicknesses of .5 feet recorded at Wells 2 and 3. Maximum thicknesses recorded at the south end of the site were .6 and 1 foot at Wells 19 and 18, respectively. As has been the case in past readings, gasoline thicknesses diminish quite rapidly away from the wells of maximum thickness.

EXPLOSIMETER READINGS

Explosimeter readings indicated no noticeable change from those taken on May 14, 1982. In general, explosimeter readings have remained at or near the 100% level at the 4-foot and 8-foot levels for most of the wells. Wells 22 and 23 have indicated no vapor levels at either the 4 or the 8-foot level since the end of April, 1982. Well 16 has indicated vapor levels less than 20% at both the 4-foot and 8-foot levels since the middle of February, 1982.

Yours very truly,

HARDING LAWSON ASSOCIATES

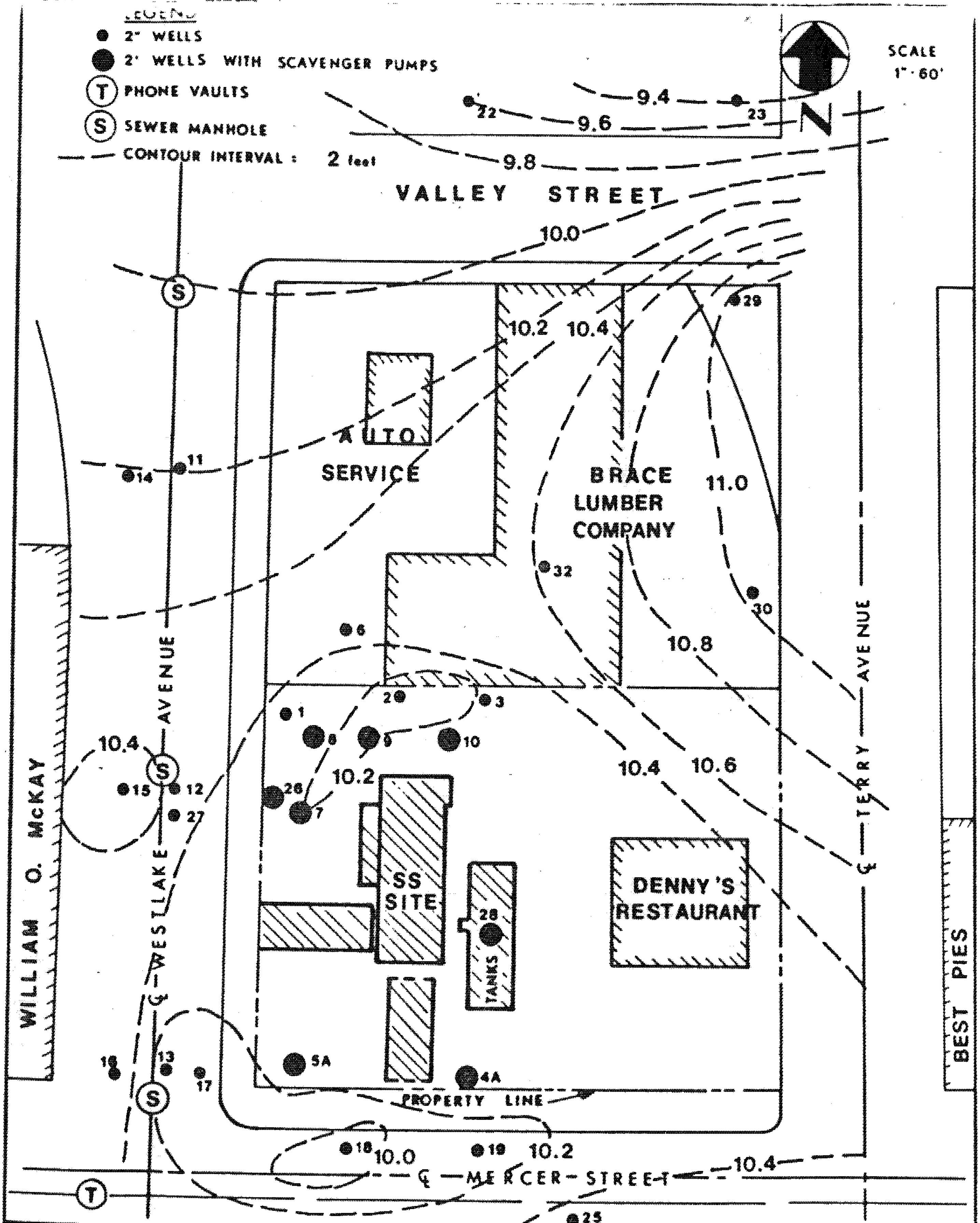
James T. Cameron

James T. Cameron
Project Manager

JTC/cag

Attachments

cc: Jim Miller
Ed Ingham



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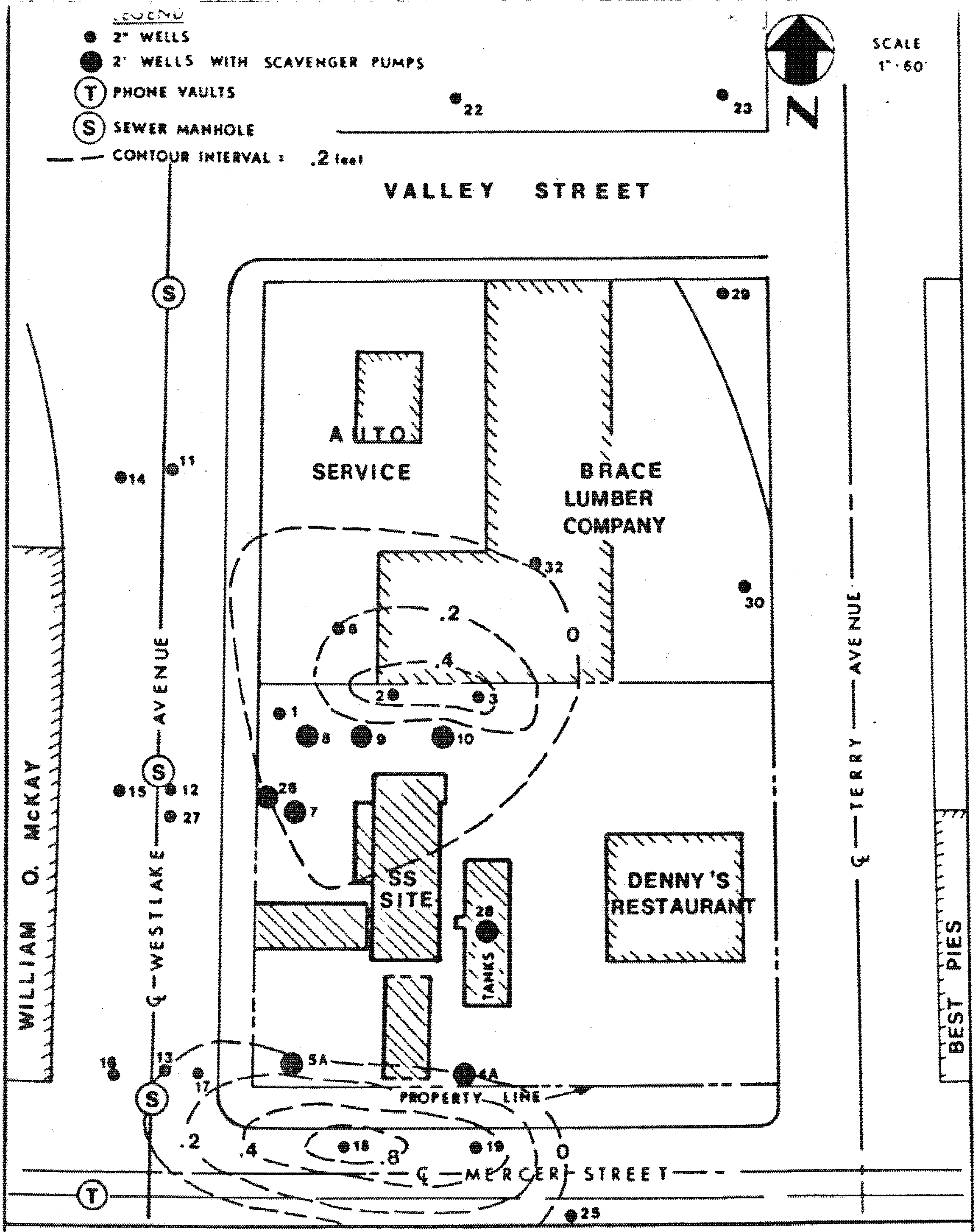
Engineers Geologists
& Geophysicists

Piezometric Elevations 5 21 82
Union Oil Company
Seattle, Washington

1



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Engineers, Geologists
& Geophysicists

Gasoline Thickness 5/21/82
Union Oil Company
Seattle, Washington

2

Harding Lawson Associates

June 18, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 39
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period of May 22 through June 11, 1982.

GASOLINE RECOVERY

The scavenger and drawdown pumps have not been operating correctly during this time period and have resulted in reduced rates of extraction of gasoline and water. No gasoline was recovered during this time period. The total volume of gasoline recovered to date remains at 41,423 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on June 11, 1982, are shown on Plate 1. The piezometric levels appear to have dropped generally .5 feet over most of the site. We feel this is probably due to the recent lack of rainfall. Piezometric levels at the north end of the block near Lake Union remain near those recorded in our previous report (June 4). The general configuration of the piezometric surface is very similar to that recorded previously and still indicates a slight ridge across the middle portion of the block blocking the flow of liquid gasoline to the north.

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GASOLINE THICKNESS

Gasoline thicknesses recorded on June 11, 1982, are shown on Plate 2. Based on comparison with gasoline thickness readings taken on May 21, 1982, it appears that gasoline thicknesses have reduced by approximately 50 percent. However, throughout the interim three week period gasoline thicknesses have fluctuated by as much as 100 percent as the scavenger pumps are rotated among the various retrieval wells. The extent of detectable gasoline at the site still remains localized in two zones; in the middle of the block and at the southern end of the block.

EXPLOSIMETER READINGS

Except for Wells 14, 16, and 22, explosimeter readings have indicated little change from previous readings. In the most recent three week period, vapor readings in Well 14 have increased from approximately 35 to 100 percent at the 4-foot level, Well 16 has increased from 0 to 40 percent at the 4-foot level and 10 to 40 percent at the 8-foot level, and Well 22 has increased from 0 to approximately 100 percent at the 4 and 8-foot levels. In addition, up to 10 percent explosimeter levels were detected in the telephone vaults east of the site and required that the fans be turned on to remove the vapors. We feel that the rise in explosimeter levels is due to the recent warm spell which encourages vapors to move more quickly away from the gasoline source than during cooler times.

Yours very truly,

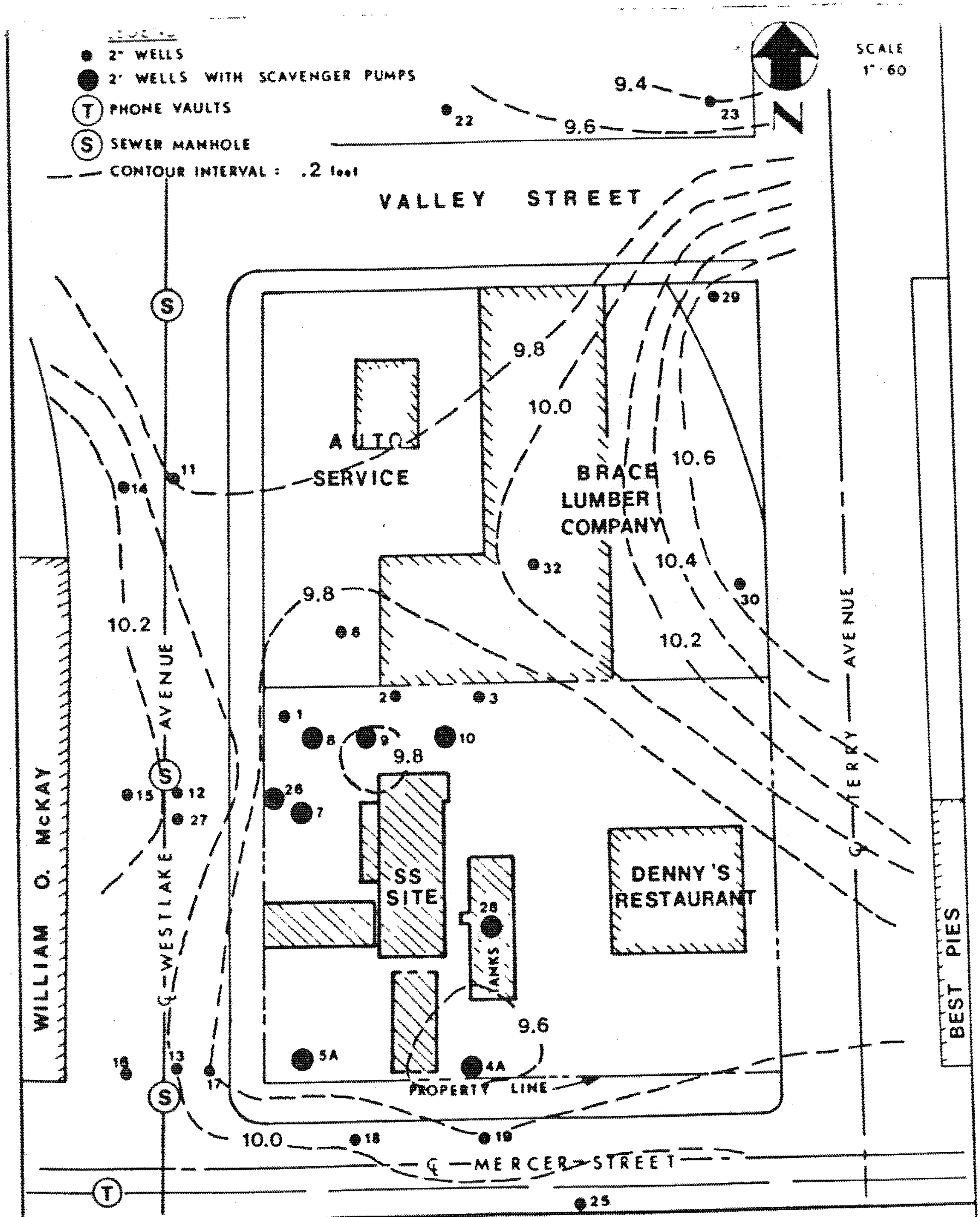
HARDING LAWSON ASSOCIATES

James T. Cameron

James T. Cameron
Project Manager

JTC/cag

cc: Jim Miller
Ed Ingham



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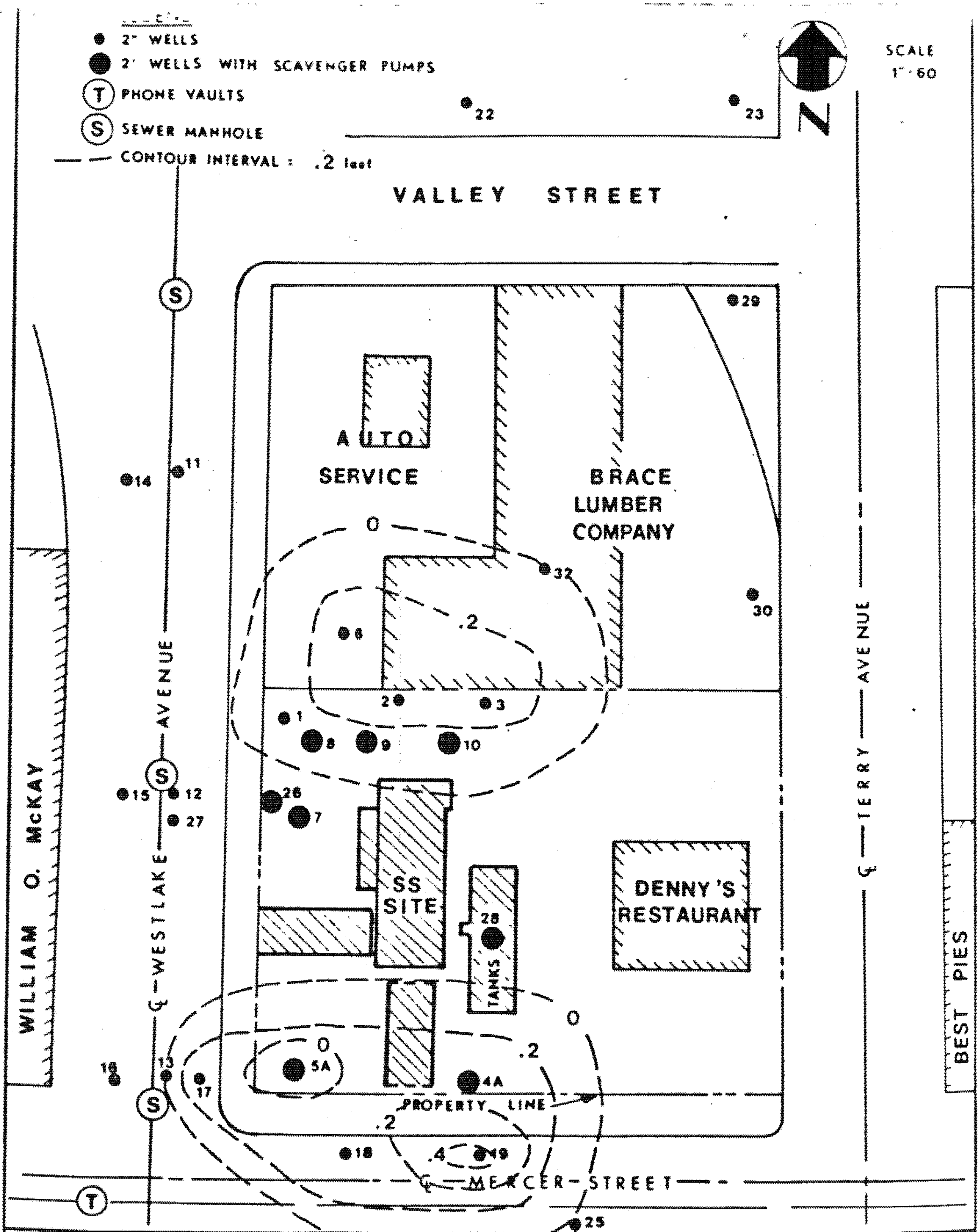
Piezometric Elevations 6/11/82
Union Oil Company
Seattle, Washington

1

14 197,006.07 6/18/82



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& Geophysicists

Gasoline Thickness 6/11/82
Union Oil Company
Seattle, Washington

2

BJT 14,197,006.07 6/2/82

Harding Lawson Associates

July 2, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 40
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period of June 12 through June 18, 1982.

GASOLINE RECOVERY

No gasoline was recovered during this time period. The total volume of gasoline recovered to date remains at 41,423 gallons.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on June 18, 1982, are shown on Plate 1. Cars or other obstructions over wells prevented a number of readings from being taken. Therefore, the estimated piezometric surface is only roughly correct, especially on the east side of the site. However, in general, it appears that the piezometric surface has not changed appreciably since that presented in our previous report for the June 11, 1982 readings. At the northern end of the site, the piezometric surface appears to have dropped on the order of 0.2 feet. The local highpoint on the piezometric surface in the vicinity of Well 5A probably reflects capillary rise due to the fine soils in this area.

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GASOLINE THICKNESS

Gasoline thicknesses recorded on June 18 are shown on Plate 2. Two general areas of liquid gasoline concentration still remain; one in the middle of the block in the vicinity of Wells 1, 2, and 3, and the other at the southern end of the block in the vicinity of Wells 4 and 5. The maximum gasoline thicknesses recorded in each of these zones was on the order of .6 feet on June 18 which is .2 to .4 feet higher than that recorded on June 11. However, the extent of the measurable liquid gasoline does not appear to have expanded.

EXPLOSIMETER READINGS

Except for Wells 11, 15, 16, and 22, explosimeter readings taken on June 18, 1982, have not changed significantly from those recorded on June 11. Wells 11, 15, 16, and 22 all dropped between 30 and 80 percent from those readings taken on June 11 at the 4-foot level. Well 13 at the 4-foot level increased from a 10 percent reading on June 11 to a 100 percent reading on June 18. However, immediately prior readings indicated 80 to 100 percent explosimeter levels in this well.

Explosimeter levels generally vary substantially throughout the site. However, the general lowering of explosimeter levels noted in the above four wells may reflect the recent cooling trend in the weather which would tend to slow down the movement of gasoline vapors through the soil.

Yours very truly,

HARDING LAWSON ASSOCIATES

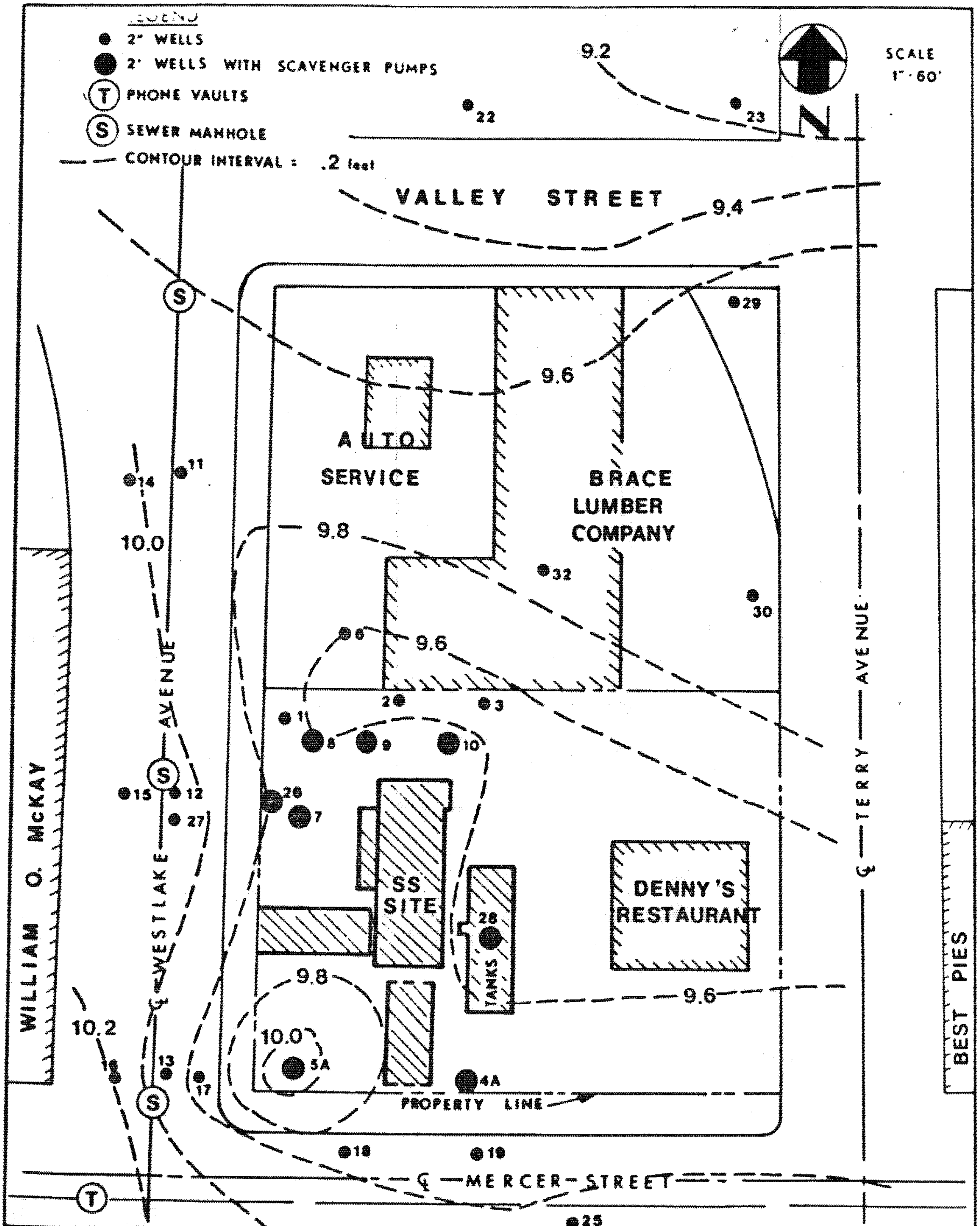
James T. Cameron

James T. Cameron
Project Engineer

JTC/cag

Attachments

cc: Jim Miller
Ed Ingham



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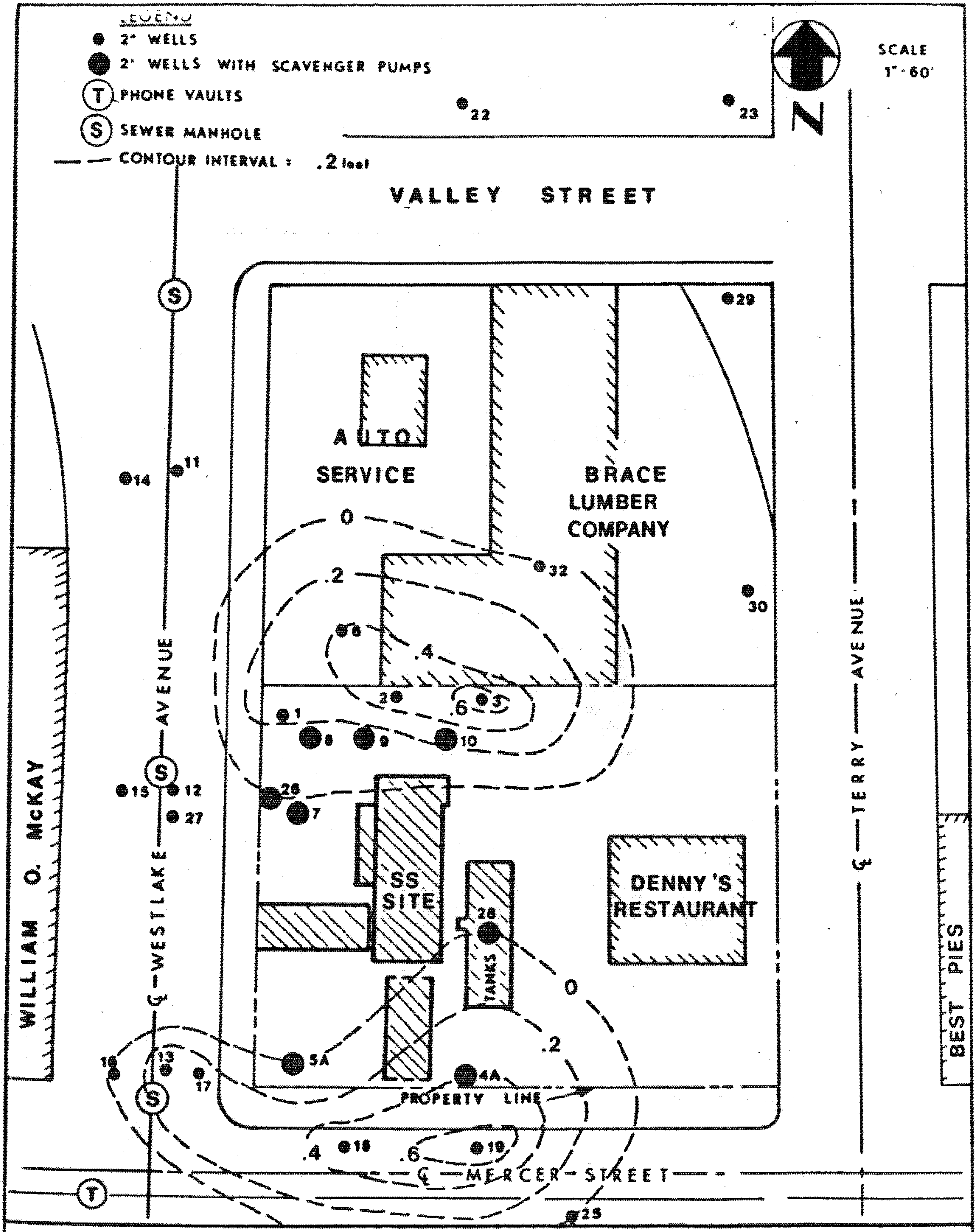
Piezometric Elevations 6/18/82
Union Oil Company
Seattle, Washington

1

BJT 14.197.006.07



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Engineers Geologists
& Geophysicists

Gasoline Thickness 6/18/82
Union Oil Company
Seattle, Washington

PLATE **2**

Harding Lawson Associates

July 16, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 41
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period of June 19 through July 7, 1982.

GASOLINE RECOVERY

Ninety five gallons of gasoline were recovered during this time period. The total volume of gasoline recovered to date is 41,518 gallons. This is the first reported gasoline recovery since May 15, 1982. This recovery indicates an average recovery rate of less than 14 gallons per week during this period. This rate of recovery is substantially lower than previously reported recovery rates.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on July 7, 1982 are shown on Plate 1. The piezometric surface has not changed appreciably since our last report.

GASOLINE THICKNESS

Gasoline thicknesses recorded on July 7, 1982, are presented on Plate 2. Gasoline thicknesses have decreased slightly from those reported in Progress Report No. 40. Two areas of liquid gasoline remain, one in the central part of the block and one in the southern part. The extent of these two zones

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has not changed appreciably. An estimated 0.1 feet of gasoline in the area of Well 8 suggests that the two areas of liquid gasoline remain connected.

EXPLOSIMETER READINGS

Explosimeter readings increased in all wells where prior readings were less than 100%. With the exception of Well 23, all wells measured indicate a 100% explosimeter reading at the 8-foot depth. Wells 11, 14, 15, 16, and 22 all had increased explosimeter readings. This increase can probably be attributed to the warmer weather during this period.

Yours very truly,

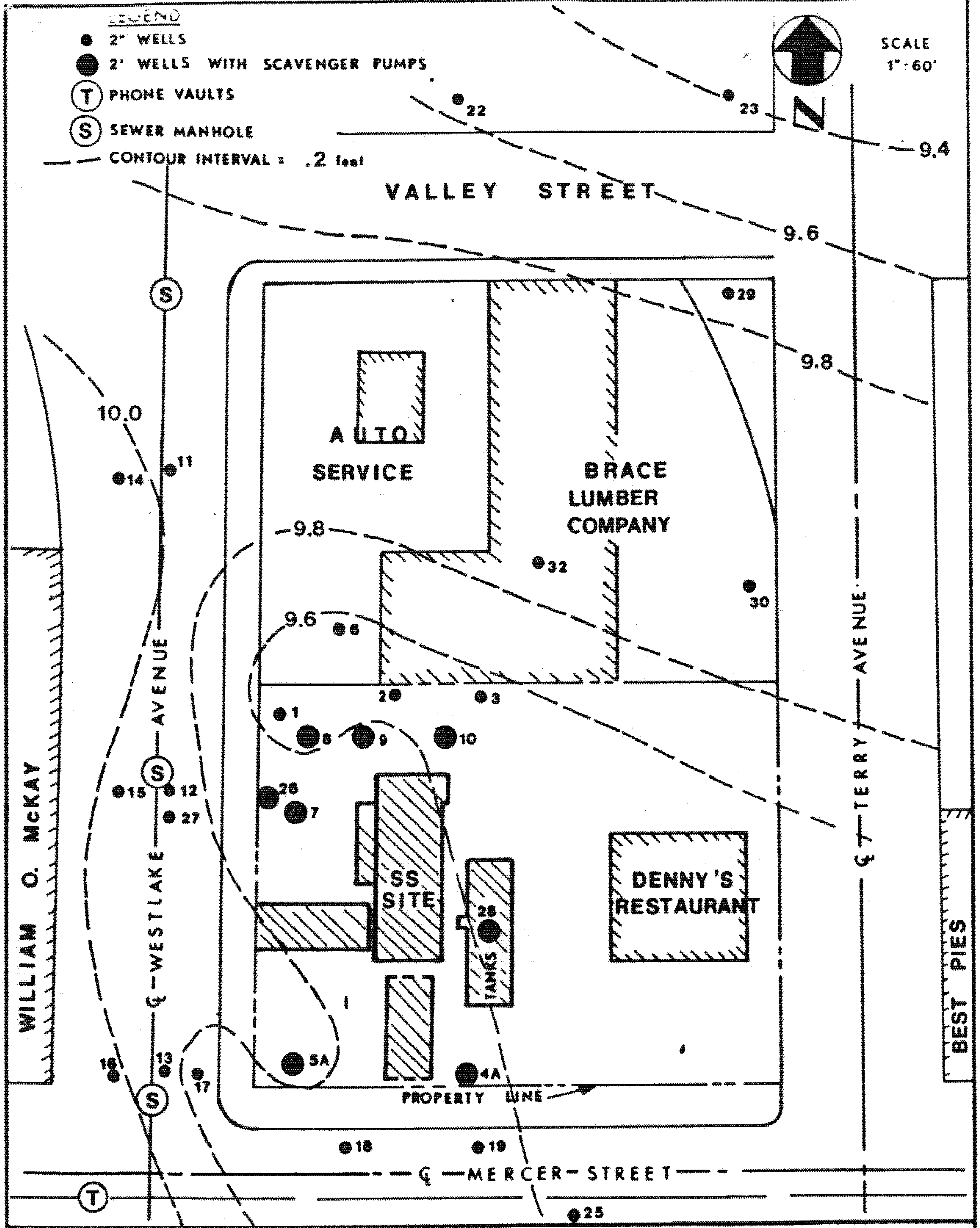
HARDING LAWSON ASSOCIATES

Stephen C. Perrigo
Geologist

SCP/cag

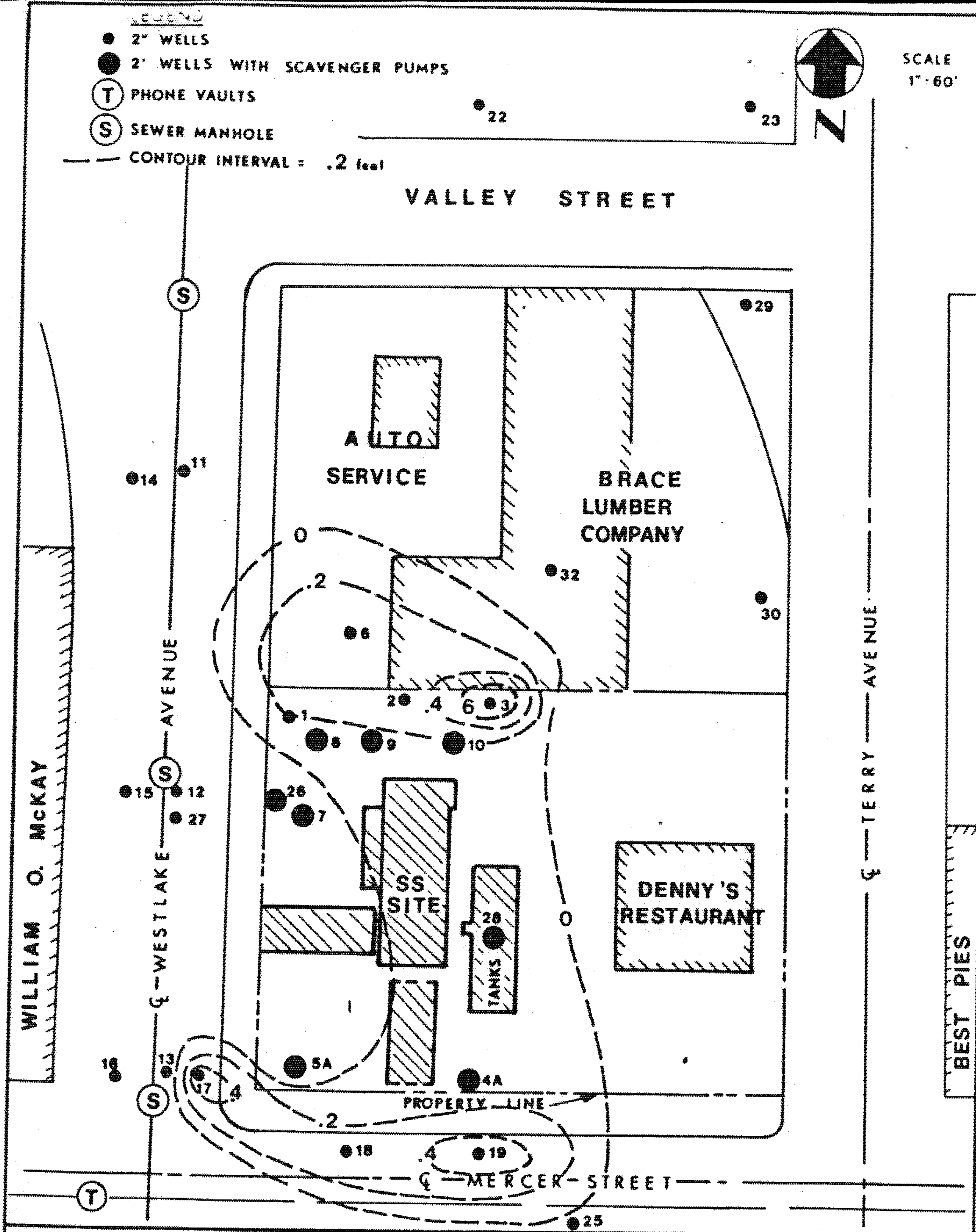
Attachment

cc: Jim Miller
Ed Ingham



Harding Lawson Associates Engineers, Geologists & Geophysicists	**Piezometric Elevations** 7/7/82 Union Oil Company Seattle, Washington	PLATE **1**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCP	7/16/82		



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Engineers Geologists
& Geophysicists

Gasoline Thickness 7/7/82

Union Oil Company
Seattle, Washington

PLATE **2**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCD	7/16/82		

Harding Lawson Associates

July 29, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 42
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring operations for the period of July 8 through July 16, 1982.

GASOLINE RECOVERY

Sixty-one gallons of gasoline were recovered during this time period. The total volume recovered to date is 14,579 gallons. During the month of June not all of the pumps were operating correctly. During the time period reported here, the pumps have operated correctly and the rate of gasoline recovery is returning to the approximate rates reported in April and May.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on July 16, 1982, are shown on Plate 1. The piezometric surface has generally risen since the last time period. The general piezometric surface configuration remains similar.

GASOLINE THICKNESS

Gasoline thicknesses recorded on July 16, 1982, are presented on Plate 2. Gasoline thicknesses remain about the same in the central part of the site and show an increase in the southern part of the site. The general configuration of the two areas of liquid gasoline remain the same.

Harding Lawson Associates

EXPLOSIMETER READINGS

Explosimeter readings at the 4-foot depth decreased in several of the wells, particularly those in which no liquid gasoline was reported. At the 8-foot depth, decreases in explosimeter readings were observed in Wells 16 and 22. The noted decrease can probably be attributed to the cooler weather during this period.

Yours very truly,

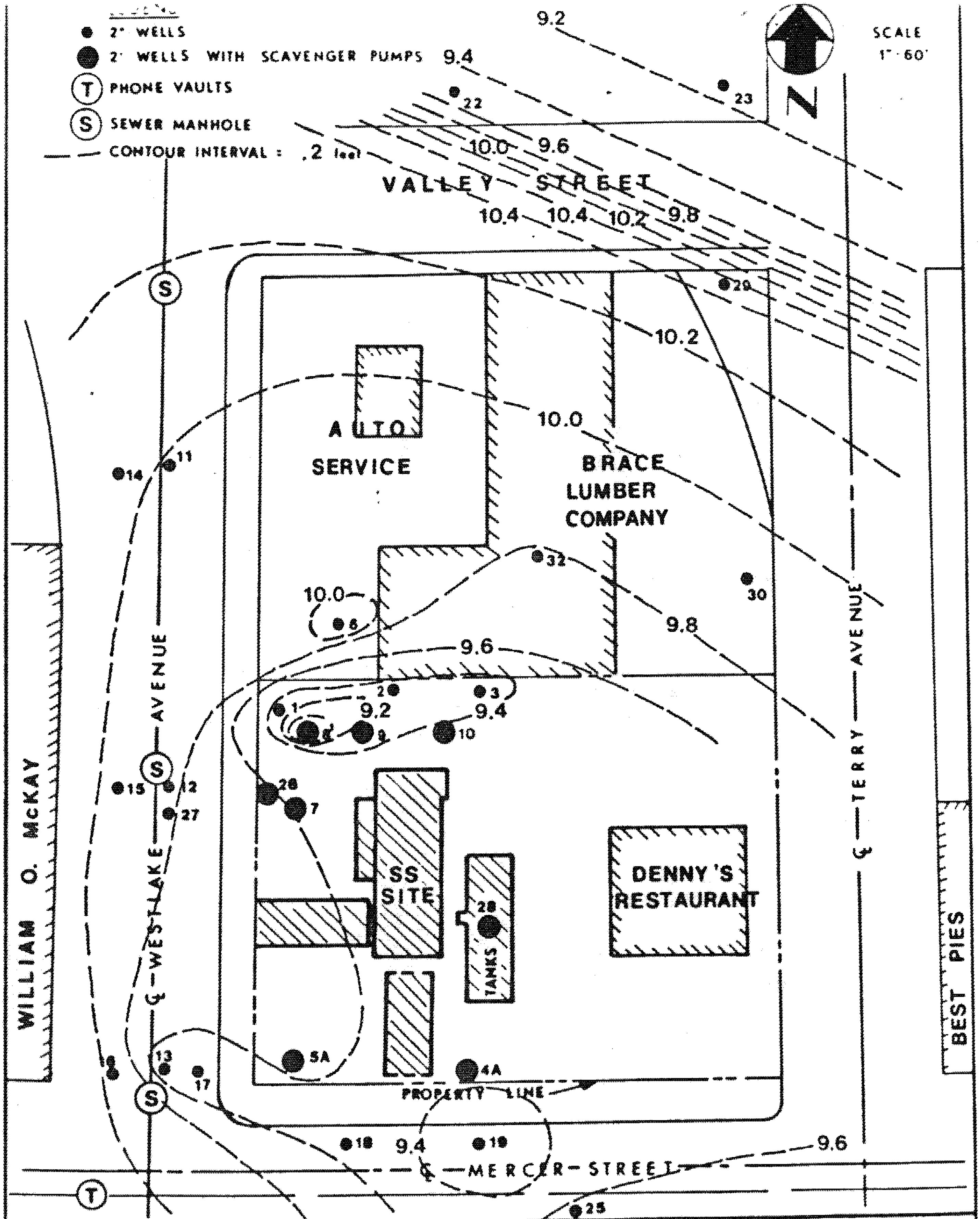
HARDING LAWSON ASSOCIATES

Stephen C. Perrigo
Geologist

SCP/cag

Attachments

cc: Mr. Jim Miller
Mr. Ed Ingham



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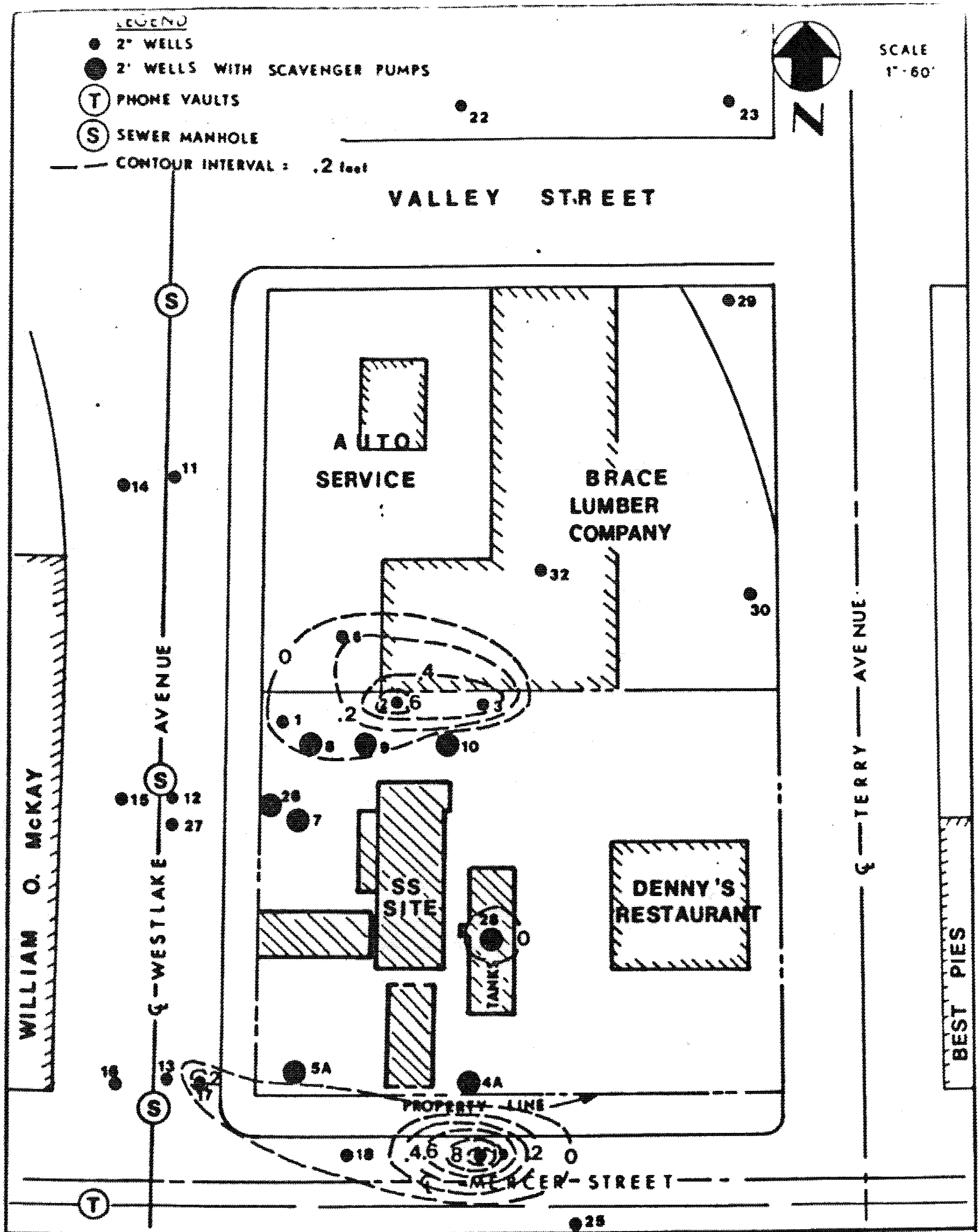
Engineers Geologists
& Geophysicists

Piezometric Elevations 7/16/82

Union Oil Company
Seattle, Washington

PLATE **1**

3/20/82



Harding Lawson Associates
Engineers, Geologists & Geophysicists

Gasoline Thickness 7/16/82

Union Oil Company
Seattle, Washington

PLATE **2**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,187,006.07		7/20/82		

August 27, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 43
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring for the period of July 16 through August 18, 1982. As agreed in our meeting of August 9, 1982, progress reports will now be prepared monthly. Plot plans illustrating gasoline thickness and piezometric elevations will continue to be prepared on a semi-monthly basis. Our previous report had one error which should be corrected. The total gasoline recovery should have been 41,579 rather than 14,579.

GASOLINE RECOVERY

One hundred and nineteen gallons were recovered during this time period. The total volume recovered to date is 41,698 gallons. Drawdown and recovery efforts are now being concentrated in the southern part of the site; however, mechanical pump failures during this time period have interrupted recovery operations. We expect that when the depressant pump in Well No. 4 is operating correctly, we will begin recovering more gasoline from the area of monitoring Wells No. 18 and 19.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on August 4 and August 18, 1982, are shown on Plates 1 and 3, respectively. Generally, over the past month, piezometric elevations have dropped on the order of about 0.2 feet. Since depressant pumps have been transferred to the southern part of the site, the gradients at the central part of the site have flattened somewhat.

GASOLINE THICKNESS

Gasoline thicknesses recorded on August 4 and August 18, 1982, are shown on Plates 2 and 4, respectively. On August 4, 1982, the gasoline thickness in Well No. 6 increased appreciably over the thickness indicated in Progress Report No. 42. This was accompanied by a corresponding lowering of the piezometric elevation in this well. With the exception of the gasoline thickness recorded in Well No. 6, there was not any appreciable change from those thicknesses reported in Progress Report No. 42 and those reported on August 4, 1982 (Plate 3).

Gasoline thicknesses on August 18, 1982, are significantly different from those reported earlier in the month. These observations indicate conditions after pumping shifted from the central part of the site to the southern area. By August 18, 1982, gasoline thicknesses had decreased significantly over the central part of the site. The area with small amounts of product (less than 0.2 feet) has increased somewhat as a response to the change in pumping activity. Gasoline thicknesses in the southern part of the site have not changed appreciably during this reporting period.

EXPLOSIMETER READINGS

During this reporting period, explosimeter readings have been increasing in all wells where levels were previously below 100 percent. On August 18, 1982, all wells measured except Well No. 23 indicated 100 percent explosimeter readings at the 8-foot level. At the 4-foot level, explosimeter readings have increased appreciably. Wells which typically show no gasoline have explosimeter readings averaging 50 percent higher than they did one month ago. This is probably due in part to warmer weather conditions and a seasonal warming of the soil environment which has the effect of increasing the vapor pressure on the gasoline.

Our records indicate a similar rise in explosimeter readings at about this time last year.

Yours very truly,

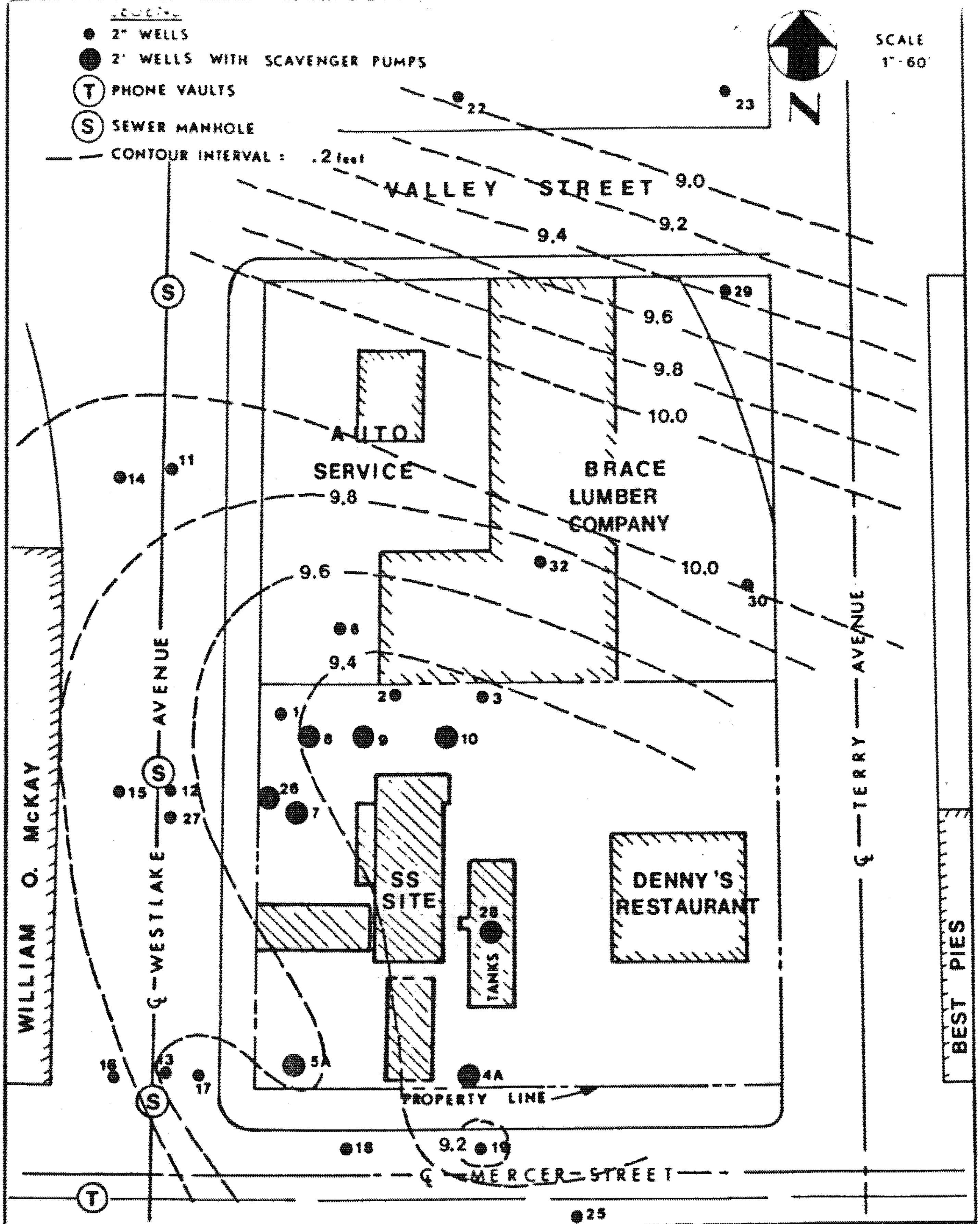
HARDING LAWSON ASSOCIATES

Stephen C. Perrigo
Geologist

SCP/cag

Attachments

cc: Jim Miller
Ed Ingham



Harding Lawson Associates
Engineers, Geologists
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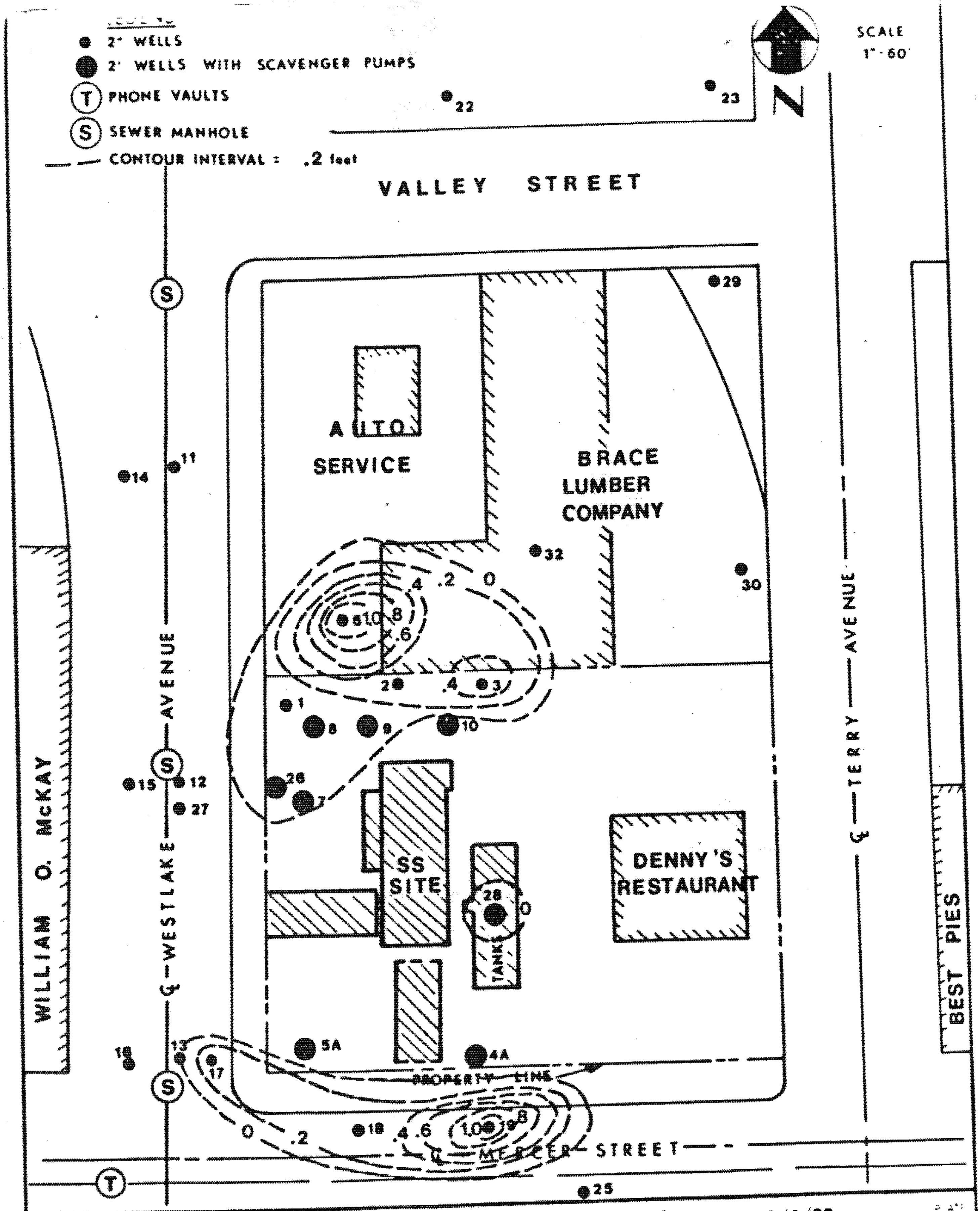
Piezometric Elevations 8/4/82
Union Oil Company
Seattle, Washington

1

BJT 14,197,006.07 SCP 8/27/82



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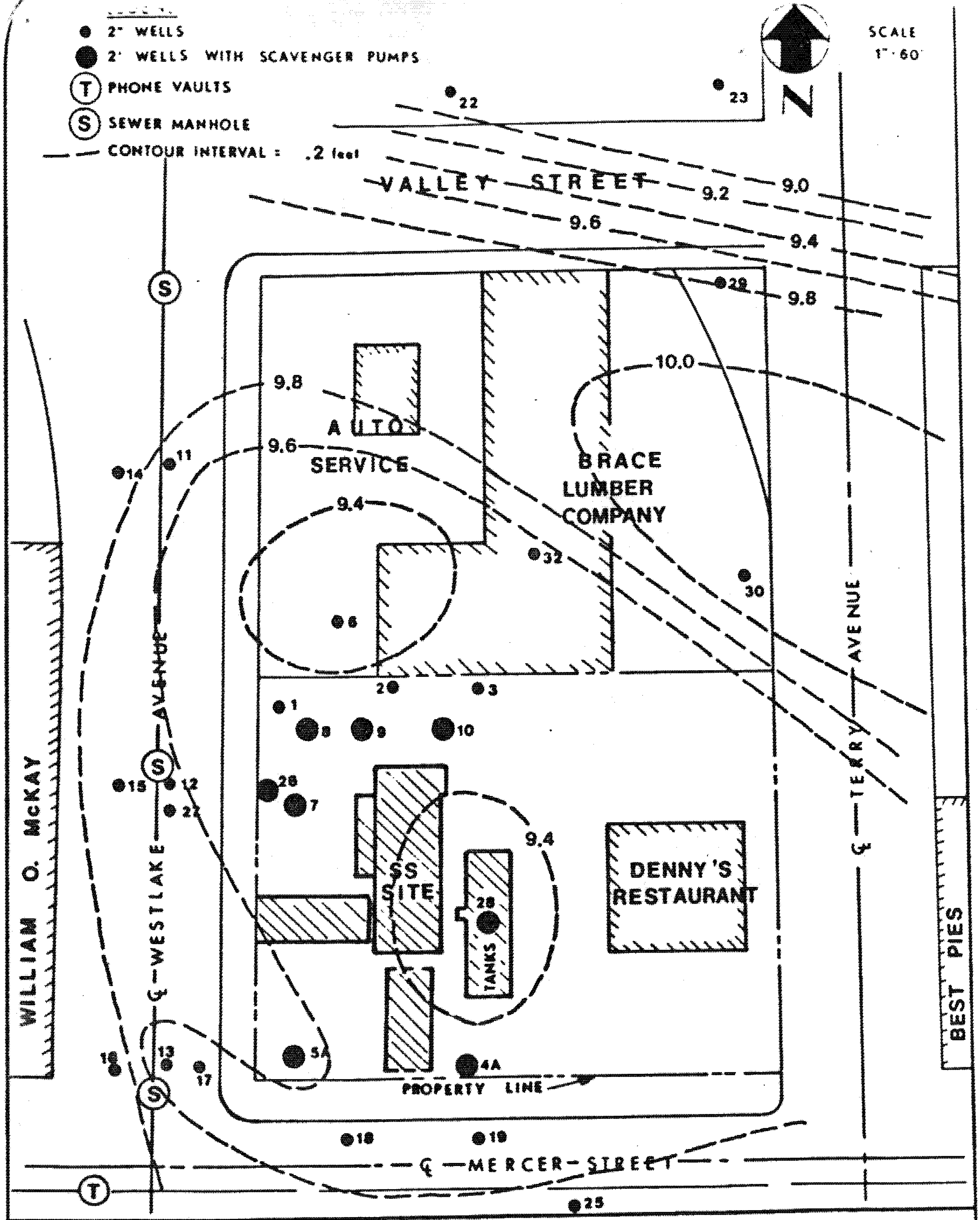
& Geophysicists

Gasoline Thickness 8/4/82

Union Oil Company
Seattle, Washington

2

BJT 14,197,006.07 SCP 8/27/82



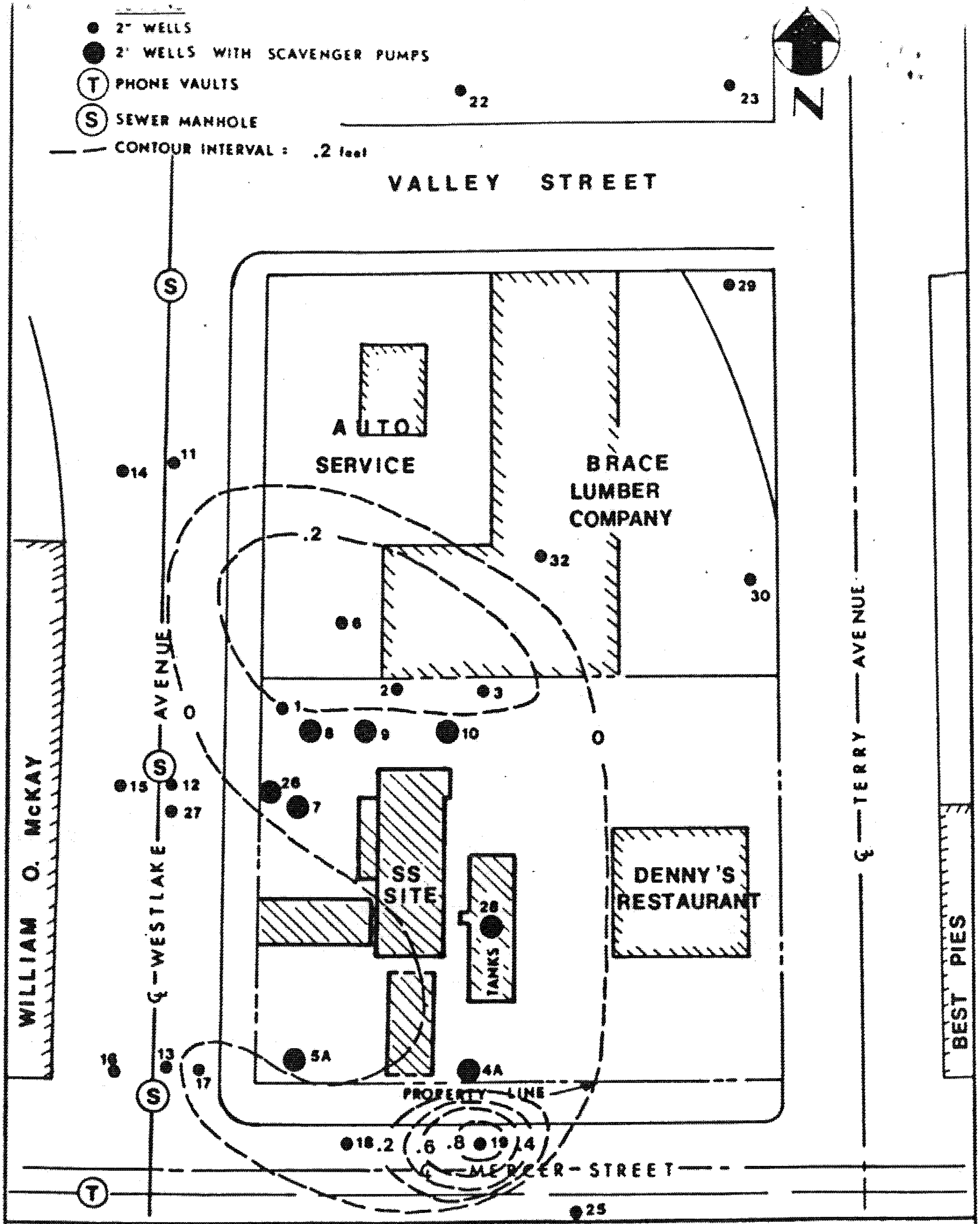
Harding Lawson Associates
Engineers, Geologists & Geophysicists

Piezometric Elevations 8/18/82

Union Oil Company
Seattle, Washington

3

BJT	14,197,006.07	SCP	8/23/82



Harding Lawson Associates
Engineers Geologists
& Geophysicists

Gasoline Thickness 8/18/82

Union Oil Company
Seattle, Washington

PLATE **4**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCP	8/27/82		

Harding Lawson Associates

September 28, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 44
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring for the period of August 18, through September 17, 1982.

GASOLINE RECOVERY

Eighty gallons of gasoline were recovered during this time period for a total volume recovered to date of 41,778 gallons. During this period the pumps were working correctly; however, an abnormally low groundwater level is inhibiting efforts to form an adequate cone of depression. Low groundwater levels are due to seasonal groundwater lowering and the near record low water levels recently recorded in Lake Union. With the advent of the winter rains and raising of the groundwater table, the efficiency of the recovery well systems should be restored. We expect that as groundwater levels rise, the rate of gasoline recovery will increase.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on September 1 and September 17, 1982, are shown on Plates 1 and 3, respectively. The piezometric elevations have continued to drop as they did during the previous month. During the period covered by this report, piezometric levels have dropped an average of 0.32 feet. During this same period, the level of Lake Union has dropped 0.47 feet according to the U. S. Army Corps of Engineers. The general shape of the piezometric surface

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has remained stable during the past month.

GASOLINE THICKNESS

Gasoline thicknesses recorded on September 1 and September 17, 1982, are shown on Plates 2 and 4, respectively. Gasoline thicknesses have not changed appreciably since our last progress report. The extent and thickness of measurable product remains about the same with the exception of the values reported in Well No. 19. During this reporting period, the gasoline thickness in Well No. 19 has increased from 0.8 feet to 1.7 feet. This increase was accompanied by a 0.5 foot drop in the piezometric elevation. We feel that the increase in gasoline thickness is largely due to release of trapped gasoline from the soil due to the lowering of the groundwater levels.

EXPLOSIMETER READINGS

During this reporting period, explosimeter readings have decreased in most of those wells in which no gasoline was reported. Explosimeter readings continue to be high at the 8-foot level. At the 4-foot level, readings have fluctuated. This fluctuation is probably a response to short term weather conditions. The tendency over the month indicates a lowering of explosivity at the 4-foot level as would be expected with cooler fall temperatures.

Yours very truly,

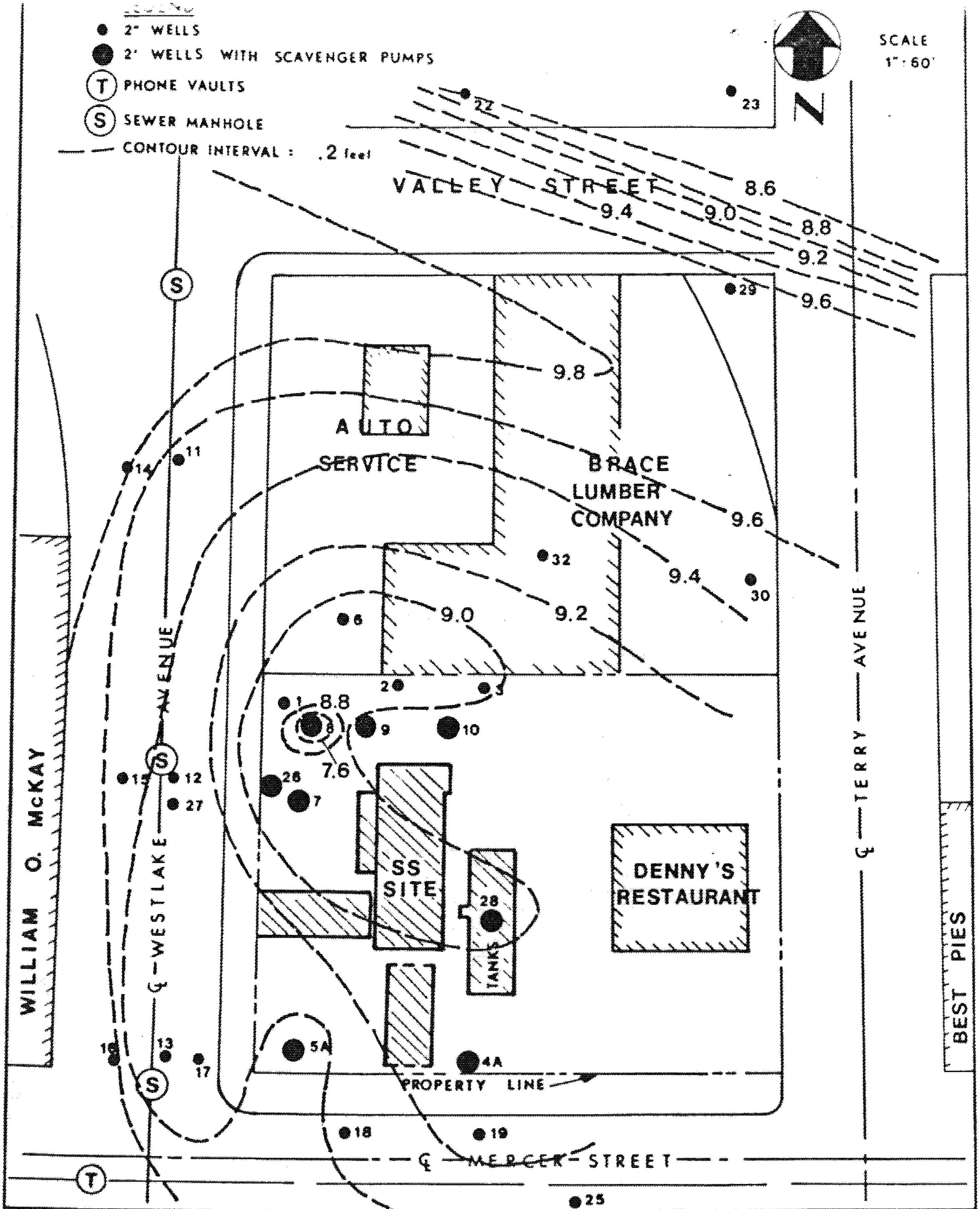
HARDING LAWSON ASSOCIATES

Stephen C. Perrigo
Geologist

SCP/cag

Attachments

cc: Ed Ingham
Jim Miller

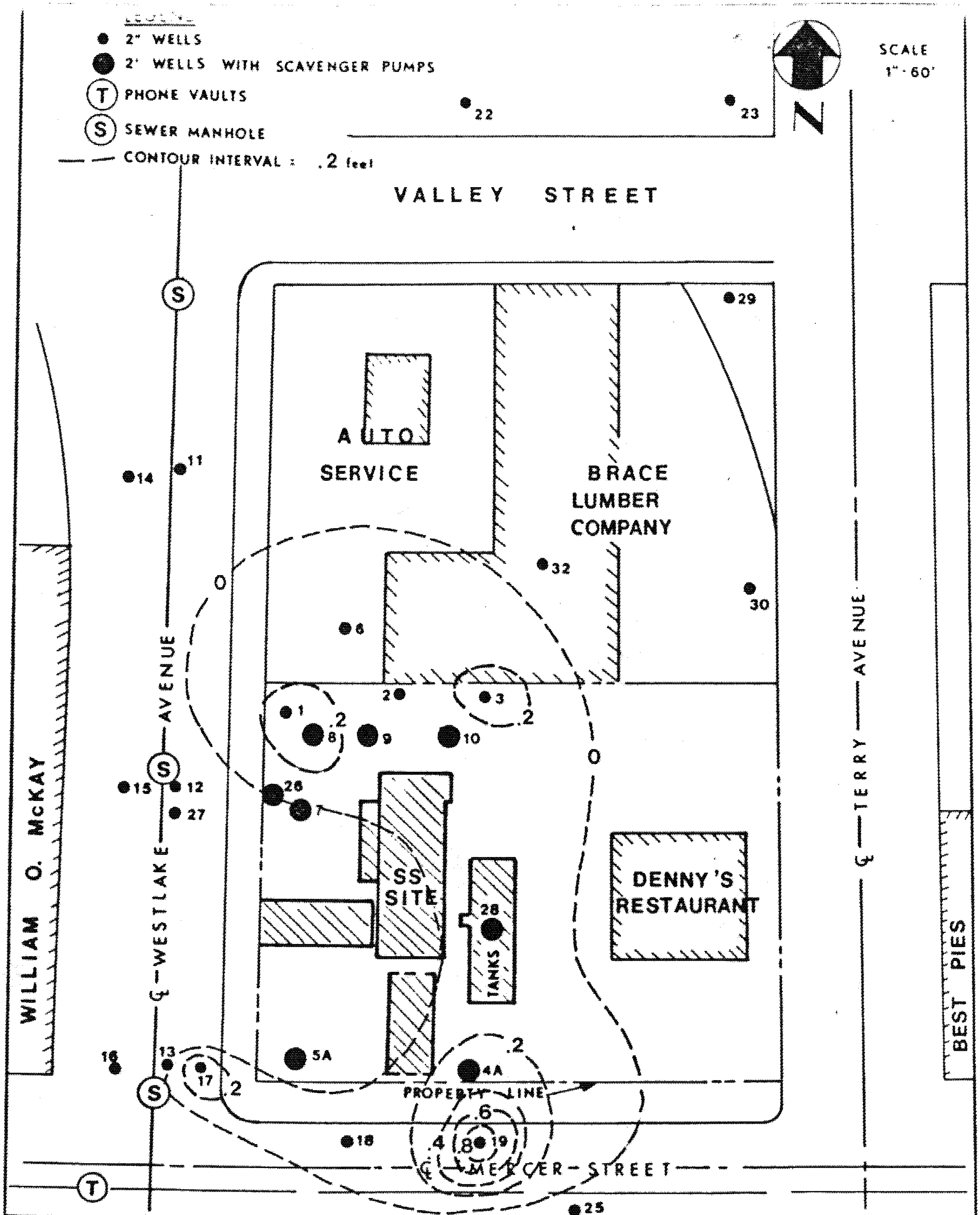


Harding Lawson Associates
Engineers Geologists
& Geophysicists

Piezometric Elevations 9/1/82
Union Oil Company
Seattle, Washington

1

BJT	14,197,006.07	SCP	9/28/82	

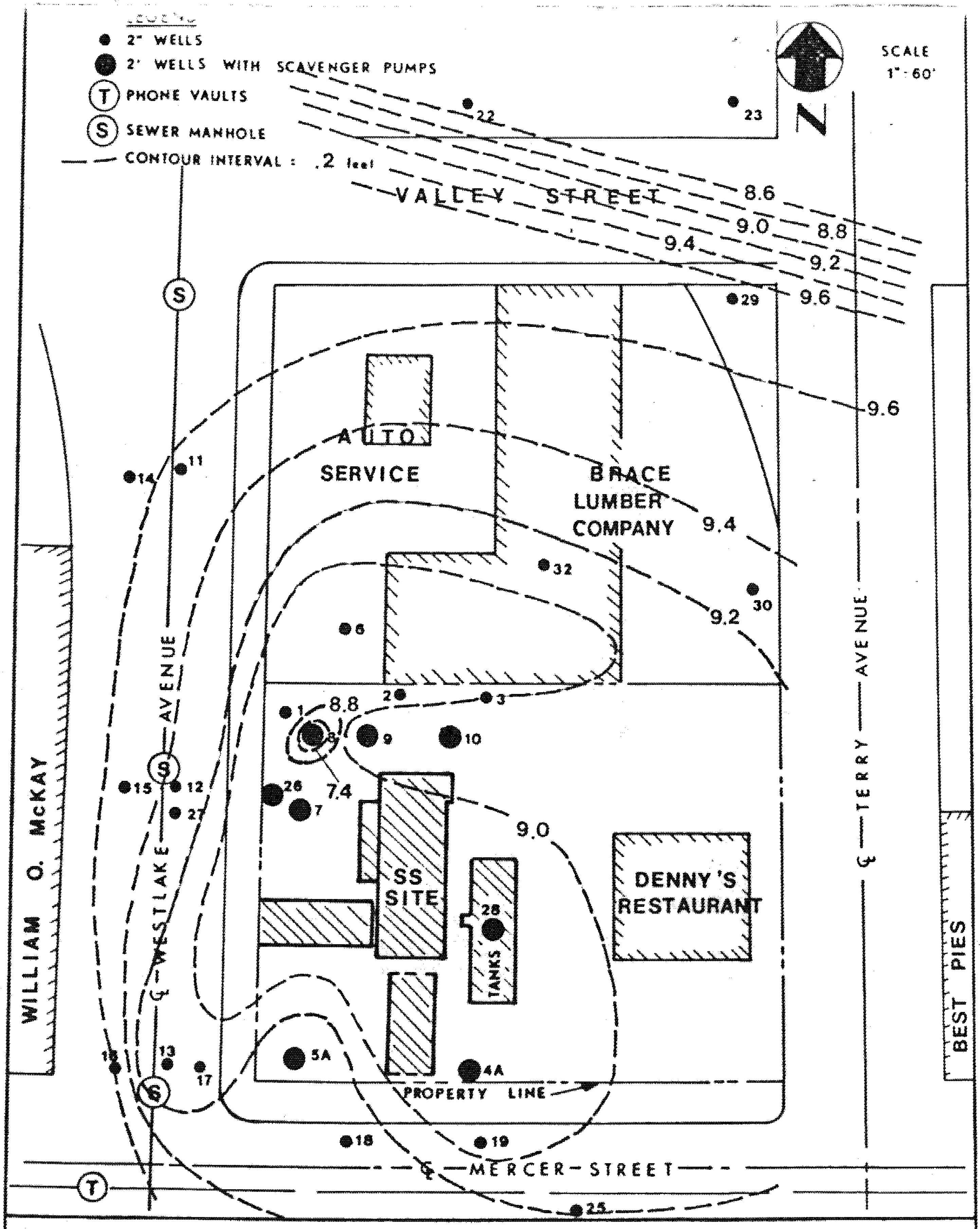


Harding Lawson Associates
Engineers Geologists
& Geophysicists

Gasoline Thickness 9/1/82
Union Oil Company
Seattle, Washington

PLATE **2**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCP	9/28/82		



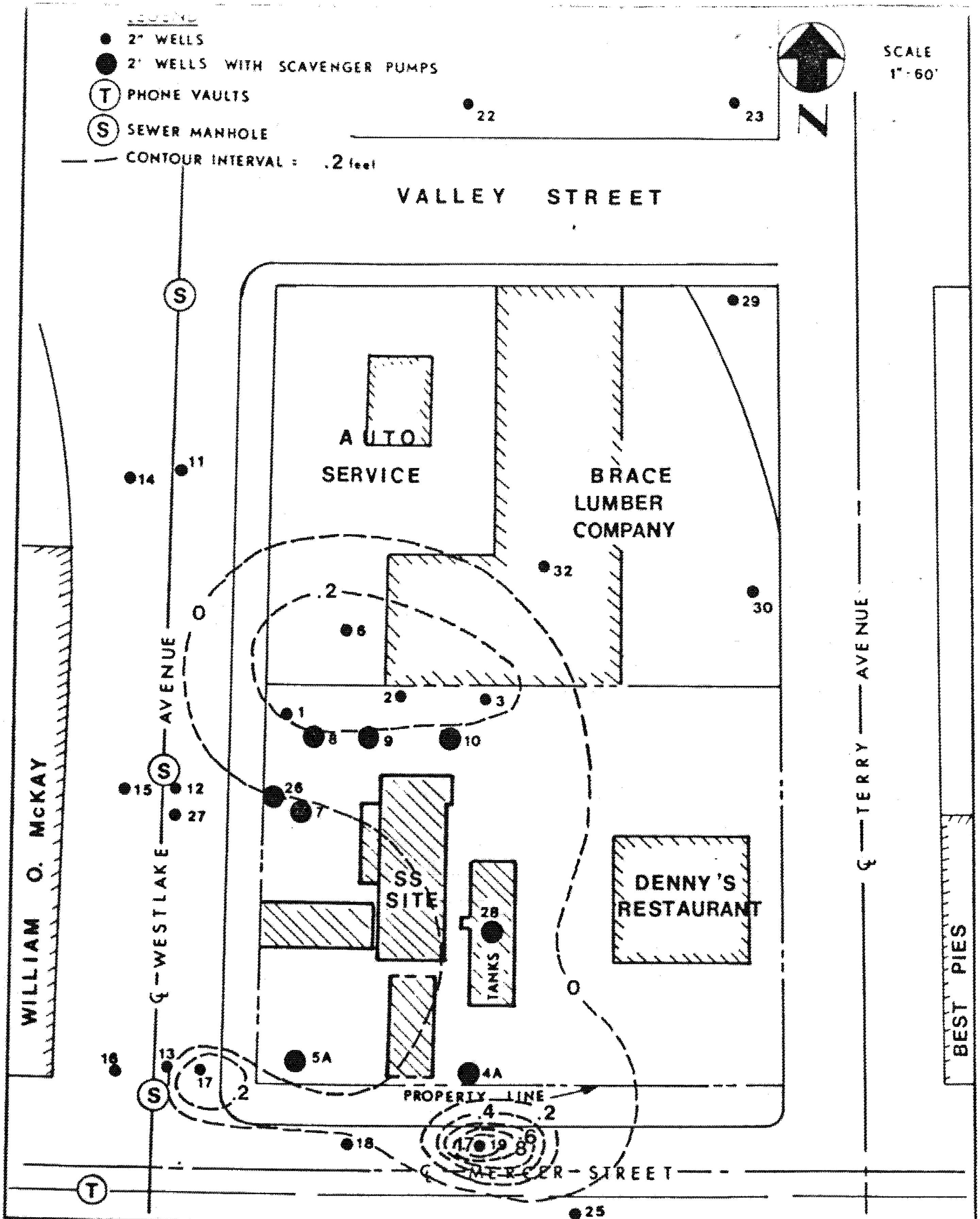
Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Piezometric Elevations 9/17/82

Union Oil Company
Seattle, Washington

PLATE **3**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCP	9/28/82		



Harding Lawson Associates
Engineers Geologists & Geophysicists

Gasoline Thickness 9/17/82
Union Oil Company
Seattle, Washington

PLATE **4**

BJT	14,197,006.07	SCP	DATE 9/28/82	REVISED	DATE

October 27, 1982

14,197,006.07

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Jeff Benoit

Gentlemen:

Progress Report No. 45
Monitoring and Recovery Operations
Westlake and Mercer Gasoline Spill
Seattle, Washington

This letter reports on gasoline recovery and monitoring for the period of September 18 through October 11, 1982. You have decided to cease pumping operations for the winter months since the rate of recovery has dropped to minimal levels. The depressant pumps and skimmer pumps have been removed from the wells. This letter includes all monitoring and recovery data collected through the cessation of pumping and final measurements of recovered product. We understand that, sometime next spring, additional monitoring may be undertaken to check the fate of the remaining gasoline product in the ground.

GASOLINE RECOVERY

One hundred and twenty-four gallons of gasoline were recovered during this time period for a total volume recovered to date of 41,902 gallons. A plot of cumulative recovery to date against the log of days since the start of pumping is presented on Plate 1. This plot makes apparent the present diminished rate of recovery.

Over the past several months the site monitoring crew headed by Jim Marston of Pacific Testing Laboratories has noted a change in the viscosity and character of the recovered product. The product remaining in the ground has become darker and more viscous. This can be attributed to several factors including the greater mobility and volatility of the lighter hydrocarbon fractions as well as natural biodegradation which tends to first attack the lighter fraction. In both cases, the heavier viscous component of the hydrocarbon is left. This remaining heavier product will exhibit a much slower mobility through the soil and will tend to adhere to soil particles much tighter than the fresh gasoline.

As reported during the past two months, the rate of gasoline recovery has been very slow. Groundwater levels are still abnormally low and this has a very significant impact upon the efficiency of the recovery well system. The seasonal rising of the groundwater levels this winter should flush additional gasoline out and increase the quantity of product lying on top of the groundwater. Without depressant pumps operating, the groundwater levels should return to normal levels with a natural gradient towards Lake Union. Therefore, we expect that some of the remaining product will migrate offsite when natural groundwater conditions are restored.

PIEZOMETRIC ELEVATIONS

Piezometric elevations recorded on October 1 and October 11, 1982, are shown on Plates 2 and 4, respectively. Piezometric elevations have remained relatively stable for the past month. Localized depressed areas are present where groundwater depressant pumps are operating. With the cessation of depressant pump operations, the groundwater levels should begin to rise.

GASOLINE THICKNESS

Gasoline thicknesses recorded on October 1 and October 11, 1982, are shown on Plates 3 and 5, respectively. Gasoline thicknesses continue to fluctuate slightly within the areas where liquid phase gasoline is present at the groundwater surface. Gasoline thickness in Well 19 has decreased significantly over the past month. This is probably due to successful depression and skimming efforts in Well 4A.

EXPLOSIMETER READINGS

During this reporting period, explosimeter readings have remained high. All wells measured on October 7, 1982, with the exception of Wells 22 and 23, had explosimeter readings of 100 percent at the 8 foot level. This tendency may be associated with the observed lowering of water level which has a corresponding effect of exposing a greater amount of gasoline coated soil to air.

SUMMARY

We concur with your decision to suspend recovery operations. Our data indicates that while some increased recovery may be expected sometime in the next month, the increase would not be sufficient to warrant the expense of recovery. It appears as if the limited quantity of product remaining on the groundwater surface is small enough to not present a significant hazard by off-site migration. In addition, we understand that the remaining gasoline product exhibits a greater viscosity which should tend to retard its lateral mobility.

We feel that it would be appropriate to continue to monitor groundwater levels and gasoline thickness on a reduced frequency during the winter months. Such a program would provide critical information on the mobility and fate of the gasoline should you decide to resume any recovery operations. A reduced monitoring period of every two weeks to monthly would be appropriate.

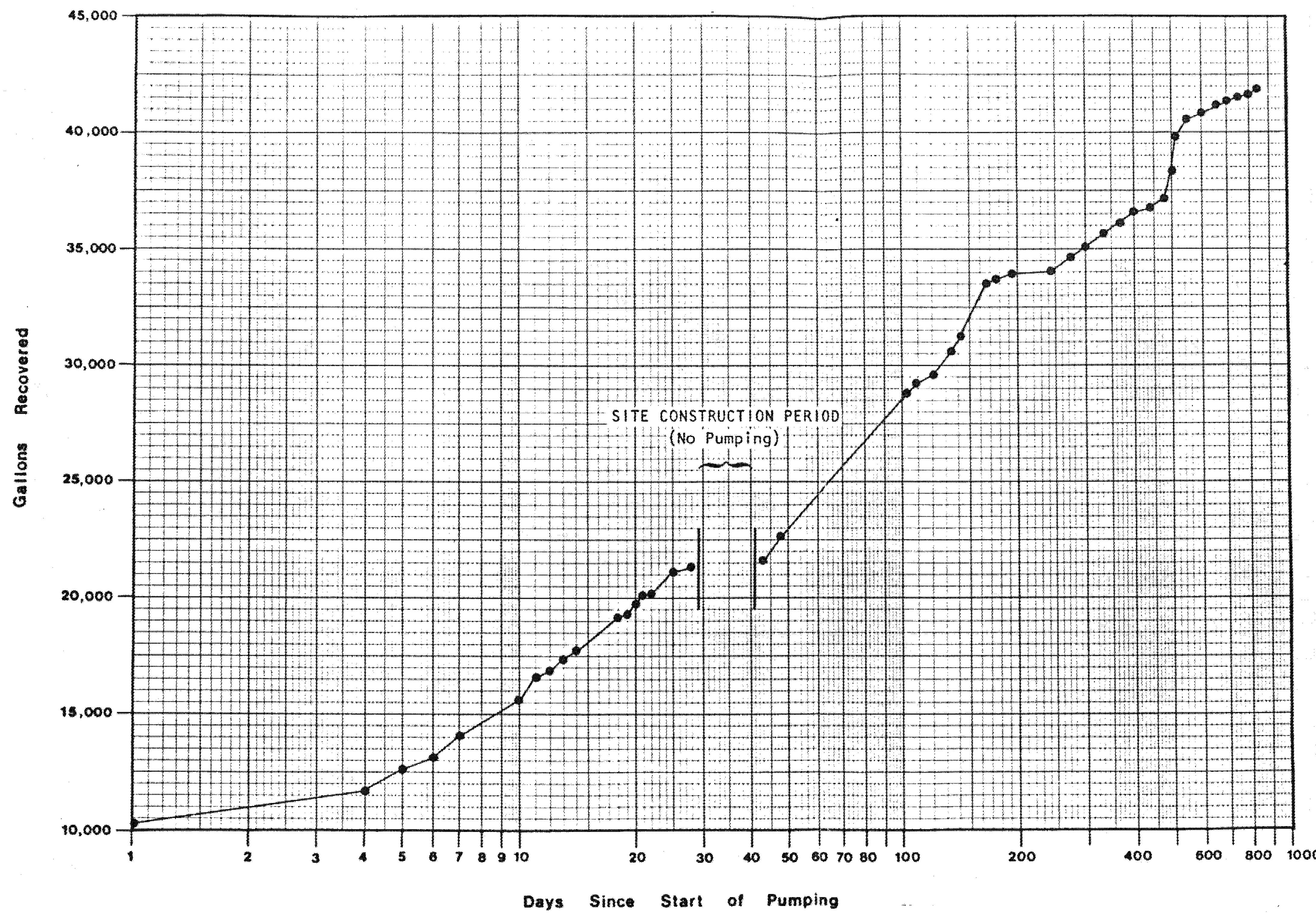
Yours very truly,

HARDING LAWSON ASSOCIATES

Stephen C.Perrigo
Geologist

SCP/djg

enclosures



Plot of cumulative gasoline recovery against the log of elapsed days since pumping began.

(6/19/80 through 10/11/82)

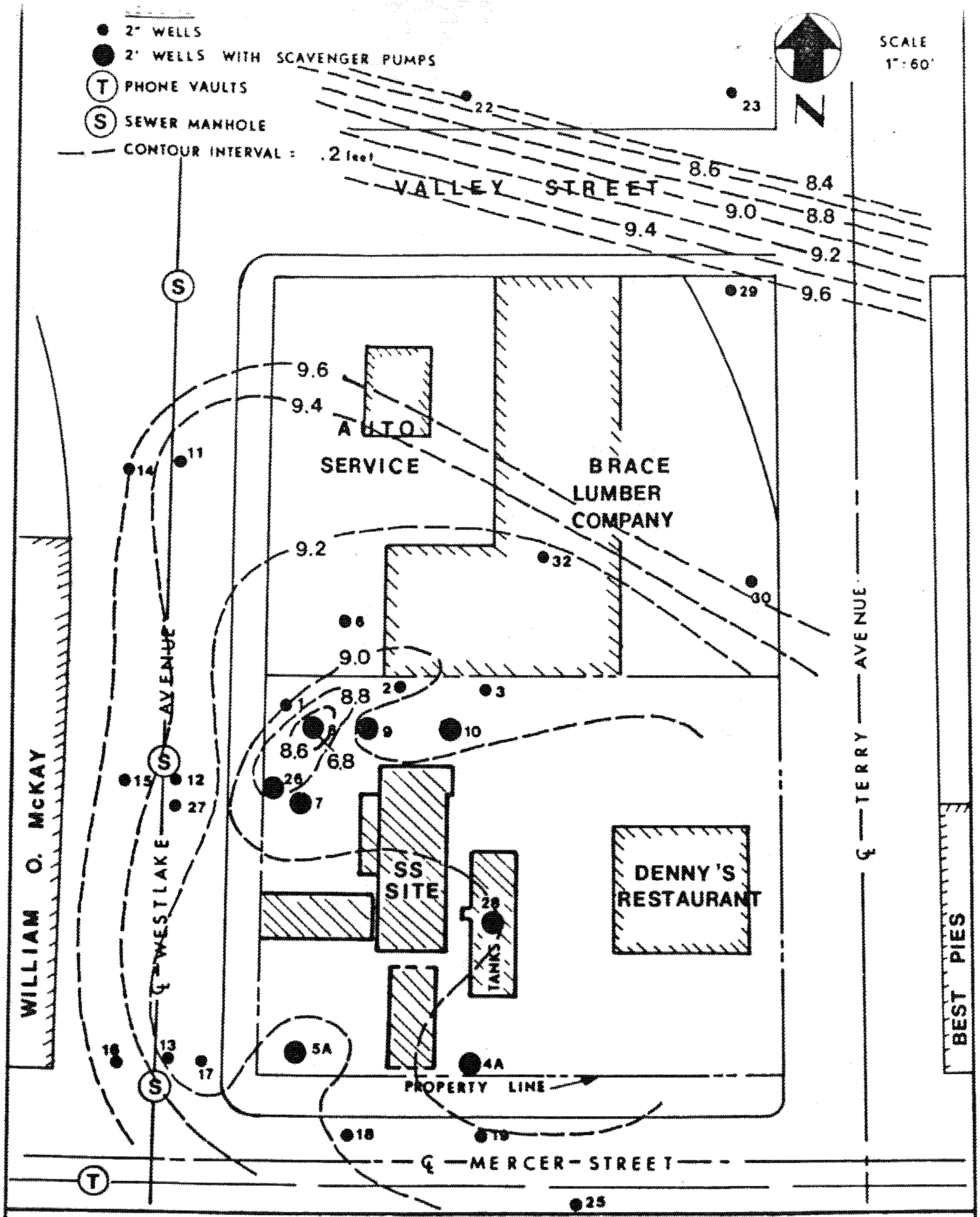
HLA Harding Lawson Associates
Engineers, Geologists & Geophysicists

Total Gasoline Recovery

Union Oil Company
Seattle, Washington

PLATE 1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCP	10/82		



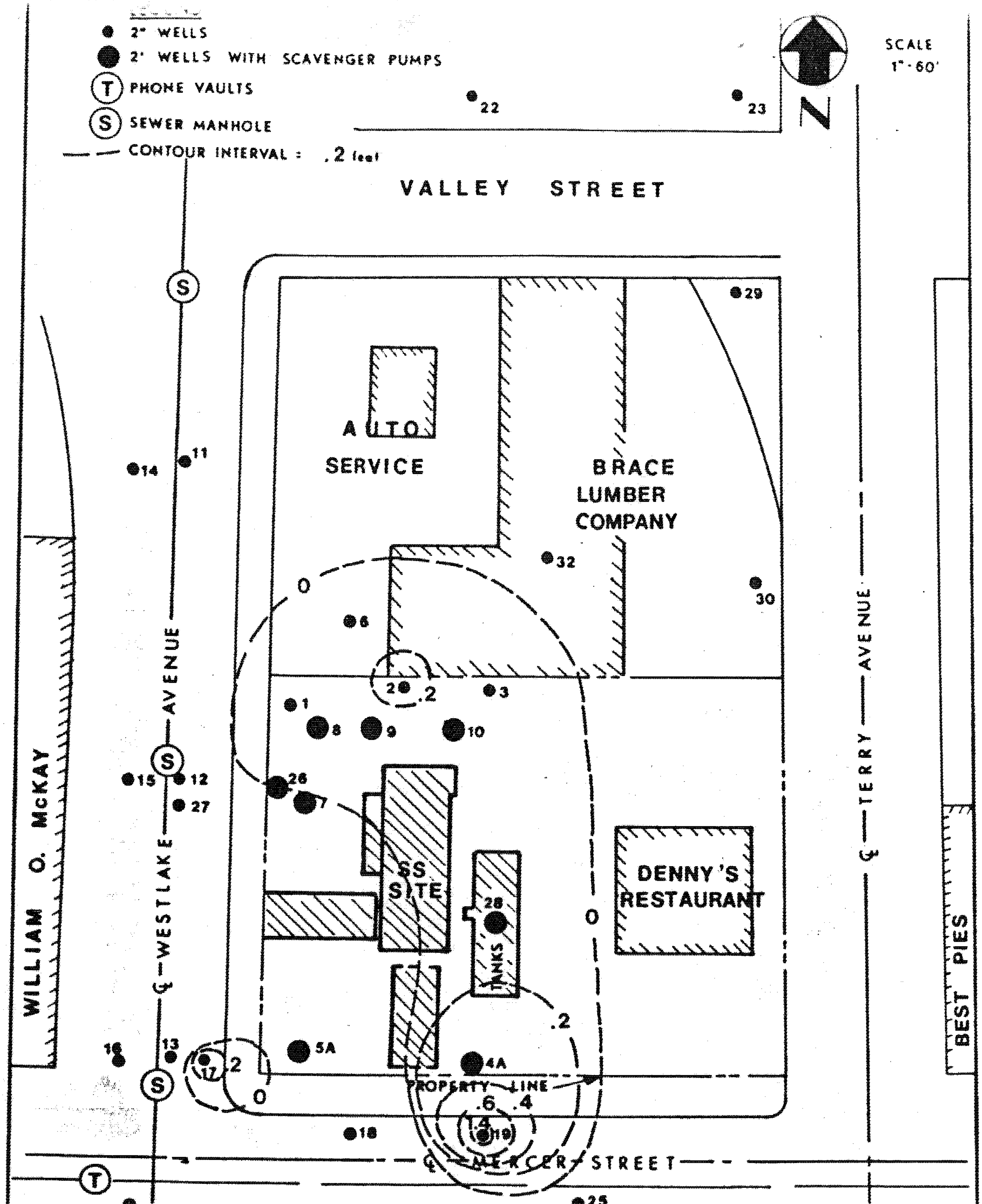
Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Piezometric Elevations 10/1/82

Union Oil Company
Seattle, Washington

PLATE **2**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCP	10/82		

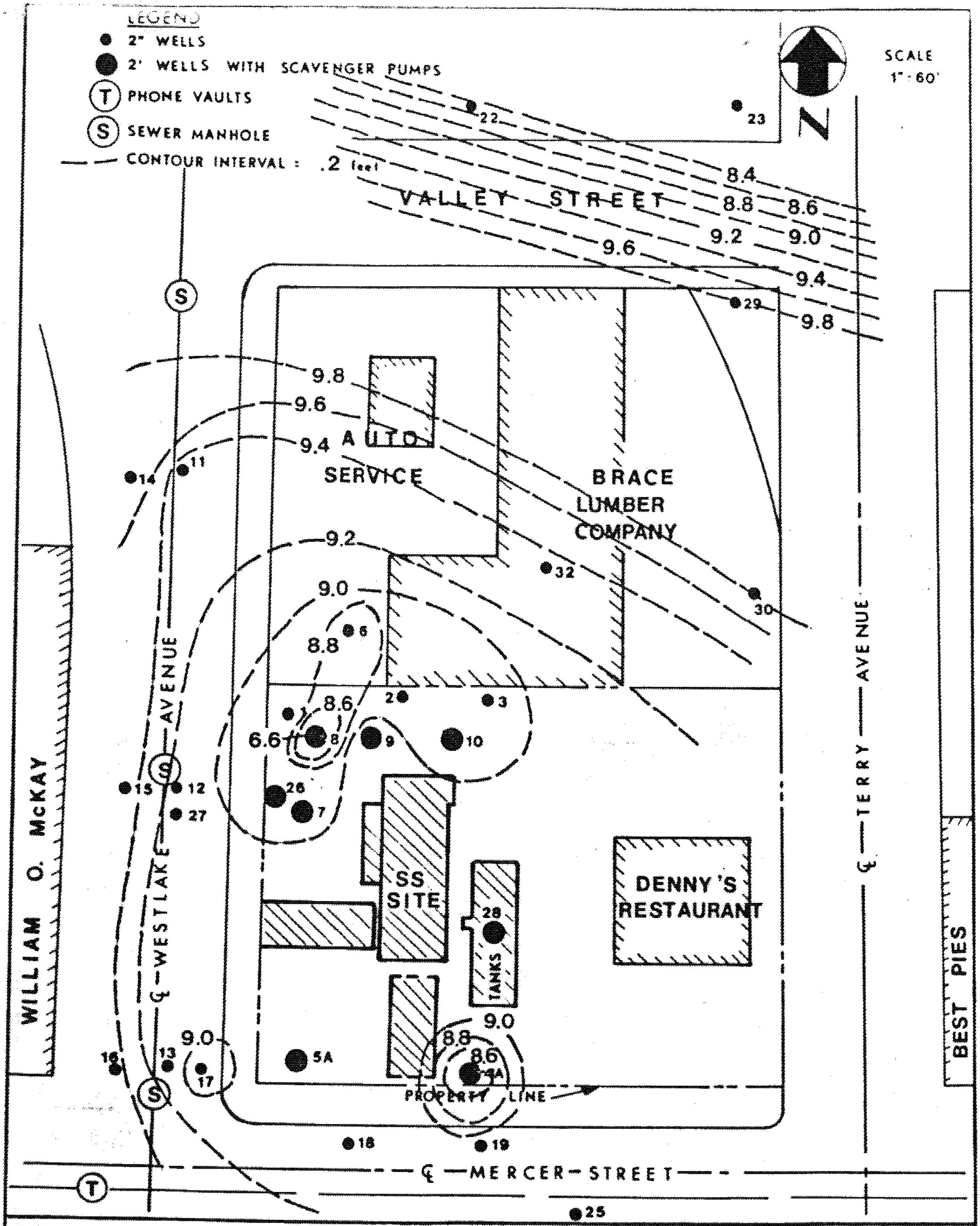


Harding Lawson Associates
Engineers, Geologists & Geophysicists

Gasoline Thickness 10/1/82
Union Oil Company
Seattle, Washington

PLATE 3

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCP	10/82		

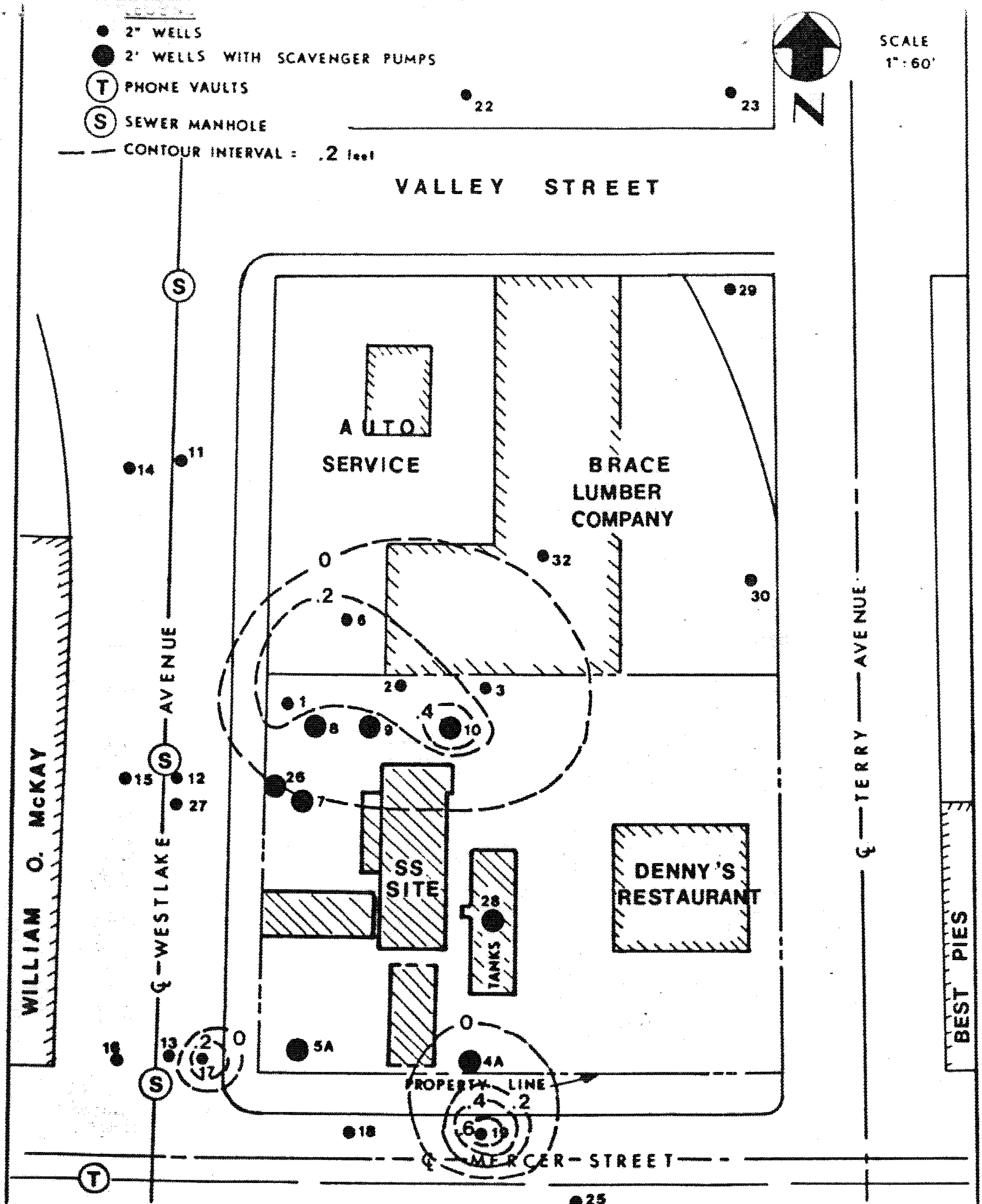


Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Piezometric Elevations 10/11/82
Union Oil Company
Seattle, Washington

PLATE **4**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCP	10/82	-	



Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Gasoline Thickness 10/11/82

Union Oil Company
Seattle, Washington

PLATE **5**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
BJT	14,197,006.07	SCP	10/82		

APPENDIX C

PROGRESS REPORT NO. 1

REMEDIAL ACTION CONSULTATION SERVICES

SUBSURFACE FUEL VAPOR EXTRACTION PROGRAM

SERVICE STATION 5353

SEATTLE, WASHINGTON

FOR

UNOCAL

GeoEngineers

July 27, 1988

Consulting Geotechnical
Engineers and Geologists

Unocal
P.O. Box 76
Seattle, Washington 98111

Attention: Mr. Leigh Carlson

Re: Environmental Loss Number: 1496426 (04/05/88)

Gentlemen:

We are submitting five copies of Progress Report No. 1 for our remedial action consultation services at the site of Unocal Station 5353 in Seattle, Washington. This initial progress report provides information for the period through July 20, 1988. Future progress reports will be issued to update the information presented in this initial report.

We appreciate the opportunity to be of continued service to Unocal. Please call if you have any questions regarding this report.

Yours very truly,

GeoEngineers, Inc.

James A. Miller

James A. Miller
Principal

SCP:JAM:cs

File No. 0161-013-4

GeoEngineers, Inc.
2405 140th Ave. NE, Suite 105
Bellevue, WA 98005
Telephone (206) 746-5200
Fax. (206) 746-5068

Geo Engineers

TABLE OF CONTENTS

List of Figures

TABLE OF CONTENTS (CONTINUED)

List of Tables

List of Appendices

Geo Engineers

PROGRESS REPORT NO. 1

REMEDIAL ACTION CONSULTATION SERVICES

SUBSURFACE FUEL VAPOR EXTRACTION PROGRAM

SERVICE STATION 5353, SEATTLE, WASHINGTON

FOR

UNOCAL

INTRODUCTION

This progress report summarizes site remediation efforts and monitoring activities at Unocal Service Station 5353 for the period of February 14, 1988 through July 20, 1988. The site is located northeast of the intersection between Mercer Street and Westlake Avenue in Seattle, Washington (Figure 1). Service Station 5353 is the site of an estimated 80,000 gallon gasoline leak that occurred prior to 1980. The information presented in this report describes activities related to the design, installation, activation and operation of a vapor recovery system (VRS) on the site. The purpose of the VRS is to further reduce the levels of residual hydrocarbons in soils in the vicinity of the site.

Figure 1 shows the main features of the site and the locations of monitor wells and recovery wells. Field data collected during this reporting period are presented in Appendix A. Laboratory analytical data are presented in Appendix B. Pertinent regulatory documents are presented in Appendix C.

SITE HISTORY

In May 1980 a gasoline leak was detected at Service Station 5353. Based upon inventory records, it was estimated that approximately 80,000 gallons of leaded premium gasoline had been lost during the prior four months. Site characterization activities at that time included 15 soil borings with monitor wells and eight excavated wells. Seven of the eight excavated wells were used to recover free (floating) gasoline. Product recovery from these recovery wells began in mid-June using product skimmers and ground water depression pumps. Additional monitor wells were installed between June and November 1980 to bring the total number of monitor wells to 24.

Monitoring during the free product recovery efforts consisted of frequent measurement of all monitor wells and recovery wells for ground water elevation, product thickness, and combustible vapors.

A total of 34,500 gallons of liquid gasoline had been recovered at the site by December 1981. Recovery of free product was terminated in October 1982 due to very slow recovery rates. A total of 41,900 gallons of gasoline was recovered during the 28-month recovery effort.

SUBSURFACE CONDITIONS

Service Station 5353 and nearby areas currently contain eight recovery wells (large diameter wells installed by excavation) and 16 accessible monitor wells (small-diameter wells installed by drilling). We have adopted the convention of preceding the well designation number with "RW" for recovery wells or "MW" for monitor wells. This report and future progress reports will use this convention.

Soil borings advanced for the installation of monitor wells in 1980 generally extended to depths of 15 to 20 feet. Most borings encountered silty sand fill through their entire depths. Occasionally the fill soils contained wood fragments and gravel. Some of the borings encountered thick sequences of sawdust fill.

Two borings, MW-29 and MW-31, were drilled to depths of 65 and 70 feet, respectively. Based upon those borings, it was estimated that the site is underlain by 35 to 40 feet of fill.

Ground water is generally encountered at a depth of about 10 feet below the ground surface at the site. Annual changes in ground water levels at the site correlate with changes in the level of Lake Union. The Corps of Engineers manages the lake level with an annual fluctuation of about two feet. Ground water flow at the site is generally northward, but suspected buried foundations and utility trenches control the movement of ground water locally.

The recovery wells were installed by placing large-diameter corrugated metal pipe (CMP) well casings in excavated trenches or pits and backfilling around the well casings with porous granular soils. Two-foot-diameter CMP was installed at each recovery well location. The CMP was slotted above and below the water table zone by cutting slits in the pipe with a cutting torch. The configuration of the excavations for each recovery well is not clear. Based upon recollections and photography, Wells RW-7 and RW-26 were installed in a large, roughly circular pit. Wells RW-8, RW-9, and RW-10 were installed in a long narrow trench. The other three recovery wells (RW-4, RW-5 and RW-28) appear to have been installed in smaller, excavated pits. Each recovery well was provided an electrical outlet for operation of recovery equipment and a common 3-inch product/water collection pipe connected to an underground holding tank located east of the service station building. After installation of the recovery wells, the areas of excavation were repaved with asphaltic concrete.

1988 PRELIMINARY SITE CHARACTERIZATION

We visited the site on February 14, 1988 to measure the thickness of free product and vapor concentrations in the monitor wells. Our well inventory located all eight of the recovery wells and 16 of the 24 monitor wells. The fate of the missing monitor wells is unclear, but it appears that several have been buried under pavement. Product thicknesses measured on February 14 are listed in Table 1.

TABLE 1

FREE PRODUCT THICKNESS, 2/14/88(1)

Well	Thickness
MW-01	0.22 Feet
RW-04	0.17 Feet
RW-07	0.23 Feet
MW-17	0.07 Feet
MW-19	0.23 Feet

(1) Free product was not present in other wells at the site.

Hydrocarbon vapor concentrations in the well casings were measured using a Bacharach TLV Sniffer instrument calibrated to hexane. This instrument operates on the same principal as the instruments used to measure vapor concentrations by prior investigators in the early 1980s. The TLV Sniffer has a maximum range of 10,000 parts per million (ppm) which corresponds to about 91 percent of the Lower Explosive Limit (LEL) of gasoline. Vapor concentrations measured in the well casings on February 14 were generally very high, as indicated in Figure 2. Of 23 wells measured, 12 resulted in vapor concentrations that exceeded 10,000 ppm.

We returned to the site on May 15, 1988 to measure the vapor concentrations in the monitor wells. A similar pattern of vapor concentrations was observed in the wells measured on that date.

We returned to the site on May 16, 1988 to collect vapor samples from three of the monitor wells for analysis of total volatile hydrocarbons and methane. The purpose of this sampling was to gain a better understanding of the composition of the subsurface vapors to evaluate further remedial options. The results of those analyses are presented in Table 2. Analytical data are presented in Appendix B.

TABLE 2

ANALYSIS OF VAPORS FROM SELECTED MONITOR WELLS, 5/16/88

	MW-01	MW-17	MW-29
Methane(1)	36,000 ppm	120,000 ppm	300,000 ppm
Total Volatile Hydrocarbons(2)	12,000 ppm	49,000 ppm	160,000 ppm
Benzene(3)	66 ppm	190 ppm	41 ppm
Ethylbenzene(3)	8 ppm	8 ppm	8 ppm
Toluene(3)	24 ppm	18 ppm	12 ppm
Total Xylenes(3)	14 ppm	14 ppm	13 ppm
TLV Reading(4)	>10,000 ppm	>10,000 ppm	>10,000 ppm

(1) Analysis by GC/FID expressed as ppm methane (vol/vol)

(2) Analysis by GC/FID expressed as ppm hexane (vol/vol)

(3) Analysis by GC/FID expressed as ppm (vol/vol)

(4) Field measurement using a Bacharach TLV Sniffer calibrated to hexane

The methane and total volatile hydrocarbon (TVH) concentrations were very high in the monitor wells that were sampled. The vapor from well MW-29 consisted of over 45 percent by volume methane and TVH. The TVH can be attributed to residual gasoline.

The concentrations of benzene, ethylbenzene, toluene, and xylenes (BETX) in the sampled gas were relatively low. BETX are among the lighter, more volatile constituents of gasoline. It would be expected that their concentrations would be diminished due to eight years of evaporation and degradation by naturally occurring bacteria.

The source of the methane in the well casings is not clear. Methane is generated by anaerobic decomposition of organic material. It is a common byproduct of decomposition in solid waste landfills and wood waste fills. The methane found at Service Station 5353 may be in part attributable to decomposition of the wood debris and sawdust in the fill. However, we believe that most of the methane can be attributed to anaerobic decomposition of the subsurface gasoline at this site. Under aerobic (oxygenated) conditions, fuel hydrocarbons are broken down by bacteria forming carbon dioxide and water. When oxygen or other critical nutrients are removed, anaerobic decomposition becomes the predominant mode of bacterial decomposition. Anaerobic decomposition proceeds at a much slower rate than aerobic decomposition. Methane and carbon dioxide would be produced as a result of anaerobic decomposition of gasoline.

We reviewed the vapor monitoring data from the period of active free product recovery in the early 1980s. If the methane was present as a result of decomposition of pre-existing wood waste material, we would have expected similar high vapor concentrations at that time. However, the concentrations of hydrocarbon vapors in 1980 were much lower than those measured in 1988, especially in outlying areas distant from the source of the leak. Based on a comparison of the 1980 and 1988 vapor data, we feel that the current high methane concentration is the result of vapor accumulation due to prolonged anaerobic decomposition of the subsurface gasoline. We expect that carbon dioxide represents much of the balance of the accumulated subsurface vapors.

VAPOR RECOVERY SYSTEM DESIGN AND OPERATION

DESIGN

Subsurface vapor removal was selected as the most viable remedial alternative to further mitigate the effects of the gasoline leak. The VRS consists of two main elements: (1) the vapor collection equipment, and (2) the vapor destruction equipment. Vapor destruction (incineration) is required at this site because of the high concentration and potentially flammable nature of the subsurface vapors.

A schematic diagram of the vapor collection system is presented in Figure 3. Vapor collection is accomplished by using the existing recovery wells at the site as vapor collection points. The recovery wells were retrofitted to minimize the inward leakage of ambient air, and the 3-inch steel water/product collection pipes were retrofitted to serve as the vapor collection lines. The VRS is divided into four segments which can be individually controlled. This facilitates adjustment of the system to allow for removal of vapors from those areas where removal activities are most productive. The four segments of the system are as follows:

- NW: Collection from Well RW-7, which was installed in a large excavated pit that also encompasses the site of RW-26. The exact dimensions of the pit are unknown, but it may have been up to 20 feet in diameter. The pit was backfilled with coarse gravel.
- NE: Collection from Well RW-9, which is located in an east-west trench that is approximately 6 feet wide and 80 feet long. The two other recovery wells located in the trench (RW-8 and RW-10) are not directly connected to the vapor collection system. Because this trench is backfilled with coarse gravel, the entire trench acts as a collection gallery for subsurface vapors.
- SW: Collection from Well RW-5, which was installed in an excavated pit that was backfilled with coarse gravel.
- SE: Collection from Well RW-4, which was installed in an excavated pit that was backfilled with coarse gravel.

The four segments are controlled with valves that are installed in below-grade vaults near Wells RW-7 and RW-9. The valves at RW-7 control flow from the NW and SW segments, and the valves at RW-9 control flow from the northeast and southeast segments. The collection lines join to form one common collection line near Well RW-9. This line emerges from below grade within the fenced incinerator enclosure (Figure 1).

The single collection line is connected to a flame arrestor, an in-line air filter to remove any particulate material, and to the blower unit. Figure 3 shows a schematic drawing of the entire VRS. The blower unit is powered by a 1-1/2 horsepower electric motor. The blower has been able to provide a flow rate of 100 to 115 CFM at a vacuum of 14 to 16 inches water column. From the blower, the vapors pass (under pressure) through another flame arrestor and into the incinerator unit. Sample ports are provided at various locations along the sample collection line.

VRS instrumentation consists of two magnahelic air pressure/vacuum gauges, one to measure system vacuum at the blower, and another to measure pressure drop across the in-line air filter. The latter magnahelic gauge is used to determine when the air filter requires replacement. A thermometer is mounted between the flame arrestor and the air filter to measure the temperature of the incoming air stream. Flow rate is measured with a flow indicator/transducer which is mounted near the outlet of the blower. This instrument can be read visually and is also wired to a continuously recording strip chart recorder.

A recirculation loop is installed around the blower to allow for the gradual introduction of source air to the incinerator. During normal operation of the system, the dilution valve is fully closed. A dilution valve is also provided to allow the introduction of clean ambient air. The dilution valve is equipped with a muffler to minimize noise from the blower unit.

Vapors collected by the system are destroyed by one of two units, (1) the thermal incineration unit, and (2) the catalytic reactor unit. Initially, vapor destruction will be done by thermal incineration. After vapor levels are reduced to below 4000 ppm, the catalytic reactor unit will be used.

The thermal incinerator unit is designed to burn vapors with hydrocarbon concentrations of 4000 ppm or greater. For vapor concentrations of between 4000 and 10,000 ppm, accessory fuel is required to maintain combustion. Hydrocarbon destruction efficiencies of 99 percent or greater are typical for this unit. The auxiliary fuel for the thermal incinerator is natural gas supplied by Washington Natural Gas Company. Manual adjustment of the natural gas feed rate is required at times when the source gas composition changes. The thermal incineration unit has numerous safeguards for automatic shut down of the entire system in the event of flame-out, power loss, or abnormalities in the natural gas and vapor delivery rates.

The catalytic reactor unit uses a platinum catalytic reactor bed operating at relatively low temperatures to oxidize hydrocarbon vapors. Instrumentation provides continuous operation information about the catalyst bed temperature to assure proper operation. The catalyst bed is provided with an electronically controlled pre-heater to maintain proper operation temperature. Temperature sensors connected to a continuously recording strip chart recorder provide information about catalyst bed temperature and the heat of combustion attained by the source vapors. The heat of combustion obtained from the source vapors can be correlated to the hydrocarbon concentration of the vapor. A destruction efficiency of 95 percent is typical for this unit. Dilution of collected vapors may be required during the operation of the catalytic reactor unit to prevent high vapor concentrations from adversely affecting the catalyst beds.

Both vapor destruction units are the subject of permits issued by the Seattle Fire Department and the Puget Sound Air Pollution Control Agency. Copies of those permits are included in Appendix C of this report.

OPERATION

Vapor recovery was initiated on June 24, 1988 with a brief trial operation of the VRS using the thermal incineration unit. The catalytic reactor unit has not yet been installed at the site. The system began continuous operation on June 28, 1988 and operated through the end of this reporting period with only brief shutdowns for maintenance and instrument installation. The system has been operated through a series of different vapor withdrawal configurations to evaluate the performance of the system and to determine the most productive operational configuration.

MONITORING ACTIVITIES

Monitoring activities were performed frequently following the onset of vapor removal efforts. We expect the intensity of monitoring to decrease as the recovery system operation and subsurface vapor conditions become more predictable. At the present time, we are performing two kinds of monitoring: (1) We are closely observing the performance of the VRS by collecting data about vapor chemistry, vapor concentrations, flow rates, and other pertinent operational data, and (2) we are periodically measuring subsurface conditions in the monitor wells, specifically those conditions that are indicative of the effectiveness of the VRS.

VRS MONITORING AND SAMPLING

The performance of the VRS has been monitored by regular measurement of a number of different operational parameters. Because the VRS has been designed to allow withdrawal of vapors from different parts of the site, much of the monitoring has been directed toward evaluating the effectiveness of the system in different withdrawal modes. Measurements of total system flow rate, system vacuum, combustible vapor concentration, and supplementary fuel consumption are taken each time the pattern of vapor withdrawal is adjusted. Vapor samples are also collected from the VRS for chemical analysis of total volatile hydrocarbons (TVH) and methane. All vapor samples have been collected at the sample ports located between the blower unit and the incinerator (Figure 3). Table A-1 in Appendix A presents all of the VRS monitoring data collected during this reporting period. Our interpretation of the significance of the VRS data is discussed later in this report.

SUBSURFACE VAPOR AND VACUUM MONITORING

Subsurface vapors and vacuum in monitor wells were measured on six occasions after the start-up of the VRS. Measurements were made on June 29, June 30, July 8, July 11, July 14, and July 18, 1988. Testing of all of the monitor wells is very difficult due to heavy traffic on

Mercer Street and Westlake Avenue. Monitoring activities in the streets are completed prior to 7:00 a.m. to minimize traffic conflicts.

Subsurface vapors have been monitored in the well casings using a Bacharach TLV Sniffer. The measurements are made in a manner which prevents the entry of ambient air into the well (which could cause dilution and result in erroneous readings). The results of subsurface vapor monitoring are presented in Table A-2 in Appendix A. Much of this field data is incomplete due to unexpected inconsistencies in the operation of the field vapor detection instruments. Data which are clearly in question are not reported. This is discussed in more detail later. At the end of this reporting period, we found that the instrumentation became more reliable as the subsurface vapors began to change in character.

Ground vacuum was measured using magnahelic gauges that have a resolution of about 0.005 inches water column vacuum. The results of ground vacuum monitoring are presented in Table A-3 in Appendix A.

FREE PRODUCT

On June 24, and June 27, 1988 B&C Equipment Company used a vacuum truck to remove free product and water from those recovery wells that had measurable amounts of free product (Table 1). On the two days, a total of approximately 125 gallons of product and approximately 2000 gallons of water were removed. We returned to the site on July 20, 1988 to measure free product levels in the recovery wells. All eight recovery wells had a hydrocarbon sheen on the ground water surface. Only one recovery well, RW-26, had a measurable thickness of free product (0.01 foot).

DISCUSSION

The fuel-related contamination at and near Service Station 5353 appears to consist mainly of hydrocarbon vapors and product that is immobilized within soil in the water table zone. This layer of soil contamination may have a vertical thickness of several feet. Very little free product appears to remain at the site, as was evidenced by the lack of recovery of free product in those wells that were pumped on June 24 and 27.

Subsurface vapor measurements on February 14, 1988 showed that high concentrations of hydrocarbon vapors were present off of Unocal property. Analytical testing of vapors from three of the wells showed that the vapors contained both methane and volatile hydrocarbons. We believe that the methane is largely derived from anaerobic decomposition of gasoline at this site.

The composition and high concentration of the subsurface vapors have severely limited the effectiveness of the field vapor monitoring using our Bacharach TLV Sniffers. The vapors are known to contain very high concentrations of hydrocarbons (volatile hydrocarbons and methane). The vapors probably also contain relatively high concentrations of carbon dioxide and low levels of oxygen. Oxygen would be depleted in the subsurface environment due to the action of aerobic bacteria combined with minimal exchange with ambient air. The Bacharach TLV Sniffer actually measures the capacity of the gas to release heat when it passes by a heated filament (the element) and the gas is oxidized. The reliability of the instrument is affected both by the absence in oxygen and by the presence of carbon dioxide. We have found that the element of the instrument can become "poisoned" while taking readings at this site. It can take the instrument up to several hours to recover from the effect of the poisoning. We believe that many of the low vapor concentration readings shown in Table A-2 are not representative of actual conditions; however, during this reporting period, we have seen a tendency toward more stability in subsurface vapor readings. This can be attributed largely to the introduction of ambient air into the subsurface environment due to VRS operation. The tendency towards stability in readings is most evident in those measurements made in the recovery wells (Table A-2). We believe that during the next reporting period, the Bacharach TLV Sniffer instrument will become a more reliable indicator of the concentration of subsurface vapors at this site.

A significant amount of flammable vapor was removed by the VRS during this reporting period, during which approximately 3,500,000 cubic feet of vapor was withdrawn from the subsurface. Assuming an average effective soil porosity of 10 percent and a depth to ground water of about 10 feet, this volume of air is equivalent to exchanging the air beneath the entire block occupied by Unocal, Denny's and Brace Lumber a total of 35 times. However, inefficiencies inherent in vapor collection allow a significant amount of ambient air to leak into the recovery system through porous backfill, utility trenches, and on-site structures. Measurement of the system vacuum and ground vacuum is one method to identify where those inefficiencies may be located.

Based upon the vacuum monitoring data, the most effective mode of operation of the recovery system is to draw vapors from the southwest and southeast recovery wells. When the system is operated with withdrawal from these wells there is a significant measurable vacuum in the system and in wells surrounding Wells RW-4 and RW-5. The zone of influence during recovery from these wells extends to the south across Mercer Street, to southwest across Westlake Avenue, and north to the property boundary.

When the system is operated with withdrawal from all segments of the system, it is evident that there is a significant loss in system vacuum. This can be attributed to inefficiencies (air leaks) in the northern part of the system. It is likely that a major part of the loss is through the backfill of utilities in Westlake Avenue which intercept the backfill of the northern recovery trenches. There may also be losses through connections with other subsurface conduits, such as the backfill around electrical lines or the product lines. When the entire system is operated, the area of influence of the VRS is greater, but the effective vacuum within the system is substantially lower. This translates into a slower recovery rate in this mode of operation. We believe that VRS operation with simultaneous withdrawal from all four collection areas is best suited for a later time when the catalytic reactor unit is brought online.

Significant progress has been made toward depletion of the existing "reservoir" of accumulated vapors beneath the site during this reporting period. We have estimated the approximate equivalent volume of hydrocarbons that have been removed from the subsurface by the VRS. Table 3 shows the approximate equivalent volume of gasoline (in gallons) and methane (in cubic feet) that have been removed and destroyed. These calculations are based upon measured flow rates and vapor concentrations. During this 23-day period, hydrocarbon vapors equivalent to about 350 gallons of liquid gasoline have been removed and destroyed by the VRS. In addition, about 50,000 cubic feet (ambient temperature and pressure) of methane has been removed and destroyed. If further testing indicates that biodegradation of the gasoline is the source of the methane, then we will develop rough estimates of the volume of gasoline that this quantity of methane represents. Approximately 100,000 cubic feet (delivery temperature and pressure) of natural gas have been used as supplemental fuel during this period.

TABLE 3

VAPOR COLLECTION SYSTEM OPERATION SCHEDULE AND VAPOR RECOVERY

Start Date	Duration (Days)	Equivalent Total Recovery Gasoline (gallons)	Equivalent Total Recovery Methane (F3)	Recovery System Configuration
06/28/88	1.1	26.9	7,696	All Open
06/29/88	1.0	78.8	8,954	South
06/30/88	1.0	71.4	7,782	South
07/01/88	4.0	31.2	8,631	East
07/05/88	0.8	9.0	1,401	All Open
07/06/88	2.0	44.8	7,577	South
07/08/88	4.0	38.5	8,918	Southeast
07/12/88	3.2	17.2	1,244	All Open
07/15/88	5.0	31.7	1,159	South
Totals:	22.1	349.5	53,362	

Figures 4 and 5 show the progress made in depletion of the existing "reservoir" of hydrocarbon vapors beneath the site. These figures also show that the operation of the southern part of the collection system is presently the most effective mode of operation. Figure 5 shows a steady decrease in the average daily recovery of methane. Once depleted, methane is not expected to be generated in great quantities during the remainder of the recovery effort. The volatile hydrocarbons, on the other hand, will continue to evaporate from those soils with residual gasoline contamination. The recent increase in volatile hydrocarbon concentration from the southern part of the system (Figure 4) may be attributed to the introduction of warmer, "clean" air into to the subsurface. This air would have a greater capacity to evaporate residual gasoline. Continued monitoring and analytical testing will help determine if such a trend is developing.

There is another very significant beneficial effect VRS operation–the introduction of ambient air into the ground. The introduced oxygen stimulates aerobic biodegradation of the residual gasoline by naturally occurring bacteria. The beneficial effects of this additional fuel destruction can exceed the rate of hydrocarbon removal by evaporation.

FUTURE ACTIONS AND MONITORING

VAPOR RECOVERY SYSTEM OPERATION

We plan to continue operation of the vapor recovery system under a program of reduced monitoring and adjustments to the system. We will withdraw vapors primarily from the southern part of the system with periodic shorter periods of withdrawal from the entire system.

MONITORING

During the next month, we plan to continue monitoring subsurface conditions on a weekly basis, being sure to obtain one set of readings during each different operation mode of the collection system. After one month, the frequency of monitoring will be reduced. Vapor samples for TVH and methane analysis will be obtained upon each change in the vapor withdrawal configuration.

Vapor concentrations will continue to be monitored to determine when to make the transition to vapor destruction by the catalytic reaction unit. This transition will occur when vapor concentrations entering the VRS remain below 4000 ppm. It is possible that this will be achieved during the next two months.

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OTHER ACTIVITIES

Transition to use of the catalytic reactor unit will require additional site construction activities. This will include the installation of additional electrical service, installation of the catalytic reactor unit, and training in its use. We will work closely with Unocal, the incinerator manufacturer, and B&C Equipment Company to make this transition as smooth as possible.

We plan to sample and analyze vapors in Wells MW-1, MW-17 and MW-29 to evaluate changes in vapor chemistry that have occurred in the vicinity of those wells since the initiation of vapor recovery. We also plan to perform additional chemical testing to ascertain the origin of the methane beneath the site. We will discuss this with Unocal before proceeding with any special sampling and analytical testing.

FUTURE REPORTING

We plan to continue to issue further progress reports on a frequency of once every four months. The next progress report will cover the period from July 21, 1988 through mid-November 1988. This reporting period may be modified at your request, especially if the progress of operation of the catalytic reactor unit or collection of significant data warrants an earlier report.

- o O o -

Please contact us if there are any questions regarding this progress report.

Yours very truly,

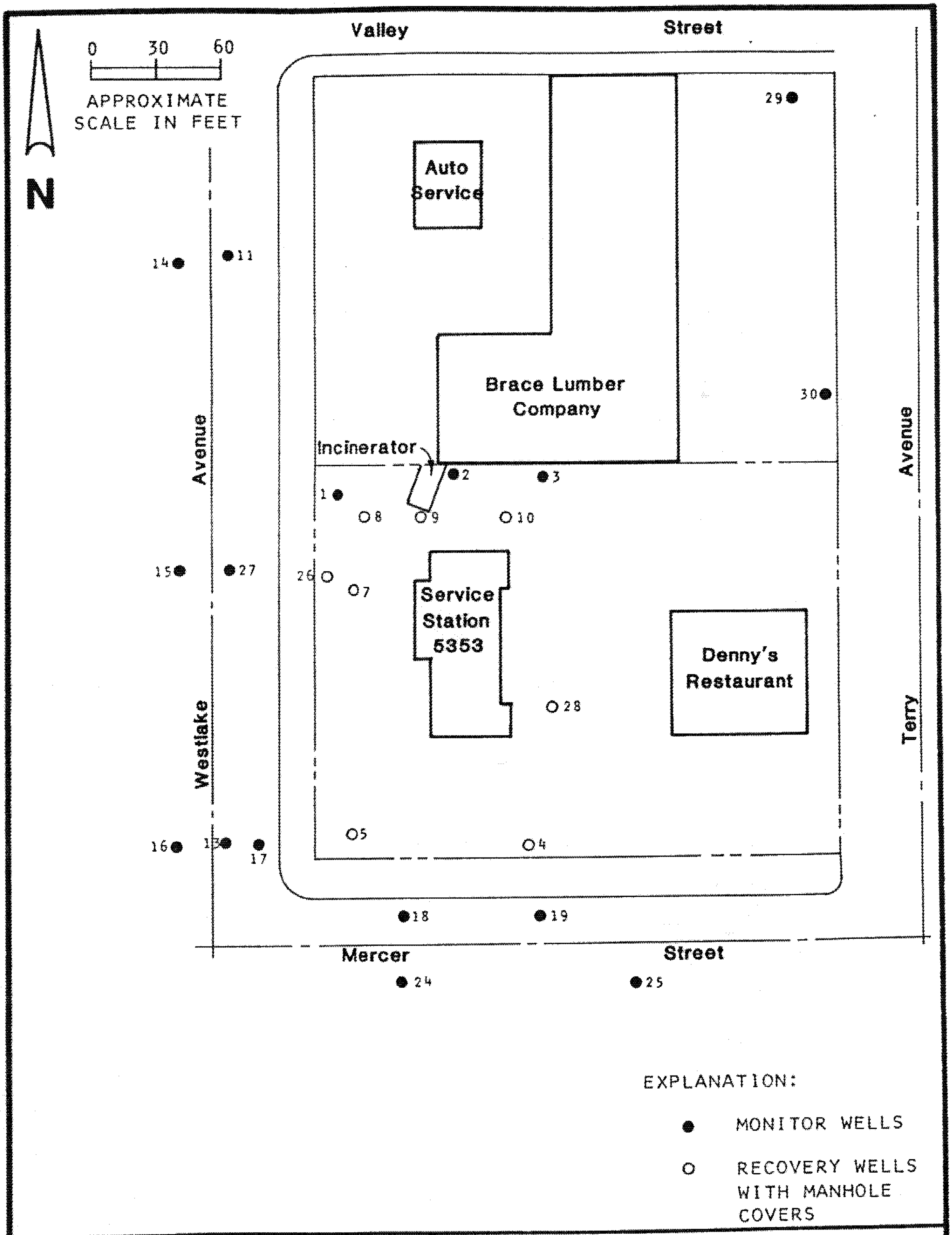
GeoEngineers, Inc.

Stephen C. Perrigo
Waste Management Specialist

James A. Miller

James A. Miller
Principal

SCP:JAM:cs



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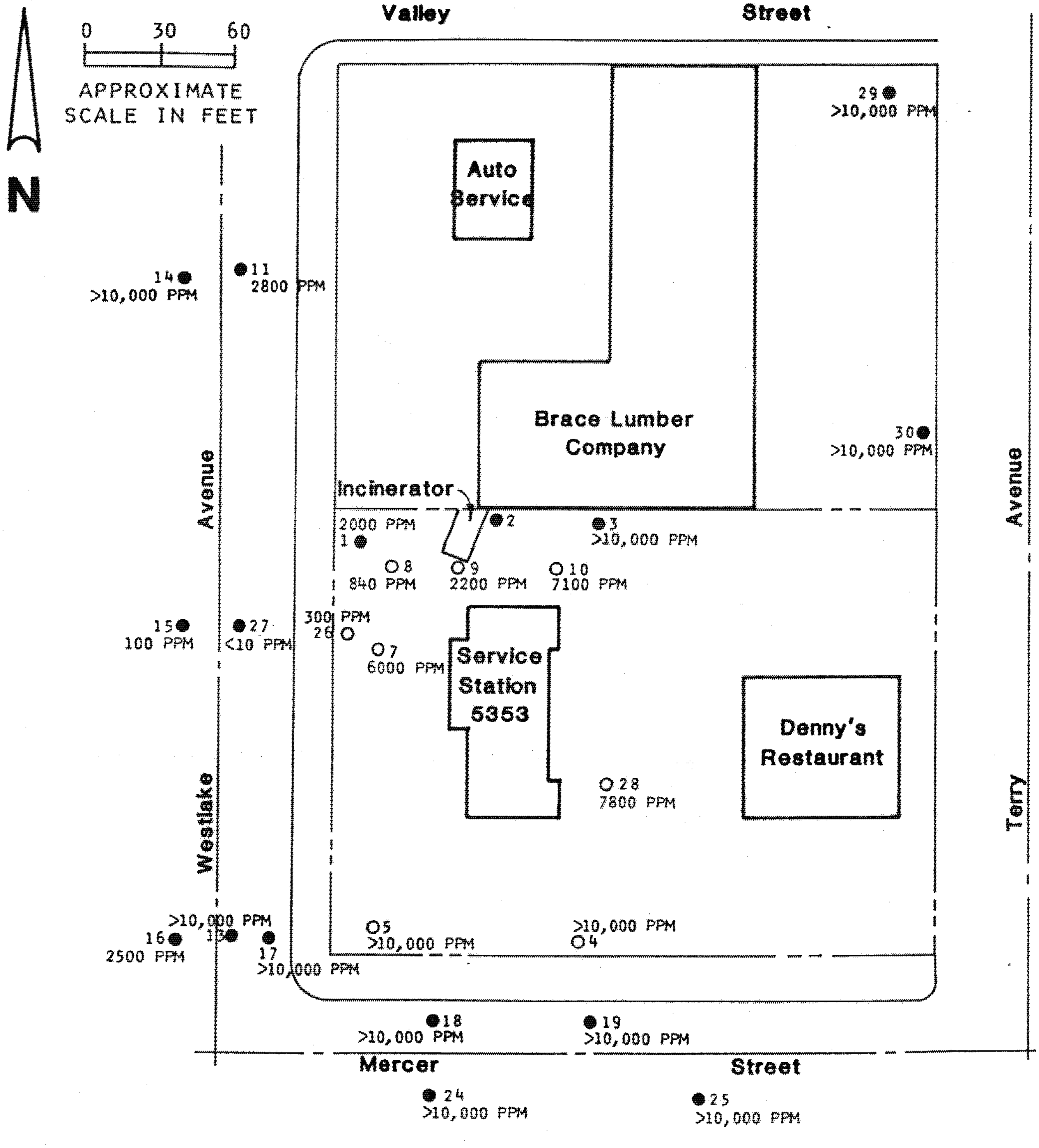
SITE PLAN

FIGURE 1



VAPOR CONCENTRATION MEASURED IN EACH WELL IS NOTED NEXT TO EACH WELL LOCATION.

EXPLANATION:

● MONITOR WELLS

○ RECOVERY WELLS WITH MANHOLE COVERS

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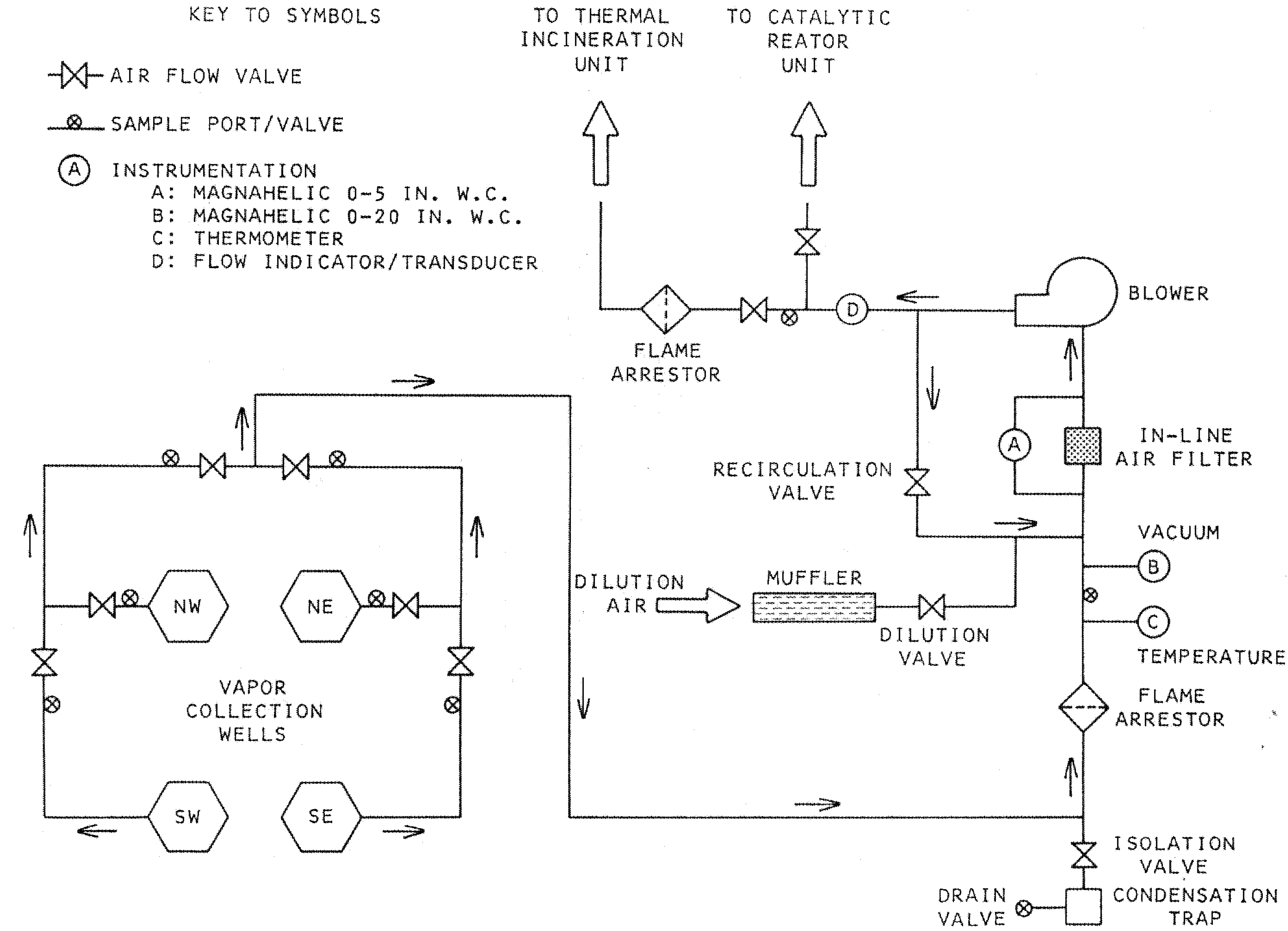
VAPOR CONCENTRATIONS 2/14/88

FIGURE 2

0161-13-4 SCP:KKT 7-26-88



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VAPOR COLLECTION SYSTEM SCHEMATIC

FIGURE 3

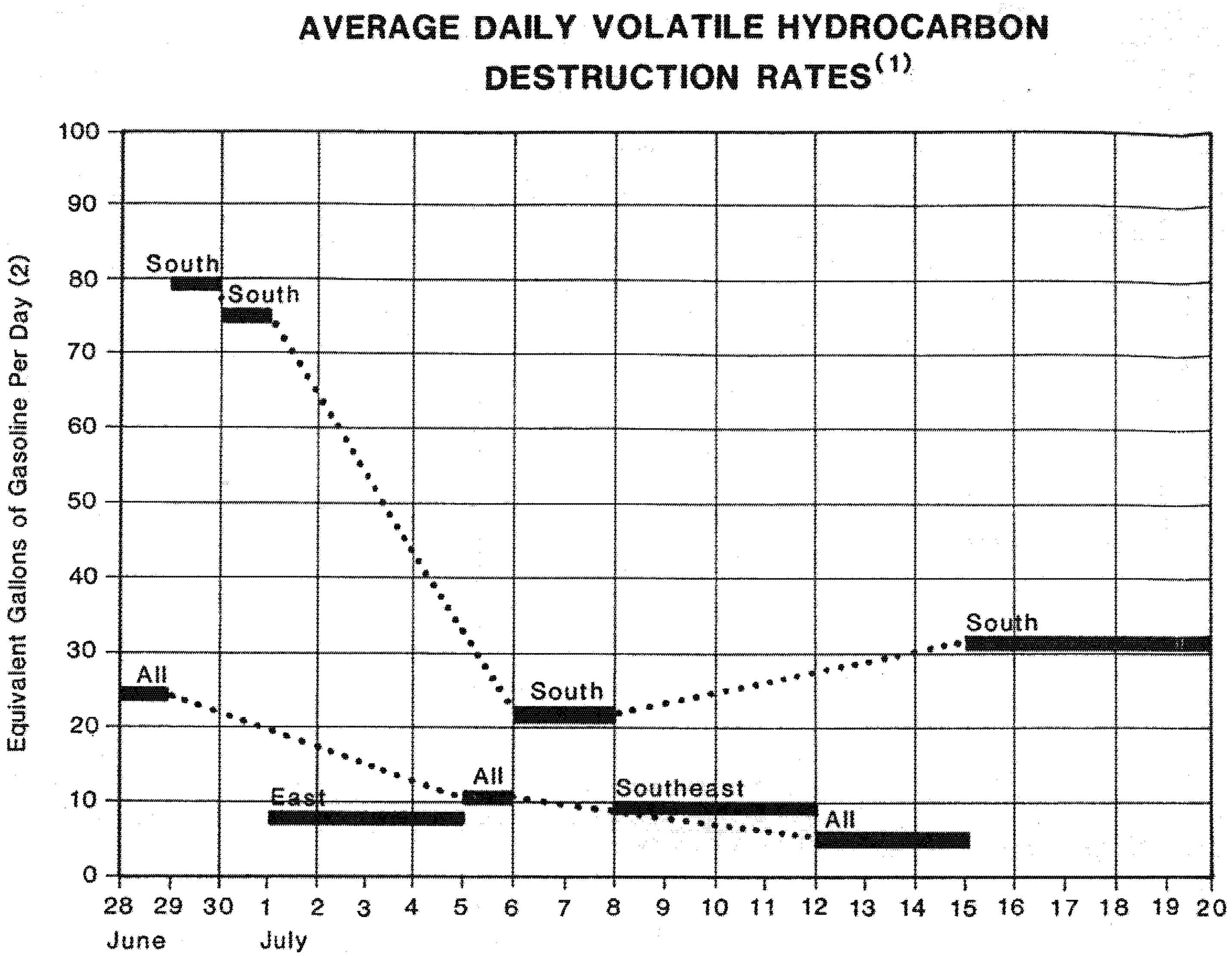

FIGURE 4

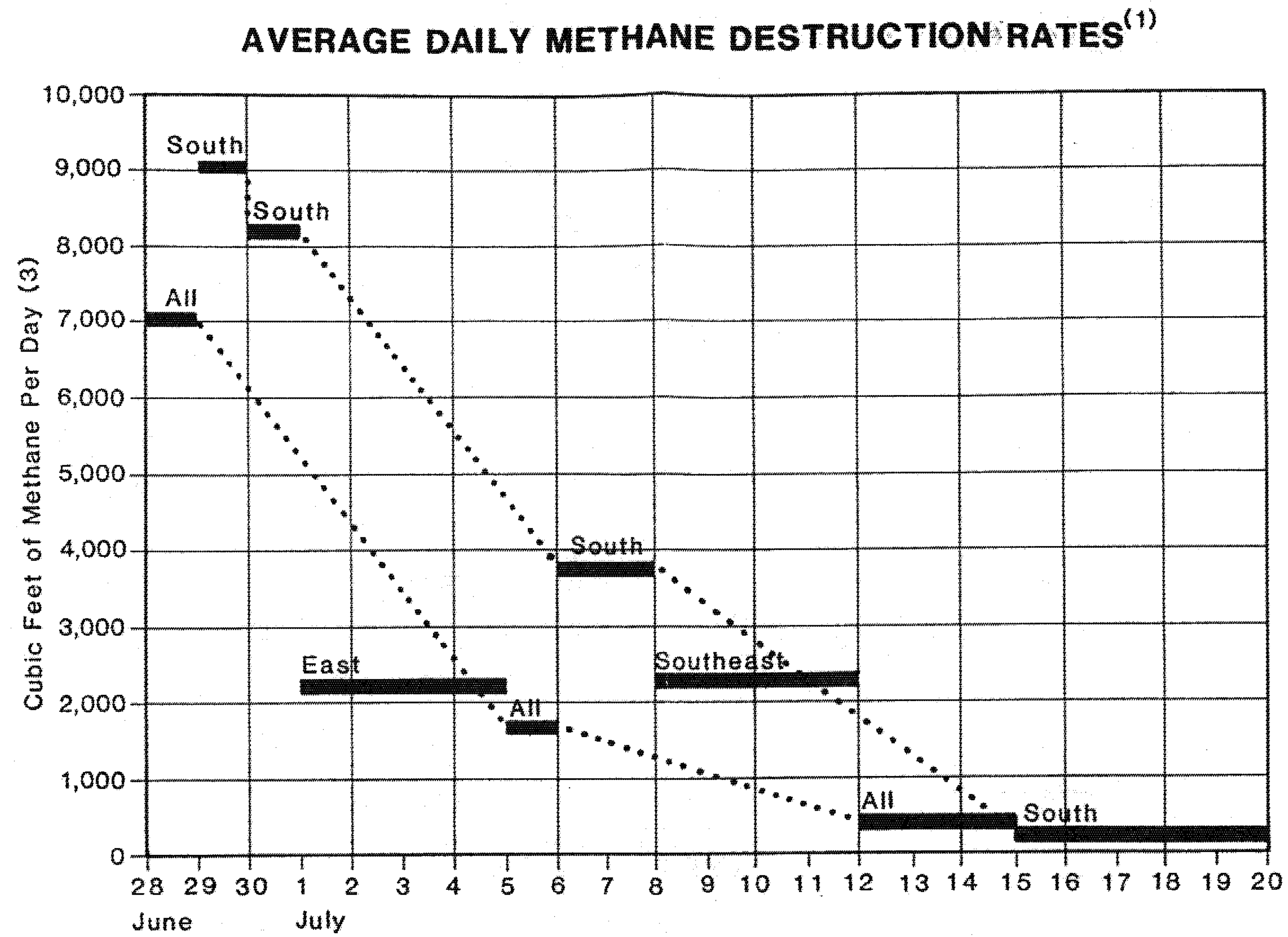

FIGURE 5

NOTES: (1) SOLID BARS REPRESENT AVERAGE DAILY HYDROCARBON DESTRUCTION RATES FOR THE PERIOD OF OPERATION IN THE SYSTEM CONFIGURATION NOTED. FOR EXAMPLE, SOUTH SIGNIFIES WITHDRAWAL FROM THE SE AND SW SEGMENTS OF THE VAPOR COLLECTION SYSTEM. DOTS CONNECTING SOLID BARS ARE ONLY TO ASSIST THE READER IN IDENTIFYING TRENDS WITHIN THE OPERATING CONFIGURATION.

(2) AVERAGE TVH DESTRUCTION RATE BASED UPON AVERAGE TVH CONCENTRATION, FLOW RATE AND AN APPROXIMATE CONVERSION FACTOR (SEE TEXT). EXPRESSED AS GALLONS OF LIQUID GASOLINE.

(3) AVERAGE SOIL VAPOR METHANE DESTRUCTION RATE BASED UPON AVERAGE METHANE CONCENTRATION AND FLOW RATE. EXPRESSED AS CUBIC FEET OF PURE METHANE AT AMBIENT TEMPERATURE AND PRESSURE.

GeoEngineers	AVERAGE HYDROCARBON DESTRUCTION RATES
	FIGURES 4 & 5

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Appendix A – Monitoring Data

Table A-1

VAPOR RECOVERY SYSTEM MONITORING DATA

Date	Time	Flow Rate (CFM)	Vacuum (Note 1)	Fuel Use (CFM) (Note 2)	System Configuration (Note 3) NW	NE	SW	SE	TLV Reading (Note 4)	TVH (ppm) (Note 5)	Methane (ppm) (Note 6)
06/24/88	1306	110	---	---	-	-	0	0	> 10,000	600	110,000
06/24/88	1408	110	---	---	-	-	0	0	> 10,000	520	110,000
System Shut Down 06/24 through 06/28/88											
06/28/88	1320	System Started									
06/28/88	1334	115	---	---	0	0	0	0	> 10,000	6,500	75,000
06/28/88	1412	105	---	---	-	-	-	0	> 10,000	1,400	110,000
06/28/88	1415	105	---	---	-	-	-	0	> 10,000	1,600	95,000
06/28/88	1421	115	---	---	-	0	-	-	615	7,600	56,000
06/28/88	1429	110	---	---	0	-	-	-	700	5,400	43,000
06/28/88	1435	110	---	---	-	-	0	-	> 10,000	450	17,000
06/28/88	1440	115	---	3.5	0	0	0	0	> 10,000	---	---
06/29/88	1512	118	8.6	---	0	0	0	0	> 10,000	760	6,600
06/29/88	1554	115	>10.0	---	-	-	0	0	> 10,000	8,800	46,000
06/30/88	1535	115	---	---	-	-	0	0	> 10,000	15,000	63,000
07/01/88	1356	110	---	---	-	-	0	0	---	8,000	38,000
07/01/88	1418	110	---	---	-	0	-	0	---	410	4,900
07/05/88	1325	115	---	---	-	0	-	0	---	2,000	22,000
07/05/88	1330	---	---	---	0	0	0	0	---	---	---
07/06/88	0955	110	7.0	---	0	0	0	0	---	1,600	10,000
07/06/88	1010	105	16.0	---	-	-	-	0	---	5,900	55,000
07/06/88	1025	110	10.0	---	-	0	-	-	---	820	11,000
07/06/88	1100	110	11.0	---	0	-	-	-	---	1,200	5,900
07/06/88	1130	110	15.5	---	-	-	0	-	---	5,200	31,000
07/06/88	1130	110	15.5	---	-	-	0	0	---	---	---
07/08/88	1020	110	11.0	---	-	-	0	0	>10,000	1,700	16,000
07/08/88	1040	105	16.8	3.3	-	-	-	0	>10,000	2,200	25,000
07/12/88	0920	105	16.0	---	-	-	-	0	4,700	990	4,600
07/12/88	0940	115	7.5	3.3	0	0	0	0	2,000	490	930
07/15/88	1505	115	7.0	---	0	0	0	0	4,100	1,100	3,700
07/15/88	1525	112	10.5	2.9	-	-	0	0	>10,000	560	1,400
07/20/88	1550	110	10.5	3.0	-	-	0	0	4,700	9,000	1,500

Notes:
(1) Vacuum expressed as inches Water Column vacuum
(2) Supplementary fuel consumption (cubic feet per minute)
(3) "-" = Closed and "0" = Open
(4) See text for a further discussion
(5) Total Volatile Hydrocarbon analysis by GC/FID, expressed as ppm (vol/vol)
(6) Methane analysis by GC/FID, expressed as ppm (vol/vol)
"---" signified "no reading taken" ">" signifies "greater than"

Table A-2

Subsurface Vapor Monitoring Data

Well	06/29/88	06/30/88	07/01/88	07/08/88	07/11/88	07/14/88	07/18/88
MW-1	---	<100	<100	NV	>10,000	300	5400
MW-2	---	<100	<100	100	>10,000	<100	360
MW-3	---	>10,000	<100	580	0	---	---
MW-11	---	1500	<100	NV	>10,000	NV	>10,000
MW-13	NV	<100	<100	<100	>10,000	NV	<100
MW-14	NV	3600	<100	<100	NV	>10,000	>10,000
MW-15	NV	<100	<150	<100	NV	NV	<100
MW-16	NV	<100	<100	<100	NV	NV	<100
MW-17	NV	<100	<100	NV	NV	NV	<100
MW-18	NV	<100	<100	<100	NV	NV	<100
MW-19	NV	<100	<100	<100	NV	NV	8400
MW-24	NV	<100	<100	NV	NV	NV	<100
MW-25	NV	<100	<100	NV	>10,000	>10,000	<100
MW-27	NV	<100	<100	<100	NV	NV	<100
MW-29	---	<100	NV	NV	>10,000	>10,000	>10,000
MW-30	---	<100	<100	NV	>10,000	---	9700
EW-4	---	5100	<100	---	4900	7100	3800
EW-5	---	2300	<100	---	<100	1600	1600
EW-7	---	<100	120	---	940	3700	320
EW-8	---	<100	<100	300	180	760	230
EW-9	---	<100	<100	<100	<100	400	<100
EW-10	---	2100	<100	740	310	180	400
EW-26	---	<100	220	---	1200	<100	280
EW-28	---	<100	<100	---	<100	100	<100

Notes: Vapor concentrations were measured using a Bacharach TLV Sniffer calibrate to hexane
Results are expressed as parts per million (vol/vol)
Most of the readings of >100 ppp are suspect. This is discussed in the text.
"NV" signifies that a measurement was taken but the value was not valid.
"<" signifies "less than"
">" signifies "greater than"
"---" signifies "no reading taken"

Table A-3

Ground Vacuum Monitoring Data

Well	06/29/88	06/30/88	07/01/88	07/06/88	07/11/88	07/14/88	07/18/88
MW-1	0.010	0.005	0.010	0.010	0.000	0.030	0.000
MW-2	0.065	0.010	0.000	0.000	0.000	0.000	0.000
MW-3	0.055	0.015	0.000	0.000	0.000	---	---
MW-11	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MW-13	0.020	0.050	0.065	0.010	0.005	0.005	0.000
MW-14	0.015	0.010	0.000	0.000	0.000	0.000	0.000
MW-15	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MW-16	0.025	0.000	0.025	0.000	0.015	0.000	0.000
MW-17	0.075	0.250	0.050	0.050	0.025	0.010	0.025
MW-18	0.190	1.300	1.000	0.540	0.460	0.120	0.380
MW-19	0.200	0.580	1.000	0.740	0.720	0.150	0.600
MW-24	0.015	0.250	0.280	0.120	0.070	0.015	0.080
MW-25	0.050	0.045	0.120	0.025	0.000	0.000	0.075
MW-27	0.010	0.000	0.005	0.000	0.000	0.000	0.005
MW-29	0.005	0.000	0.000	0.000	0.000	0.000	0.000
MW-30	0.000	0.000	0.000	0.000	0.000	---	0.000
EW-4	---	8.800	3.400	7.400	>10.000	1.400	6.600
EW-5	---	9.200	10.000	5.400	0.230	1.200	8.200
EW-7	---	0.030	0.010	0.005	0.000	0.025	0.000
EW-8	---	0.000	0.010	0.000	0.000	0.027	0.000
EW-9	---	0.025	0.010	0.000	0.000	0.027	0.000
EW-10	---	0.000	0.005	0.000	0.000	0.300	0.000
EW-26	---	0.000	0.000	0.002	0.000	0.270	0.000
EW-28	---	0.035	0.050	0.020	0.035	3.000	0.010

Vapor Collection System Operational Status

Northwest	0	-	-	-	-	0	-
Northeast	0	-	-	-	-	0	-
Southwest	0	0	0	0	-	0	0
Southeast	0	0	0	0	0	0	0

Notes: Measurements were made using magnehelic gauges with a resolution of 0.005 inches water column
">" signifies "greater than"
"---" signifies "no reading taken"
Vapor collection system operational status shows the configuration of vapor withdrawal at the time the vacuum readings were taken. "0" = Open and "-" = Closed.

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Appendix B - Laboratory Analytical Data

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

May 24, 1988

Steve Perrigo, Project Coordinator
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on May 16, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: May 24, 1988
Date Submitted: May 16, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR BTX AND ETHYLBENZENE
Results Reported as nL/mL (ppm)

Sample #	Benzene	Toluene	Et-Benzene	Xylene *m,p*	Xylene *o*
MW-1 air	66	27	8	7	7
MW-17 air	190[a]	18	8	7	7
MW-29 air	41	12	8	6	7
Quality Assurance					
Method Blank	<5	<5	<5	<5	<5
MW-17 (Replicate)	190[a]	17	8	7	8

a - Value reported exceeded the calibration range established for the sample.

Date of Report: May 24, 1988
Date Submitted: May 16, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL
SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm)
MW-1 air	36,000[a]
MW-17 air	120,000[a]
MW-29 air	300,000[a]

Quality Assurance	
Method Blank	<10
MW-17 (Replicate)	120,000[a]

a - Value reported exceeded the calibration range established for the sample.

Date of Report: May 24, 1988
Date Submitted: May 16, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL HYDROCARBONS AS n-HEXANE

Sample #	(ppm)
MW-1 air	12,000[a]
MW-17 air	49,000[a]
MW-29 air	160,000[a]

Quality Assurance	
Method Blank	<10
MW-17 (Replicate)	47,000[a]

a - Value reported exceeded the calibration range established for the sample.

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

June 27, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on June 24, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: June 27, 1988
Date Submitted: June 24, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm) v/v
062488-#1 gas	110,000
062488-#2 gas	110,000

Quality Assurance	
Method Blank	<10
062488-#1 Replicate	100,000
062488-#2 Replicate	100,000

Date of Report: June 27, 1988
Date Submitted: June 24, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS *n*-HEXANE

Sample #	(ppm)
062488-#1 gas	600
062488-#2 gas	520

Quality Assurance	
Method Blank	<1

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

July 1, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on June 28, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: July 1, 1988
Date Submitted: June 28, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL
SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm)
880628-1	75,000[a]
880628-2	110,000[a]
880628-3	95,000[a]
880628-4	58,000[a]
880628-5	43,000[a]
880628-6	17,000[a]

Quality Assurance

Method Blank	<10

a - Value reported exceeded the calibration range established for the sample.

Date of Report: July 1, 1988
Date Submitted: June 28, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS n-HEXANE

Sample #	Total Volatile Hydrocarbons As n-Hexane (ppm)
880628-1	6,500
880628-2	14,000
880628-3	18,000
880628-4	7,800
880628-5	5,400
880628-6	450

Quality Assurance

Method Blank	<1

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

July 1, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on June 29, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: July 1, 1988
Date Submitted: June 29, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm) v/v
880629-1 gas	8,600
880629-2 gas	46,000a
Quality Assurance	
Method Blank	<10
880629-1 (Duplicate)	8,000

a - Value reported exceeded the calibration range established for the sample.

Date of Report: July 1, 1988
Date Submitted: June 29, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL
SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS n-HEXANE

Sample #	Total Volatile Hydrocarbon As n-Hexane (ppm) v/v
880629-1 gas	760
880629-2 gas	8,800

Quality Assurance

Method Blank	<1
880629-1 (Duplicate)	720

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

July 1, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on June 30, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: July 1, 1988
Date Submitted: June 30, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm) v/v
880630-1	63,000[a]

Quality Assurance

Method Blank	<10
880630-1 (Duplicate)	57,000[a]

a - Value reported exceeded the calibration range established for the sample.

Date of Report: July 1, 1988
Date Submitted: June 30, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS n-HEXANE

Sample #	Total Volatile Hydrocarbon as n-Hexane (ppm)
880630-1	15,000
Quality Assurance	
Method Blank	<1
880630-1 (Duplicate)	14,000

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

July 6, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on July 1, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: July 6, 1988
Date Submitted: July 1, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm)
880701-1	38,000a
880701-2	4,900

Quality Assurance

Method Blank	<10
880701-2 (Replicate)	5,700

a - Value reported exceeded the calibration range established for the sample.

Date of Report: July 6, 1988
Date Submitted: July 1, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS N-HEXANE

Sample #	Total Volatile Hydrocarbons (ppm) v/v
880701-1	8,000
880701-2	410

Quality Assurance

Method Blank	<1
880701-2 (Replicate)	450

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

July 12, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on July 5, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: July 12, 1988
Date Submitted: July 5, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm)
880705-3	22,000
Quality Assurance	
Method Blank	<100
880705-3 (Replicate)	23,000

Date of Report: July 12, 1988
Date Submitted: July 5, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS N-HEXANE

Sample #	Total Volatile Hydrocarbons (ppm)
880705-3	2,000
Quality Assurance	
Method Blank	<10
880705-3 (Replicate)	2,100

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

July 12, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on July 6, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: July 12, 1988
Date Submitted: July 6, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL
SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm)
880706-1	10,000
880706-2	55,000
880706-3	11,000
880706-5	5,900
880706-6	31,000

Quality Assurance

Method Blank	<100

Date of Report: July 12, 1988
Date Submitted: July 6, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS N-HEXANE

Sample #	Total Volatile Hydrocarbons (ppm)
880706-1	1,600
880706-2	5,900
880706-3	820
880706-5	1,200
880706-6	5,200

Quality Assurance

Method Blank	<10

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

July 12, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on July 8, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: July 12, 1988
Date Submitted: July 8, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm)
880708-1	16,000
880708-2	25,000

Quality Assurance	
Method Blank	<100
880708-1 (Replicate)	15,000

Date of Report: July 12, 1988
Date Submitted: July 8, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS *n*-HEXANE

Sample #	Total Volatile Hydrocarbons (ppm)
880708-1	1,700
880708-2	2,200

Quality Assurance

Method Blank	<10
880708-1 (Replicate)	1,700

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

July 12, 1988

Kathy Killman, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Kathy:

Enclosed are the results of the analyses of samples submitted on July 12, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: July 12, 1988
Date Submitted: July 12, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm)
880712-1	4,800
880712-2	930
Quality Assurance	
Method Blank	<100

Date of Report: July 12, 1988
Date Submitted: July 12, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS N-HEXANE

Sample #	Total Volatile Hydrocarbons (ppm)
880712-1	990
880712-2	490

Quality Assurance

Method Blank	<10

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

July 18, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on July 15, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF/cag

Enclosures

Date of Report: July 18, 1988
Date Submitted: July 15, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm)
880715-1	3,700
880715-2	1,400
Quality Assurance	
Method Blank	<100
880715-1 (Replicate)	3,700

Date of Report: July 18, 1988
Date Submitted: July 15, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS *n*-HEXANE

Sample #	Total Volatile Hydrocarbons (ppm)
880715-1	1,100
880715-2	860

Quality Assurance

Method Blank	<10
880715-1 (Replicate)	1,000

FARR, FRIEDMAN & BRUYA, INC.
ENVIRONMENTAL CHEMISTS

James K. Farr, Ph.D.
Andrew John Friedman
James E. Bruya, Ph.D.

3008 B - 16th West
Seattle, WA 98119
(206) 285-8282

GeoEngineers

JUL 25 1988

Routing SCP SP

File

July 21, 1988

Steve Perrigo, Project Manager
GeoEngineers, Inc.
2405-140th Avenue N.E., Suite 105
Bellevue, WA 98005

Dear Steve:

Enclosed are the results of the analyses of samples submitted on July 20, 1988 from Project 0161-13-4.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

James K. Farr

James K. Farr, Ph.D.

JKF

Enclosures

Date of Report: July 21, 1988
Date Submitted: July 20, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIROMENTAL SAMPLES FOR METHANE BY GC/FID

Sample #	Methane (ppm)
880720-1 gas	1,500

Quality Assurance

Method Blank	<100
880720-1 (Duplicate)	1,300

Date of Report: July 21, 1988
Date Submitted: July 20, 1988
Project: 0161-13-4

RESULTS OF ANALYSES OF ENVIRONMENTAL SAMPLES FOR TOTAL VOLATILE HYDROCARBONS AS N-HEXANE

Sample #	Total Volatile Hydrocarbons (ppm)
880720-1 gas	9,000a
Quality Assurance	
Method Blank	<1
880720-1 (Duplicate)	8,800a

a - Value reported exceeded the calibration range established for the sample.

Appendix C – Regulatory Documents and Permits

Date This Permit Expires: 5-15-89/NEW

PERMIT

SEATTLE FIRE DEPARTMENT

301 SECOND AVENUE SOUTH
SEATTLE, WASHINGTON 98104

Date: 5-17-88
Station:
Occupancy File No.:

Permit No.: 65652
Receipt No.: 132707

1989

Serial No. 117653

Unocal
3131 Elliott Avenue
Seattle, WA 98121

Operation Address:
600 Westlake Ave N
Westlake Union Service Station

Phone Number:
623-8272

TITLE: COMBUSTIBLE VAPOR INCINERATOR

CODE: 999

TYPE OF MATERIAL	U.N. NUMBERS	AMOUNT	LOCATION

Permission is hereby granted under the provisions of the Fire Code (Ord. 111001) to

Install multimode combuster for vapor Incineration.

SEE ATTACHED CONDITIONS.

THIS PERMIT MUST BE POSTED IN A CONSPICU

NOT TRANSFERAB

Issued by: Capt. Davis : DF

Claude Harris

CHIEF OF THE FIRE DEPARTMENT

1989	1990	1991	1992	1993
Serial No. 117653	Serial No.	Serial No.	Serial No.	Serial No.

Permit Conditions

1. The Entire area to be protected by security fence.

2. Incinerator to be 25' from tank vents and dispensing.

3. Incinerator to be 10' from property line and combustible structures

4. Install remote shutoff in station.

5. Install remote shutoff at fenced area.

6. Installation to be properly grounded.

7. Automatic shut down with alarm for:

   a. Gas pressure too high
   b. Gas pressure too low.
   c. Fan off.
   d. Incinerator operating over temperature.

8. Tank manholes to be tested for L.E.L. prior to business operation. If operation is shut down for any reason manholes shall be retested for L.E.L.

Puget Sound Air Pollution Control Agency

Notice of Construction No. 3088

Date JUN 27 1988

HEREBY ISSUES AN ORDER OF APPROVAL TO CONSTRUCT, INSTALL, OR ESTABLISH

One Vapor Removal System controlled by a King, Buck/Hasstech Multi-Mode Combustor Model MMC-5 with a Hasstech Vapor Control Processor Model VCP-100 and a Catalytic Reactor Model MMC-5-CAR.

APPLICANT

Mr. Leigh Carlson
Unocal
NAME

3131 Elliott Ave.
STREET

Seattle, WA 98101
CITY STATE ZIP

OWNER

Same
NAME

STREET

CITY STATE

INSTALLATION ADDRESS

600 Westlake Ave. N., Seattle, WA 98101
STREET CITY STATE

THIS ORDER IS ISSUED SUBJECT TO THE FOLLOWING RESTRICTIONS AND CONDITIONS

1. Approval is hereby granted as provided in Article 6 of Regulation I of the Puget Sound Air Pollution Control Agency to the applicant to install, alter or establish the equipment, device or process described hereon at the INSTALLATION ADDRESS in accordance with the plans and specifications on file in the Engineering Division of PSAPCA.
2. Compliance with this ORDER and its conditions does not relieve the owner or operator from the responsibility of compliance with Regulations I or II, RCW 70.94, or any other emission control requirements, nor from the resulting liabilities and/or legal remedies for failure to comply.
3. This approval does not relieve the applicant or owner of any requirement of any other governmental agency.

GeoEngineers

JUL 11 1988

--CEIVED
- 1988

Routing

File

MAINT. & CONT.

Harry A. Watters
Reviewing Engineer
cvm

~~A. R. Dammkoehler~~
(Acting) Air Pollution Control Officer

Form 50-118, (1/85)

NOTICE OF COMPLETION

WARNING:

Regulation I, Section 6.09(a), requires that the owner or applicant notify the Agency of the completion of the work covered by the application and when its operation will begin. This form is provided for your convenience to assist you in complying with this part of the Regulation.

APPLICANT or OWNER SECTION

Mail to: Puget Sound Air Pollution Control Agency
Plan Review Section
200 West Mercer Street, Room 205
Seattle, Washington 98119–3958

Gentlemen:

The project described below was completed on ______________________ and will be in operation on ______________.

______________________ Signature of Owner and/or Applicant

______________________ Title

______________________ Date

FOR AGENCY USE ONLY

Notice of Construction No. 3088

Project Description: One Vapor Removal System controlled by a King, Buck/Hasstech Multi-Mode Combustor Model MMC-5 with a Hasstech Vapor Control Processor Model VCP-100 and a Catalytic Reactor Model MMC-5-CAR

☐ Conditions On Reverse Side

Owner's Name Mr. Leigh Carlson, Unocal, 3131 Elliott Ave., Seattle, WA 98101

Location 600 Westlake ave. N., Seattle, Wa 98101

☒ Inspector check ☐ Engineer ______________ and Inspector check

Follow–up ______________________ (Estimated Completion Date Plus 7)

Date Inspected ______________________ Inspector ______________________

REMARKS: ______________________

☐ See Attachment

FORM 63–11.1 (4/88)

Unocal Refining & Marketing Division
Unocal Corporation
3131 Elliott Avenue, P.O. Box 76
Seattle, Washington 98111
Telephone (206) 281-7666

GeoEngineers

UNOCAL 76

JUN 14 1988

June 13, 1988

Routing [illegible] SCP

File 161-13

Mr. Craig S. Baker
Washington Dept. of Ecology
Northwest Regional Office
4350 - 150th Avenue Northeast
Redmond, Washington 98052-5301

Dear Mr. Baker:

Re: SERVICE STATION 5353
Remedial Operations

UNOCAL is presently planning to resume remedial operations at the site of a leak of gasoline from our Service Station 5353 at Westlake and Mercer Street in Seattle, Washington. The spill occurred prior to May, 1980. Your department was involved at that time. From 1980 through October, 1982 a recovery system was able to recover about 41,000 gallons of fuel. Recovery efforts were terminated in 1982 with Washington Department of Ecology's concurrence.

As we all know, environmental standards have changed considerably since 1982. Based on UNOCAL's current corporate policies, we feel that it is necessary to return to the site and implement further remedial measures. We plan to install and operate a vapor extraction/incineration system to remove and treat hydrocarbon vapors that are present in the soil beneath the site. The duration of the vapor extraction program is not known at this time, but we are tentatively planning on operating such a system for up to two years.

We have contacted GeoEngineers, Inc., to assist with the design, operation and monitoring of the vapor recovery system. Attached to this letter is a brief overview of the design and operation of the system planned for this site. We expect to begin system operation during mid to late June.

We will keep Ecology informed of the operation and effectiveness of this sytem. Regular progress reports submitted by GeoEngineers will be forwarded to Ecology.

We request that you review this proposed program to determine if it satisfies the requirements of Ecology for remediation at this site. If you have any further questions about our plans for this vapor recovery system, please contact Mr. Steve Perrigo of GeoEngineers at 746-5200. Please concur with our plans by executing and returning one copy of this letter to UNOCAL.

Yours very truly,

V L Carlson

V. L. CARLSON
Construction Engineer

VLC:ct

Attachment

cc: J. L. Ashlock
A. L. Barone
J. Miller, GeoEngineers, Inc. (w/attach)

Proposal accepted this ______ day of ______, 1988

____
Department of Ecology

GeoEngineers

June 8, 1988

Consulting Geotechnical
Engineers and Geologists

Unocal
P.O. Box 76
Seattle, Washington 98111

Attention: Mr. V.L. Carlson

Gentlemen:

Vapor Extraction System Overview
Subsurface Gasoline Leak
Unocal Service Station 5353
Westlake Avenue & Mercer Street
Seattle, Washington
File No. 0161-13-4

INTRODUCTION

This letter briefly describes the design, installation and operation of a vapor extraction system that is currently under construction at Unocal Service Station 5353 in Seattle, Washington. The purpose of the vapor extraction system is to remove hydrocarbon vapors trapped in the soil beneath the service station site and surrounding areas. The vapors have been generated as a result of volatilization of residual gasoline from contaminated soils near the water table. Methane vapors are also present beneath the site and surrounding areas. The source of the methane is probably from decomposition of sawdust fill and other organic material that is unrelated to the service station.

Service Station 5353 was the site of an 80,000-gallon leak of gasoline that occurred prior to May 1980. A free product recovery system was installed at the site and operated until October 1982. The recovery system consisted of a network of ground water/product recovery wells on the service station property. The total volume of liquid gasoline

GeoEngineers, Inc.
2405 140th Ave. NE, Suite 105
Bellevue, WA 98005
Telephone (206) 746-5200
Fax. (206) 746-5068

recovered with this system was about 41,900 gallons. Natural processes of evaporation and biodegradation have also contributed to removal of product from the site. Residual contamination still remains at the site, including soil contamination, subsurface fuel vapors, and a limited amount of free product in several monitor wells. A number of options for further site mitigation have been considered, including continued free product recovery, ground water pumping, in-situ biodegradation and soil vapor extraction. The vapor extraction option is considered to be the most practical and cost effective for this site.

VAPOR EXTRACTION SYSTEM DESIGN AND OPERATION

GENERAL

The vapor extraction system will utilize the existing free product recovery wells and recovery galleries for the collection of subsurface hydrocarbon vapors. The vapors will be collected from the large-diameter product recovery wells using a vacuum blower system. The recovered vapors will be incinerated with a Multimode Combustor unit (MMC) supplied by King, Buck/Hasstech of San Diego, California. The initial MMC unit will consist of a thermal incinerator unit to burn the high-concentration combustible gases that are expected during the first few months of system operation. As the vapor recovery program progresses, vapor concentrations in the ground are expected to decrease gradually. The initial thermal incinerator unit will be replaced with a catalytic reactor when vapor concentrations decrease to levels that are impractical to treat by direct combustion.

VAPOR COLLECTION SYSTEM

Five existing large diameter ground water/product recovery wells will be used for the collection of subsurface vapors. These wells currently have well casing perforations that extend above the water table and a gravel pack surrounding each well screen. An air-tight seal will be fitted on the manhole opening of each recovery well. Existing 3-inch-diameter pipes that are connected to each well will be extended to the new vacuum blower. Vapor flow rates from each recovery well will be controlled by individual valves to allow flexibility in system operation. Vapor sampling ports will also be installed at each recovery well.

BLOWER SYSTEM

The vacuum system will be powered by a three-horsepower motor designed to provide a flow of about 100 CFM from the collection system. Flow from the blower system can be controlled manually if reduced flow rates are needed. Instrumentation will provide continuous information regarding flow from the blower. The blower system and the MMC will be installed within a secured fenced area along the northern edge of the service station property.

MULTIMODE COMBUSTOR UNITS

Incineration Unit: The initial thermal incineration unit is designed to treat vapors with hydrocarbon concentrations of 4000 ppm or greater. For vapor concentrations of between approximately 4000 ppm and 10,000 ppm, accessory fuel will be required to maintain combustion. Hydrocarbon destruction efficiencies of greater than 99 percent are typical for this unit. The auxiliary fuel will be natural gas supplied by Washington Natural Gas. We expect that the incineration unit will used for about 2 to 4 months at which time vapor hydrocarbon concentrations are expected to drop to below 4000 ppm. The thermal incinerator unit will then be replaced with a catalytic reactor unit.

Catalytic Unit: The catalytic unit uses a platinum catalytic reactor bed to oxidize hydrocarbon vapors at relatively low temperatures. Instrumentation will provide continuous information about the catalyst bed temperature to assure proper operation. A destruction efficiency of 95 percent is typical for this unit. The catalyst bed will be provided with an electric pre-heater to maintain proper operation temperature.

Safety: Both the thermal incinerator and catalytic units have numerous safeguards and automatic shut-off systems. Installation and operation will be performed under conditions of permits issued by the Seattle Fire Department and the Puget Sound Air Pollution Control Agency.

MONITORING

Approximately 30 subsurface monitoring points exist on the service station property and surrounding areas. These monitoring points consist of small diameter slotted PVC well screens that were installed in 1980 and 1981 to design and monitor the former free product recovery program. These monitor wells were installed to intercept the water table and are screened above the water table. We propose to monitor vapor concentrations and ground vacuum using these wells. Periodically, vapor samples will be collected to determine the ratio of fuel-derived hydrocarbon vapors to methane. Also, certain wells may be selected for the monitoring of water levels and remaining free product thickness.

We plan frequent monitoring during the initial stages of system operation to understand the dynamics of the vapor extraction system and to observe expected changes in vapor concentrations. Ultimately we plan to monitor conditions at the site on a monthly basis. Monitoring of all wells at this site is very difficult because 11 monitoring points are located in Mercer Street or Westlake Avenue and traffic on these roadways is heavy.

\- o O o -

GeoEngineers

We anticipate that progress reports will be prepared for Unocal on a frequency of once every four months. Verbal reporting or interim written reports may be prepared if significant changes are noted at the site.

Yours very truly,

GeoEngineers, Inc.

Stephen C. Perrigo/by JAM

Stephen C. Perrigo
Waste Management Specialist

James A. Miller

James A. Miller
Principal

SCP:JAM:wd

VL CARLSON

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
4350-150th Ave. N.E. • Redmond, Washington 98052-5301 • (206) 867-7000

GeoEngineers JUN 23 1988

JUN 27 1988

Routing OCP
File 0161-13-4

June 22, 1988

Mr. V. L. Carlson
Unocal Corporation
3131 Elliott Avenue
P.O. Box 76
Seattle, Washington 98111

Dear Mr. Carlson:

On June 14, 1988, we received your proposal for vapor recovery and incineration at service station 5353, located at Westlake and Mercer.

Upon review of the subject document, our approval has been given.

Sincerely,

Craig S. Baker

Craig S. Baker
Spill Response Manager
Environmental Quality

CSB:gm

RECEIVED
JUN 23 1988
MAINT. & CONT.

Geo Engineers

June 8, 1988

Consulting Geotechnical
Engineers and Geologists

Unocal
P.O. Box 76
Seattle, Washington 98111

Attention: Mr. V.L. Carlson

Gentlemen:

Vapor Extraction System Overview
Subsurface Gasoline Leak
Unocal Service Station 5353
Westlake Avenue & Mercer Street
Seattle, Washington
File No. 0161-13-4

INTRODUCTION

This letter briefly describes the design, installation and operation of a vapor extraction system that is currently under construction at Unocal Service Station 5353 in Seattle, Washington. The purpose of the vapor extraction system is to remove hydrocarbon vapors trapped in the soil beneath the service station site and surrounding areas. The vapors have been generated as a result of volatilization of residual gasoline from contaminated soils near the water table. Methane vapors are also present beneath the site and surrounding areas. The source of the methane is probably from decomposition of sawdust fill and other organic material that is unrelated to the service station.

Service Station 5353 was the site of an 80,000-gallon leak of gasoline that occurred prior to May 1980. A free product recovery system was installed at the site and operated until October 1982. The recovery system consisted of a network of ground water/product recovery wells on the service station property. The total volume of liquid gasoline

GeoEngineers, Inc.
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recovered with this system was about 41,900 gallons. Natural processes of evaporation and biodegradation have also contributed to removal of product from the site. Residual contamination still remains at the site, including soil contamination, subsurface fuel vapors, and a limited amount of free product in several monitor wells. A number of options for further site mitigation have been considered, including continued free product recovery, ground water pumping, in-situ biodegradation and soil vapor extraction. The vapor extraction option is considered to be the most practical and cost effective for this site.

VAPOR EXTRACTION SYSTEM DESIGN AND OPERATION

GENERAL

The vapor extraction system will utilize the existing free product recovery wells and recovery galleries for the collection of subsurface hydrocarbon vapors. The vapors will be collected from the large-diameter product recovery wells using a vacuum blower system. The recovered vapors will be incinerated with a Multimode Combustor unit (MMC) supplied by King, Buck/Hasstech of San Diego, California. The initial MMC unit will consist of a thermal incinerator unit to burn the high-concentration combustible gases that are expected during the first few months of system operation. As the vapor recovery program progresses, vapor concentrations in the ground are expected to decrease gradually. The initial thermal incinerator unit will be replaced with a catalytic reactor when vapor concentrations decrease to levels that are impractical to treat by direct combustion.

VAPOR COLLECTION SYSTEM

Five existing large diameter ground water/product recovery wells will be used for the collection of subsurface vapors. These wells currently have well casing perforations that extend above the water table and a gravel pack surrounding each well screen. An air-tight seal will be fitted on the manhole opening of each recovery well. Existing 3-inch-diameter pipes that are connected to each well will be extended to the new vacuum blower. Vapor flow rates from each recovery well will be controlled by individual valves to allow flexibility in system operation. Vapor sampling ports will also be installed at each recovery well.

BLOWER SYSTEM

The vacuum system will be powered by a three-horsepower motor designed to provide a flow of about 100 CFM from the collection system. Flow from the blower system can be controlled manually if reduced flow rates are needed. Instrumentation will provide continuous information regarding flow from the blower. The blower system and the MMC will be installed within a secured fenced area along the northern edge of the service station property.

MULTIMODE COMBUSTOR UNITS

Incineration Unit: The initial thermal incineration unit is designed to treat vapors with hydrocarbon concentrations of 4000 ppm or greater. For vapor concentrations of between approximately 4000 ppm and 10,000 ppm, accessory fuel will be required to maintain combustion. Hydrocarbon destruction efficiencies of greater than 99 percent are typical for this unit. The auxiliary fuel will be natural gas supplied by Washington Natural Gas. We expect that the incineration unit will used for about 2 to 4 months at which time vapor hydrocarbon concentrations are expected to drop to below 4000 ppm. The thermal incinerator unit will then be replaced with a catalytic reactor unit.

Catalytic Unit: The catalytic unit uses a platinum catalytic reactor bed to oxidize hydrocarbon vapors at relatively low temperatures. Instrumentation will provide continuous information about the catalyst bed temperature to assure proper operation. A destruction efficiency of 95 percent is typical for this unit. The catalyst bed will be provided with an electric pre-heater to maintain proper operation temperature.

Safety: Both the thermal incinerator and catalytic units have numerous safeguards and automatic shut-off systems. Installation and operation will be performed under conditions of permits issued by the Seattle Fire Department and the Puget Sound Air Pollution Control Agency.

MONITORING

Approximately 30 subsurface monitoring points exist on the service station property and surrounding areas. These monitoring points consist of small diameter slotted PVC well screens that were installed in 1980 and 1981 to design and monitor the former free product recovery program. These monitor wells were installed to intercept the water table and are screened above the water table. We propose to monitor vapor concentrations and ground vacuum using these wells. Periodically, vapor samples will be collected to determine the ratio of fuel-derived hydrocarbon vapors to methane. Also, certain wells may be selected for the monitoring of water levels and remaining free product thickness.

We plan frequent monitoring during the initial stages of system operation to understand the dynamics of the vapor extraction system and to observe expected changes in vapor concentrations. Ultimately we plan to monitor conditions at the site on a monthly basis. Monitoring of all wells at this site is very difficult because 11 monitoring points are located in Mercer Street or Westlake Avenue and traffic on these roadways is heavy.

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Geo Engineers

We anticipate that progress reports will be prepared for Unocal on a frequency of once every four months. Verbal reporting or interim written reports may be prepared if significant changes are noted at the site.

Yours very truly,

GeoEngineers, Inc.

Stephen C. Perrigo/by JAM

Stephen C. Perrigo
Waste Management Specialist

James A. Miller

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Consulting Geotechnical Engineers and Geologists

November 14, 1985

Union Oil Company
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. Andy Barone

Gentlemen:

Summary of Geotechnical Consultation
Subsurface Gasoline Leak
Service Station No. 5353
Westlake Avenue and Mercer Street
Seattle, Washington
File No. 161-13

INTRODUCTION AND BACKGROUND

The results of our geotechnical consultation regarding subsurface conditions at Service Station No. 5353 are presented in this letter. Our services were authorized verbally by Mr. Barone on October 17, 1985.

Service Station No. 5353 experienced an underground leak of leaded super gasoline in the spring of 1980. The total volume of gasoline lost was estimated at approximately 80,000 gallons. Subsequent gasoline recovery operations were successful in removing approximately 42,000 gallons of liquid gasoline from the subsurface. Gasoline recovery and monitoring efforts were suspended in October 1982.

Several of the monitor wells and recovery wells in the leak area had liquid gasoline floating on the water table when the recovery program was suspended. The gasoline recovery rate decreased to approximately five gallons per day at that time, and the risk of off-site migration of the remaining liquid gasoline was judged to be small.

The City of Seattle is presently evaluating options for improving the transportation system in the immediate vicinity of Station 5353. The City is also considering land use changes in association with transportation improvements. The transportation plan currently preferred by the City of Seattle involves widening of Mercer Street, combined with the construction of two reversible traffic lanes below grade. The below-grade lanes would likely be at least 15 feet deep, with approximately the lower 4 feet of the excavation extending below the present water table.

GeoEngineers was contacted by Mr. Barone with regard to potential safety hazards which may exist with future deep excavations beneath Mercer Street in the immediate vicinity of Station 5353. These hazards are related to the potential presence of liquid gasoline and/or gasoline-contaminated soil in the excavation. Mr. Barone requested that GeoEngineers review the present conditions at the site in consideration of the City's plans and advise Union Oil regarding available options.

SITE MEASUREMENTS

We visited the service station on October 25 and October 27 to assess current conditions within the monitor wells and recovery wells located on the service station property and nearby streets. Wells located in streets were measured on Sunday morning (October 27) to minimize disruption of local traffic. The thickness of liquid gasoline floating on the water table (if any) was measured, and the air space within the wells was tested for flammable vapors with an explosimeter. The results of the field measurements are tabulated below.

Results of October 1985 Well Measurements

Well No.	Gasoline Thickness (feet)	Explosimeter Reading (% Lower Explosive Limit)
1	0.17	100+
2	0.00	100+
3	0.03	100+
4A	0.37	100+
5A	0.00	100+
6	0.41	100+
7	0.30	100+
8	0.06	100+
9	0.09	100+
10	0.10	100+
11	0.00	100+
13	0.00	100+
14	0.00	100+
15	0.00	100+
16	0.00	100+
17	0.09	100+
18	0.09	100+
19	0.41	100+
24	dry	—
25	0.00	100+
26	0.04	100+
27	0.00	100+
28	0.05	100+

The well measurements indicate the presence of more than 3 inches of liquid gasoline floating on the water table in Recovery Wells 4A and 7 and in Monitor Wells 6 and 19. Lesser thicknesses of gasoline were measured in other wells, as listed above. The pattern of gasoline distribution is similar to that which existed during the later stages of the 1980-82 gasoline recovery program. This suggests that the remaining free gasoline is relatively immobile. The explosimeter readings indicate that the gasoline vapor plume is very extensive. The boundaries of the vapor plume extend beyond the limits of the existing monitor well network.

CONCLUSIONS

Our site measurements indicate that liquid gasoline remains in the ground at and near Station 5353, despite the passing of more than five years since the occurrence of the leak and three years since termination of gasoline recovery operations. Liquid gasoline and soils contaminated by gasoline presently exist in the immediate area of excavations proposed by the City of Seattle for Mercer Street improvements.

In our opinion, if Mercer Street improvement excavations are made with subsurface conditions as they currently exist, there would be a strong likelihood of encountering liquid gasoline on the water table in portions of the excavation. The City may design the project such that the subsoils are dewatered prior to excavation. If dewatering is done, liquid gasoline could be encountered in dewatering wells located near Station 5353. Special handling or treatment may be required for water removed from the dewatering wells and the excavation area. Even if liquid gasoline is not encountered, gasoline vapors undoubtedly will be generated by excavation of contaminated soils. Confined conditions with liquid gasoline or gasoline vapors imply significant hazards to workers located in and near the excavation area.

We understand that it may be years before actual construction begins for the proposed Mercer Street improvements. The subsurface gasoline will gradually diminish during the intervening planning and design period. However, it is our opinion that the subsurface gasoline contamination associated with Station 5353 will take many years to be fully dissipated by natural processes. Excavation within soils contaminated by gasoline could present fire and explosion hazards for many years into the future, until complete dissipation occurs.

RECOMMENDATIONS

GENERAL

The technology presently exists for accelerating the rate of dissipation of subsurface gasoline through bioreclamation and soil venting. Bioreclamation was evaluated by Union Oil on a preliminary basis in 1982. Although bioreclamation may be of definite benefit in accelerating hydrocarbon dissipation, there are a number of factors which limit its practicality at this site. These include:

1. Nutrient solutions would need to be injected around the perimeter of the contaminant plume and recovered near the middle of the plume. This would necessitate construction of below-grade nutrient lines to connect with existing or new monitor wells located in Mercer Street and Westlake Avenue. The construction would require lane closures and "off-hours" work. In our opinion, public knowledge of the reasons for the work would be inevitable, and press coverage likely.
2. Effective treatment of contaminated soils in the water table zone could take 2 years or longer if full-time water pumping, nutrient injection and soil venting is done. An even longer treatment period would be necessary for contaminated soils located above the water table zone.
3. Total treatment of contaminated soil cannot be guaranteed.
4. Bioreclamation is very expensive.

In consideration of these constraints, and the uncertainties as to whether the Mercer Street improvements will ever be constructed, we do not recommend implementation of a bioreclamation program. We do recommend that efforts toward recovery of remaining liquid product be made and that site conditions be monitored and evaluated periodically. Details of these recommendations are presented later in this letter.

Gasoline contamination will likely remain in the ground for many years if bioreclamation is not done. It appears to us that it would be in Union Oil's best interest to resist plans by the City of Seattle to construct below-grade streets or underpasses in the vicinity of Station 5353. Union

Oil should keep informed of the City's plans and be prepared to disclose potential hazardous conditions to the City when the Mercer Street improvement project gets to the detailed planning or design phase. Once this disclosure has been made, it may be in your best interest to work with the City to resolve design and construction problems related to the presence of subsurface gasoline contamination.

ADDITIONAL GASOLINE RECOVERY

Recovery Wells 4A, 5A, 7, 8 9, 10 and 28 are constructed with power and plumbing to allow gasoline removal with floating "Scavenger" oil recovery pumps. The gasoline lines that are connected to these wells lead to a buried 10,000-gallon tank that is not presently used. This buried tank is equipped with a high-level float switch and alarm to prevent overfilling of the tank.

Several of the recovery wells are not deep enough to allow simultaneous gasoline recovery and water pumping. Water table depression in these wells would require deepening the wells. Water pumping would also necessitate periodic removal of the pumped water from the site or construction of new water treatment/handling facilities. In our opinion, water table depression is no longer essential for this site due to the apparent limited volume of liquid gasoline that remains in the ground and the apparent immobility of that gasoline.

We recommend that additional gasoline recovery be accomplished in Wells 4A, 7, 10 and 28 in order to increase the rate of ultimate dissipation of the gasoline and to reduce fire and explosion hazards associated with future excavations in the vicinity of Station 5353. We recommend that a single Scavenger unit be rotated through each of these four wells. The Scavenger should be operational in one of the wells for a period of one week, and then removed and placed in the next well. This rotational pumping program would result in recovery within each of the listed wells for at least one week a month.

All of the gasoline recovery lines and electrical systems should be checked prior to implementing the recommended gasoline recovery operations.

MONITORING

We recommend that the monitor wells and recovery wells be measured monthly for the presence of liquid gasoline and flammable vapors. Liquid gasoline should be removed (bailed) from all monitor wells that have gasoline thickness of 0.05 feet or greater. We have found that bailing of product from monitor wells after each round of well measurements results in more reliable data regarding product distribution and thickness than repetitive measurement of "static" wells. The gasoline and water that is removed from the monitor wells should be poured into the recovery well that currently has an active Scavenger unit. We would be pleased to provide monthly monitoring services, if you desire.

We recommend that the 10,000-gallon holding tank be measured weekly for the volume of water and gasoline. The contractor responsible for rotating the Scavenger pump should be responsible for making these stick gage measurements. The results of the weekly tank measurements will provide the basis for evaluating the performance of the recovery program and the need for pumping out the holding tank.

LIMITATIONS

We have prepared this letter for exclusive use by the Union Oil Company in evaluating response options related to subsurface gasoline contamination at Service Station No. 5353. Our interpretations of existing and future conditions at the site are based on review of 1980-82 data, evaluation limited recent data and the past experience of our firm.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No other conditions, express or implied, should be understood.

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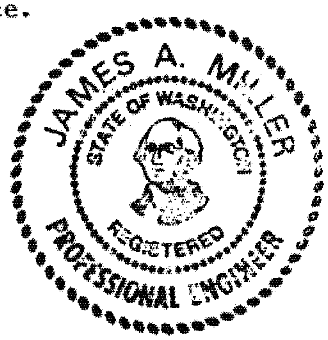
We appreciate the opportunity to be of service. Please call if you have any questions regarding this letter or if we may be of additional assistance.



Yours very truly,

GeoEngineers, Inc.

James A. Miller

James A. Miller
Associate

JAM:wd

Three copies submitted

APPENDIX D

Geo Engineers

October 3, 1988

Consulting Geotechnical
Engineers and Geologists

Unocal
P.O. Box 76
Seattle, Washington 98111

Attention: Mr. Leigh Carlson

Gentlemen:

Interim Status Report
Subsurface Vapor Extraction Program
Service Station 5353
Seattle, Washington
File No. 0161-13-4

This interim status report summarizes vapor recovery progress and our proposed changes to the operation of the vapor recovery system at Unocal Station 5353 in Seattle, Washington. Our Progress Report No. 1 summarizes the design of the system and its operation from June 24 through July 20, 1988. We also plan on issuing a second progress report covering the period of operation from July 21 through mid-November, 1988.

Progress Report No. 1 summarizes recovery progress for gasoline and methane. These values are computed based upon measured concentrations in the recovered vapors and the vapor flow rate. Since that report, we estimate that additional recovery of gasoline vapors and methane through September 24, 1988 account for an additional equivalent of approximately 1,100 gallons of gasoline and 10,390 cubic feet of methane. This brings the total equivalent recovery to 1,450 gallons of gasoline and 63,750 cubic feet of methane for a total operational period of about 90 days. We are presently evaluating analytical methods to determine if the methane is derived from anaerobic degradation of gasoline.

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Once the vapor recovery system became operational, we evaluated the long-term operational costs for the system as it was planned to be operated. The proposed operation of the system called for the transition of the vapor destruction process from the initial thermal incinerator to a catalytic reactor once hydrocarbon concentrations in the vapors dropped to levels that the catalytic reactor could handle without incurring catalyst damage. In comparing costs between the two systems, it became apparent that the cost for continued operation of the thermal incinerator was less than that for the conversion to the catalytic reactor. The lower operational costs are primarily the result of low natural gas costs in Seattle. Other benefits of remaining on the thermal incineration process (as opposed to the catalytic reactor) for vapor destruction include: (1) greater vapor destruction efficiency, (2) no additional installation or training costs, and (3) no increased monitoring costs during transition.

We recommend that the system continue to be operated in its current thermal incineration mode. The thermal incineration unit was initially planned to be a short-term rental unit. Purchase of the system will realize a cost savings over the expected life of the project. We have discussed the purchase price with King, Buck & Associates, the incinerator manufacturer. The cost of the system, including credit applied to the lease of the unit, is $22,845. This price includes the blower unit, the incinerator, an additional flame arrestor, and instrumentation for continual recording of system operation and vapor flow rates.

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GeoEngineers

We appreciate the opportunity to assist you with this project. Please call if you have any questions about this letter or the continued operation and monitoring of the vapor recovery system.

Yours very truly,

GeoEngineers, Inc.

Stephen C. Perrigo / by JAM

Stephen C. Perrigo
Waste Management Specialist

James A. Miller

James A. Miller, P.E.
Principal

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