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FINAL REPORT
UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

VOLUME I

CAMP GEIGER FUEL FARM
MARINE CORPS BASE

CAMP LEJEUNE, NORTH CAROLINA

February 8, 1992

Law Engineering Job No. J47590-6014

Law Engineering, Inc.
Raleigh, North Carolina

LAW ENGINEERING

LAW ENGINEERING

GEOTECHNICAL, ENVIRONMENTAL
& CONSTRUCTION MATERIALS
CONSULTANTS

February 7, 1992

Commander
Naval Facilities Engineering Command
Atlantic Division
Norfolk, Virginia 23511-6287

Attention: Code 1821, Mr. Trueman Seamans
Engineer-In-Charge

Subject: **REPORT OF UNDERGROUND FUEL INVESTIGATION AND COMPREHENSIVE SITE ASSESSMENT**
CAMP GEIGER FUEL FARM, MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

Dear Mr. Seamans:

In accordance with Naval Facilities Engineering Command Order for Supplies and Services Contract No. N62470-90-D-7625/0002 dated September 29, 1990, Law Engineering is pleased to present this report of our environmental services recently performed at the above-referenced project site. The scope of our services, as described in the attached Report of Comprehensive Site Assessment, included drilling of soil-test borings and collection of soil samples for chemical testing; collection of Hydropunch ground-water samples for chemical testing; installation of ground-water monitoring wells and collection of ground-water samples for chemical testing; and investigation of the geology and hydrogeology in the area of the Camp Geiger Fuel Farm. The objective of our services was to provide an assessment of the extent/severity of and possible exposure to subsurface petroleum contamination caused by leaks from the fuel storage tank system.

This report is intended for the exclusive use of Naval Facilities Engineering Command, Atlantic Division. The contents should not be relied upon by any other parties without the expressed, written consent of Law Engineering. The findings are relevant to the dates of our site work and should not be relied upon to represent site conditions on other dates.

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We appreciate the opportunity to continue to work with you and the Navy on your environmental projects. If any questions arise, please contact us at (919) 876-0416.

Sincerely,

LAW ENGINEERING, INC.

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Project Geologist

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cc: Code 09A2122, Mr. G.G. Aiken, P.E.
Mr. Tom Morris

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1.0 INTRODUCTION

1.1 Purpose of Investigation

On September 29, 1990, the Commander of the Atlantic Division Naval Facilities Engineering Command (LANTDIV) in Norfolk, Virginia, contracted with Law Companies Group, Inc. to perform a Comprehensive Site Assessment (CSA) at the Camp Geiger Fuel Farm, Marine Corps Base (MCB), Camp Lejeune, North Carolina (Drawing 1.1). The purpose of the investigation was 1) to identify the presence, magnitude and extent of possible free-product accumulation and ground-water contamination and 2) to assess potential exposure to subsurface contaminants resulting from the release(s) of petroleum fuels. As stated in the CSA Workplan contained in Appendix A, the objective of the investigation was to provide sufficient data to meet the requirements of Sections 280.63 and 280.65 of 40 CFR Part 280, Federal Technical Standards for Underground Storage Tanks. This data should also be sufficient to meet the requirements of Sections .0704 and .0706 of Title 15A, Chapter 2, Subchapter 2N, North Carolina Criteria and Standards Applicable to Underground Storage Tanks.

1.2 Scope of Work

Authorization to proceed with the investigation was granted by the Commander of LANTDIV of Norfolk, Virginia, via Contract/Purchase Order No. N62470-90-D-7625/0002 dated September 29, 1990.

As outlined in the contract and the CSA Workplan, the Scope of Work included preparation of a health and safety plan, collection of ground-water samples using the Hydropunch ground-water sampling system, performance of a soil-gas survey and tracer testing of the underground fuel lines, excavation of soil borings, installation of monitoring wells, collection and analysis of soil and ground-water samples, performance of a preliminary exposure assessment, performance of a preliminary evaluation of remedial alternatives, preparation of a final report of investigation and presentation of data and conclusions. Specific methods employed during performance of the project activities are described within the appropriate sections of this report.

1.3 Previous Investigations

A leaking underground line was reportedly discovered at the Camp Geiger Fuel Farm (Fuel Farm) in 1957-58. Law Engineering could not locate written documentation of this incident, but found reference to it in a report by Environmental Science & Engineering (ESE) of Plymouth Meeting, Pennsylvania (1990). This report stated that the Camp Lejeune Fire Department estimated that thousands of gallons of fuel was released; the records documenting the exact quantities of the spill have been destroyed. The spill migrated to the east and northeast into Brinson Creek. Gasoline at the top of the surficial aquifer was exposed by digging trenches; the fuel was then ignited and burned. Fuel which reached Brinson Creek was also ignited and burned. Mr. Ron Waters of Direct Support Stock Control of the Logistics Department at Camp Geiger, who has been employed at Camp Geiger for 35 years, stated that a fireman from the Camp Geiger Fire Department had told him that the leak occurred when a dispensing pump was damaged. He was also told that the Fire Chief had to wade through the spilled product to turn off the valve to the pump.

MCB Camp Lejeune is listed on the National Priority List (NPL) and Wastelan Preremedial Report, both of which are compiled by the Environmental Protection Agency (EPA) and monitored by the Division of Solid Waste Management of the North Carolina Department of Environment, Health and Natural Resources. MCB Camp Lejeune was placed on the NPL in 1983, after Water and Air Research, Inc. of Gainesville, Florida performed an Initial Assessment Study of 76 potentially-contaminated sites at the base. Water and Air Research identified 21 of these sites as warranting further investigation. Camp Geiger Fuel Farm is one of the 21 sites recommended for further investigation. A twenty-second site at Camp Lejeune was later added to this list.

ESE performed Confirmation Studies of the 22 sites requiring further investigation and performed the Fuel Farm study between 1984 and 1987 (ESE, 1990). During this study, ESE advanced three hand-auger borings, collected ground-water and soil samples from each and documented ground water contaminated with lead and soil contaminated with lead, oil and grease. In 1986, ESE collected sediment and surface-water samples from Brinson Creek and installed three monitoring wells, two east of and one west of the Fuel Farm. These wells were sampled after installation and again in 1987. Laboratory analysis did not reveal surface-water contamination, but did document lead, oil and grease in the sediment and soil samples. Ground water from both the upgradient and downgradient wells was found to be contaminated with volatile organic compounds. ESE could not identify a source for the contamination documented in the upgradient well. ESE identified two possible sources for the contamination in the downgradient wells. The first was the fuel spill which occurred at the fuel farm in the 1950's and the second was an automotive maintenance shop located southeast to the Fuel Farm, in Building No. TC-474.

NUS Corporation performed an investigation in the area north of the Fuel Farm in 1990. According to the NUS report (NUS, 1990), fuel was observed in a stormwater drainage ditch. Base personnel constructed an earthen dam in the drainage ditch to contain the fuel and rerouted storm drainage to the south. NUS installed four monitoring wells, three in the vicinity of the ponded stormwater and one in an apparent upgradient position. Results of laboratory tests performed by NUS revealed that ground water in one well and soil from the cuttings of two soil borings in the vicinity of this drainage ditch were contaminated with petroleum-fuel constituents. No free-phase petroleum hydrocarbons (free product) were reportedly observed in the wells. Ms. Amy Hubbard, project manager of the investigation for NUS, stated that NUS personnel did not observe any free product over the 8-week period of their investigation. Ms. Hubbard stated that she believes that the contamination resulted from a one-time surface release of product. Ms. Stephanie del Re-Johnson of the Installation/Restoration Division of the Environmental Management Department (EMD) at Camp Lejeune stated that she had observed a 5-foot thickness of free product on the surface of the ponded water. NUS determined from the four monitoring wells that the local direction of ground-water flow was to the northeast.

During their investigation, NUS also conducted a geophysical survey in an attempt to determine if underground storage tanks (USTs) remained at the site of the former gasoline station. This gasoline station was located west of the Fuel Farm and south of the headwaters of the drainage ditch in which the fuel was discovered. From the data acquired during this geophysical survey, NUS identified an anomaly to the north of the foundation of the gasoline station.

In addition to the ESE and NUS assessments, the United States Geological Survey (USGS) performed an investigation at MCB Camp Lejeune (Harned et al, 1989). This study is referenced fully in Section 8.0 of this report and includes discussions of the hydrology and hydrogeology of Camp Lejeune.

2.0 DESCRIPTION OF SITE

2.1 Area of Investigation

The Camp Geiger Fuel Farm is located on the north side of Fourth Street at its intersection with G Street at Camp Geiger, Camp Lejeune MCB, Onslow County, North Carolina (Drawing 1.1). The site is situated entirely within the confines of Camp Geiger. The study area is bounded on the west by D Street, on the north by Second Street, on the east by Brinson Creek, and on the south by Building No. TC-474

(Drawing 2.1). Mr. Tom Morris of the Installation/Restoration Division of the EMD and Mr. John Starcalla of the Public Works Department at Camp Lejeune provided numerous site drawings showing the locations of underground utilities and aboveground structures. We have included a list of these drawings in Table 2.1.

2.2 History and Operations of the Site

2.2.1 History of the Site

Construction of Camp Lejeune began in 1941. Construction of Camp Geiger was completed in 1945. We have not been able to identify when Camp Geiger Fuel Farm was constructed, although we have reviewed a site plan for the Fuel Farm which is dated July 17, 1941 (Y. and D. Drawing No. 161783). When constructed, the tanks at the Fuel Farm were used for the storage of No. 6 fuel oil. The tanks were converted for storage of other petroleum products when No. 6 fuel was no longer needed. Law Engineering could not determine when this conversion occurred.

Law Engineering has identified three sites in the study area which once were the sites of structures which have since been demolished. The first site is an ice house, which was located adjacent to the railroad spur on the west side of the Fuel Farm. The ice house was supplied with ice brought to the site by train. Mr. Morris provided drawings of the ice house (Building No. TC-360, Y. & D. Drawing Nos. 161813 and 161814, dated June 26, 1941). The site drawing does not show underground utilities other than water and water drains. We cannot determine when the ice house was demolished. The foundation and pilings which supported the ice house remain at the site.

The second site is a "filling" (gasoline) station, which was located on the northeast corner of the intersection of F and Fourth Streets, adjacent to the ice-house site. Mr. Morris provided a site drawing of the building which had occupied the site (Building No. 341, P.W. Drawing No. 2816, dated November 12, 1947) but could not locate a site plan showing the location of the storage tanks, distribution lines and dispensing pumps. We cannot determine when the filling station was demolished. The foundation to the filling station remains at the site.

The third site is a mess hall, with an associated boiler and underground storage tank (UST), which was located adjacent to D Street, between Third and Fourth Streets. Mr. Morris provided a drawing (Y. and D. Drawing No. 161873) showing the location of an underground fuel distribution line, which extended from the Fuel Farm to the UST, and the approximate location of the UST. Mr. Morris stated that this UST stored

No. 6 fuel oil when the boiler was in operation. We cannot determine when the mess hall was demolished, although Mr. Morris stated that he believed this occurred in the 1960's.

In Building No. TC-474, south of the Fuel Farm, Law Engineering understands that automotive maintenance was performed until approximately 4 years ago. Although this building is outside of the study area, activities undertaken there may have had an environmental impact on the area around the Fuel Farm.

Mr. Anthony Koonce, civilian-in-charge of fuel dispensing at the fuel farm, discussed with Law Engineering an incident which occurred approximately 4 years ago. Mr. Koonce stated that daily inventory-control records at the Fuel Farm were out of balance by approximately 30 gallons per day. After review, this imbalance was attributed to a leak in the gasoline line which carried gasoline from the pump house to the dispensing island. This line was sealed off at both ends and replaced by a line which runs along the eastern side of the Fuel Farm. A subsurface investigation was not undertaken at the time of the possible release to document soil or ground-water contamination which may have resulted from this leak.

Law Engineering identified a UST located behind and adjacent to Building TC-480 which was installed in 1976. This UST has a capacity of 550 gallons and contains #2 fuel oil, which is used to heat Building TC-480.

2.2.2 Operations of the Site

The Fuel Farm contains aboveground storage tanks (ASTs) which are used to dispense gasoline, diesel and kerosene to government vehicles and to supply USTs in use at Camp Geiger and the Air Station. These ASTs are refilled by trucks which are operated by commercial carrier and which deliver product to fill ports at the southern end of the storage facility. The operation of the Fuel Farm is supervised by two attendants who operate the facility from a small building (Building No. TC-364, Drawing 2.2) at the southern end of the Fuel Farm. There are five ASTs at the Fuel Farm:

- two diesel fuel ASTs, each with a capacity of 15,000 gallons,

- two unleaded gasoline ASTs, each with a capacity of 15,000 gallons, and

- one kerosene AST with a capacity of 15,000 gallons.

According to the site drawing referenced in Section 2.2.1, the initial tanks were placed in service in the early 1940's. Mr. Waters stated that the original tanks have never been replaced.

There are six underground lines used to distribute fuel within the fuel farm (Drawing 2.3). These are:

- an unleaded gasoline line approximately 70 feet long which connects the fill port and pump house;

- an unleaded gasoline line approximately 140 feet long which connects the pump house and vehicle dispensing pump;

- a diesel line approximately 70 feet long which connects the fill port and pump house;

- a diesel line approximately 120 feet long which connects the pump house and both the overhead dispensing pump and the vehicle-dispensing pump on the pump island;
- a kerosene line approximately 80 feet long which connects the fill port and pump house; and
- a kerosene line approximately 110 feet long which connects the pump house and the overhead dispensing pump.

The underground lines now in place are those originally installed, with the exception of the recently-installed gasoline line referenced in Section 2.2.1. Mr. Koonce stated that their standard operating procedures include performing daily inventory-control procedures.

There are also three underground lines at the Fuel Farm which are no longer used and which have been sealed off. These three abandoned lines are:

- a gasoline line approximately 60 feet long which connected an abandoned fill port and the pump house;

- a diesel line approximately 20 feet long which connected an abandoned fill port and the pump house; and
- a gasoline line approximately 120 feet long which connected the pump house and pump island.

Law Engineering has found evidence that there also may be one additional line connecting the Fuel Farm and an underground storage tank (UST). The path of this line is shown on Drawing No. 2.4. As indicated in Section 2.2.1, this line carried No. 6 fuel oil from the Fuel Farm to a UST which may still be located at the site of a former mess hall. Law Engineering could not determine if this line was removed when the UST was abandoned.

2.3 Inventory of Contaminant Sources

USTs identified in and around the Fuel Farm are listed in Table 2.2. The location of USTs with respect to the site are presented in Drawing 2.5. Please note that Table 2.2 includes only those tanks that have been identified during the course of this investigation. The possibility remains, however, that other unidentified USTs are present near or were in the past located near the Camp Geiger Fuel Farm.

In addition to the USTs listed in Table 2.2, nine active and inactive product transmission lines are or have been located in the study area, as identified in Section 2.2.2. These product lines are also presented in Drawing 2.5.

2.4 Inventory of Water Wells

As part of our survey to identify potential receptors of ground-water contaminants, Law Engineering performed a survey of drinking-water wells in the vicinity of Camp Geiger Fuel Farm by reviewing USGS Report 89-4096 and through discussions with Mr. Morris. This report shows the locations of drinking-water wells in Camp Geiger, all of which are located adjacent to A Street and over 2000 feet west of the Fuel Farm (Drawing 2.6). Our survey of wells targeted those located within one-half mile of the project site in order to provide an adequate area of coverage. A discussion of the results of the survey of potential receptors is provided in Section 6.0 of this report.

We have presented a summary of the well inventory in Table 2.3, which provides information on the well depth, casing diameter, well usage and the well's approximate distance from the Fuel Farm. Each of the wells identified was constructed as an open-hole wells in the Castle Hayne Aquifer. The Castle Hayne aquifer and the hydrogeology of the area are introduced and referenced in Section 3.0 of this report.

2.5 Survey of Underground Utilities

Subsurface utility trenches can often provide preferential pathways for migration of contaminants. Therefore, Law Engineering attempted to identify and locate subsurface utilities in the vicinity of Camp Geiger Fuel Farm. Mr. Morris provided plans and drawings showing the locations of subsurface utilities, the locations of which are shown in Drawings 2.7, 2.8 and 2.9. Typically, underground utility lines are buried 2 to 6 feet below land surface (bls). As previously indicated, underground fuel transmission lines are exhibited in Drawing 2.5.

3.0 SITE HYDROGEOLOGIC CHARACTERIZATION

3.1 Site Topography

As indicated by the Jacksonville South, N.C. topographic quadrangle, published by the United States Geological Survey in 1952 and photorevised in 1971 (Drawing 1.1), the elevation of land surface in the vicinity of Camp Geiger Fuel Farm generally ranges from 3 to 17 feet above mean sea level (msl) and the land surface slopes toward the northeast. Most of the study area is not serviced by storm sewers, and runoff generally travels by sheet flow before entering natural drainage ditches which discharge into Brinson Creek, to the east and northeast of the study area.

3.2 Regional Geology/Hydrogeology

The study area is located within the Lower Coastal Plain Soil System (Wiscomico and Talbot System) and the Coastal Plain/Castle Hayne Limestone hydrologic area. A brief summary of the geologic/hydrogeologic setting at the Camp Geiger Fuel Farm is provided in Section 2.2 of the CSA Workplan (Appendix A). In general, downward movement of ground water is obstructed by the presence of clay layers in Coastal Plain formations and consequently most of the ground-water recharge migrates laterally toward discharge areas through the surficial aquifer (Heath, 1980). Further details of regional geologic/hydrogeologic characteristics are provided in the USGS Water-Resources Investigation previously cited (Harned 1989).

3.3 Site Soils and Geology

Law Engineering performed field activities on August 15-30, 1991, which consisted of the following:

- Advancing 18 soil borings, which were subsequently used for the installation of monitoring wells;
- Advancing 5 soil borings to check for the presence of soil contamination;
- Advancing 3 stratigraphic borings to determine the geology of the subsurface in the study area; and
- Advancing 9 shallow hand-auger borings to check for the presence of soil contamination in suspect areas.

The locations of these borings are shown on Drawing 3.1. We were unable to complete boring B-3 as planned. We attempted this boring six times and each time encountered auger refusal due to steel reinforcing wire in the concrete pad or unidentified obstructions just below the pad.

Law Engineering accomplished all drilling using hollow-stem augers and techniques described in ASTM D-1452. We steam-cleaned our down-hole drilling equipment prior to work at each drilling location. We used augers with an inside diameter of either

3.25 or 3.75 inches for the drilling of a "pilot" hole and for the collection of soil samples. After completing the "pilot" hole, we reentered each monitoring-well borehole using augers with an inside diameter of 8.25 inches to allow the placement of two sets of PVC pipe in the well. We grouted to land surface those soil borings not used for the installation of monitoring wells.

Site geologists collected soil samples from each of the soil borings for field classification, headspace testing and chemical testing. We generally obtained soil samples for field classification at depths of 0 to 1.5 feet, 1.5 to 3 feet, 3 to 4.5 feet and on 5-foot centers thereafter to boring termination. We collected these soil samples with a split-spoon sampler 24 inches long and with an inside diameter of 1.375 inches (outside diameter of 2 inches). We obtained each soil sample by repeatedly allowing a 140-pound hammer to fall free for 30 inches, until the sampler was driven 18 inches into the substrate. We performed split-spoon sampling in general accordance with ASTM D-1586 and recorded on the field boring log the number of blows required to drive the sampler each 6-inch increment. After donning laboratory-grade gloves, we placed representative portions of each sample in two, pre-labeled plastic bags and sealed each bag for subsequent headspace testing.

Site geologists examined in the field the soil collected at each interval using visual/manual techniques described in ASTM D-2487 and ASTM D-2488 and classified the soil in general accordance with the United Soil Classification System. We have included a record of each test boring in Appendix B.

The soil and stratigraphic borings penetrated three distinctive units. The first unit is a fine- to medium-grained, unconsolidated sand. The thickness of this unit ranges from 15 to 30 feet. Law Engineering selected two samples of this unit to be analyzed for grain-size distribution, the results of which are presented in Appendix C. We performed these analyses on samples from MW-23, collected from a depth of 8.5 to 10.5 feet, and from MW-24, collected from a depth of 13.5 to 15.5 feet. These analyses revealed that the samples generally contain 96% sand and 4% silt and clay.

The second unit is a oolitic, fossiliferous limestone which ranges in thickness from 6.5 to 20 feet. The fossils consist of fragments of mollusks; the matrix consists of fine-grained sand, fine-grained phosphate grains and lime mud. Under the Folk classification (Blatt et al, 1972), this unit is a biosparite. Mr. Rick Shiver of the Wilmington Regional Office of the DEM stated that this unit is common in the Jacksonville area and is considered part of the unconfined, surficial aquifer. Law Engineering believes this unit is the River Bend Formation.

The third unit is an unconsolidated, dark gray to black silty, clayey sand. Because this unit may be a confining unit separating the surficial and Castle Hayne aquifers, Law Engineering did not attempt to completely penetrate this clayey sand, and therefore, the thickness is not known. We sampled this unit in SB-1, SB-2, SB-3 and MW-19 and observed this unit up to 4 feet thick in SB-2. Law Engineering selected the sample of this unit from SB-1 to be analyzed for grain-size distribution, the results of which are presented in Appendix C. This analysis revealed that the sample contained 79% fine sand, 9% silt and 12% clay.

This clayey sand is probably the same described by Harned et al (1989) as one of many occurring in the surficial aquifer and the Castle Hayne. These units are reportedly not confining units in the Camp Lejeune area because the units are thin and discontinuous. This report noted, however, that the units appears to be thicker and more continuous in the northwestern part of Camp Lejeune, where the Fuel Farm is located. Law Engineering believes that this clayey sand acts as a confining unit in the study area due to its relatively high percentage of silt and clay. We believe that this unit separates the surficial aquifer from the underlying Castle Hayne aquifer.

Law Engineering developed two cross sections from soil-boring records in order to facilitate lithologic interpretation. The locations of these cross sections are exhibited in Drawing 3.2; the cross sections are illustrated in Drawings 3.3 and 3.4. As shown in the cross sections, the stratigraphic units encountered within the surficial aquifer consist of the unconsolidated sand, lithified limestone (River Bend Formation) and clayey sand. Law Engineering believes that the upper contact of the River Bend Formation is not a planar surface and we expect its thickness to be highly variable. We observed this variability in SB-3 and MW-19. While only 240 feet apart, the thickness of the River Bend in SB-3 is 20 feet and the thickness in MW-19 is 6.5 feet.

3.4 Site Hydrogeology

Law Engineering installed a total of 18 ground-water monitoring wells, utilizing the materials and installation procedures described in the CSA Workplan. In order to monitor ground water at multiple depths and delineate the vertical extent of ground-water contamination at the Fuel Farm, we installed "paired" monitoring wells in 17 of 18 boreholes, each with a "shallow" screened interval and a "deep" screened interval. There is one well (MW-20) that is not paired; we encountered auger refusal with the large-diameter augers at the top of the River Bend Formation and therefore were not able to set a deep screen. Installing paired wells allowed us to sample the ground water at the water table and at depths of 10 to 20 feet below the water table, thus enabling us to investigate the vertical extent of contamination.

The specifications for each soil boring included decontaminating the drilling equipment and well construction materials with a pressurized steam-cleaning unit, emplacing a silica-sand filter pack and a bentonite seal above the filter pack, grouting the well above the bentonite seal with a cement/bentonite slurry, and developing the well through low-yield pumping. In Tables 3.1 and 3.2, we have listed the approximate volumes of water removed during well development and our observations of turbidity of the development water.

The wells constructed by Law Engineering are protected by a lockable, stick-up cover constructed of steel. This stick-up cover is embedded in a concrete pad and is protected by three steel bollards filled with concrete. Details for the installation of the monitoring wells are included in Appendix D.

During the period September 3-5, 1991, Law Engineering measured depths to ground water in all monitoring wells, the results of which are listed on the Monitoring-well Casing and Water-elevation Worksheets in Appendix E. Elevations of all measuring points were reviewed and certified by a Registered Land Surveyor; these points are also listed in these worksheets.

Based on ground-water elevations measured in the "shallow" monitoring well of each well pair and several of the pre-existing wells, we prepared a water-table contour map, from which we determined the direction of ground-water flow (Drawing 3.5). Ground water in the surficial aquifer generally flows across the project site to the east, towards Brinson Creek. As indicated by comparing water level elevations recorded on September 3, 1991 between "shallow" and "deep" screened intervals, ground water in the surficial aquifer generally moves laterally across the project site with no significant vertical gradient. However, we observed a slight vertical component of upward movement in MW-23 and MW-25, both of which are located near natural discharge points -- Brinson Creek and the intermittent streams which discharge into Brinson Creek. At these locations we would normally expect some upward component of ground-water flow as ground water seeks to discharge into surface drainage features. We did not use the ground-water elevations measured in EMW-6 and EMW-7 because these wells are screened below the water table and the elevations were inconsistent with measurements obtained from nearby wells. Likewise, we did not use the ground-water elevation measured in MW-24 because the measurement was so dissimilar from nearby wells. Law Engineering cannot determine the reason for this dissimilarity.

The rate or average linear velocity of ground-water movement across the project site is a function of the hydraulic conductivity (K) of the aquifer medium, the effective porosity (n) of the aquifer medium and the hydraulic gradient (dh/dl) that exists in the surficial aquifer. We calculated the hydraulic conductivity of the unconsolidated sands in the surficial aquifer at the study area based on results of previous studies performed on unconsolidated sands by F.D. Masch and K.J. Denny (in Freeze and Cherry, 1979). We used the data in the grain-size gradation curves (Appendix C) in these calculations for the samples from MW-23 and MW-24. Based on the results of the calculations, we expect the hydraulic conductivity of the unconsolidated sands within the surficial aquifer to be approximately 28 feet/day (Appendix C). Based on the recharge rate of the wells screened over this unit and a review of hydraulic conductivity estimates published by Freeze and Cherry (1979), we expect that the hydraulic conductivity of the River Bend is at least as great as that of the unconsolidated sand.

We calculated the average, linear velocity of ground-water flow in the unconsolidated sands within the surficial aquifer, using the computer program Water-Vel (1989). This program allows us to predict the general direction and average, linear velocity of ground-water flow based on three values: piezometric (water-table elevation) measurements, calculated value of hydraulic conductivity, and estimated values for effective porosity. Water-Vel calculations are based on Darcy's Law ($q=K\ [dh/dl]$)

and the relationship between Darcy velocity (q) and average, linear, velocity of ground water (v=q/n).

Using Water-Vel, we calculated a range of average, linear velocities of between 0.99 feet/day (n=25%) and 1.66 feet/day (n=15%) using values for effective porosity of 15% to 25% for fine sand, as estimated by Walton (1984). These calculations are included in Appendix F. The values for effective porosity are an estimate and are based on the predominant soil types encountered during construction of borings at the project site. Please note that this calculated velocity is an average velocity across the entire project site; the actual rate at a specific location at the site may be more or less than the rate calculated herein.

4.0 ASSESSMENT OF SUBSURFACE CONTAMINATION

4.1 Tracer Tight Leak Testing

Law Engineering subcontracted with Tracer Research Corporation of Tucson, Arizona to perform a tracer test of the underground fuel lines within the Fuel Farm, the report of which is included as Appendix G. This test was accomplished by adding a highly-volatile liquid tracer to the fuel in the fuel system and allowing approximately two weeks for the tracer to become distributed throughout the system. On August 19, 1991, personnel from Tracer Research and Law Engineering installed 29 soil-gas probes along the underground fuel transmission lines at the fuel Farm (Drawing 4.1) to detect tracer gas that may have been released to the surrounding soil.

Tracer gas was not detected in samples collected by the probes. Based on this result, Tracer determined that the tank and pipe systems that were tested at the Fuel Farm passed the precision leak test, which is capable of detecting leaks of 0.05 gallons per hour with a probability of detection of 0.97 and a probability of false alarm of 0.029. However, samples collected by the probes did contain volatile hydrocarbons in three locations, as shown in Figure 2 of the Tracer study. The largest vapor "plume" occurs below the fuel-loading pad and may have resulted from the contamination from the leaking gasoline line referenced in Section 2.2.1. There are two smaller plumes under the fuel tanks which may have resulted from surface spills. We used the results of this study to determine locations of soil borings B-2 and B-3 and hand-auger borings HA-3 and HA-4, which are located in two of the three plumes identified in the Tracer study.

4.2 Soil Contamination

4.2.1 Scanning Procedures

Law Engineering monitored all soil-investigation activities with a photoionization detector (PID) manufactured by HNu Systems (Model PI 101) which had been calibrated to isobutylene. We used the PID to qualitatively measure total volatile organics in the borehole, in ambient air, and in the individual soil samples. Values recorded with the PID are qualitative only and are not directly comparable to actual laboratory analytical results. However, the PID is useful in providing a relative indication of the presence of volatile organics in soil samples.

4.2.2 Hand-auger Borings

Law Engineering advanced hand-auger borings, each to a depth of 5 feet, to accomplish two objectives. The first objective was to check for the presence of USTs in the vicinity of the geophysical anomaly identified during the ESE investigation (Drawing 3.1) at the site of the former gasoline station. We advanced 16 hand-auger borings in this area but did not detect evidence of USTs or soil contamination by volatile organics.

The second objective of the hand-auger borings was to check for the presence of soil contamination and USTs in suspect areas. We performed these borings in four areas (Drawing 3.1). In the first area, we advanced hand-auger borings HA-1 and HA-2 where we suspected the presence of the UST associated with the former mess-hall operations. HA-1 encountered auger refusal at a depth of approximately 2 feet, which may have been due to the presence of this UST. HA-2 was advanced approximately 10 feet east of HA-1 and encountered soils with anomalous PID readings. Based on these readings, we drilled boring B-4 to check for soil contamination.

In the second area of hand-auger borings, we advanced HA-3 and HA-4 near the pump house where we identified data anomalies in the soil-gas survey. We collected soil samples for laboratory analysis from each of these borings.

In the third area of hand-auger borings, we advanced HA-5 and HA-6 behind the gasoline station and to the west of the 16 hand-auger borings, in a location where Mr. Morris had suggested that a UST may remain. We observed no indication of USTs or soil contamination in either of these borings.

In the fourth area of hand-auger borings, we advanced HA-7, HA-8 and HA-9 near where the fuel line extending from the Fuel Farm to the mess-hall UST makes a 90°

turn to the west (Drawing 4.2). We chose this location because it was in the vicinity of the contaminant plume identified by the Hydropunch sampling and because pipe joints are particularly susceptible to leakage. We collected one soil sample from HA-7 based on PID readings.

4.2.3 Soil Borings

Locations of the soil borings (B-1 through B-6, SB-1 through SB-3) and wells constructed from soil borings (MW-8 through MW-25) are shown in Drawing 3.1. Depths of the soil-test borings ranged from 15 to 44.5 feet. Moist soil conditions were generally encountered at a depth of 8 to 10 feet bls. None of the soil borings penetrated the Castle Hayne Formation, which supplies drinking water for Camp Lejeune.

We collected soil samples from each boring for headspace testing and laboratory chemical analysis according to the following procedure:

- The decontaminated split-spoon sampler was driven to the desired depth interval.

- The split-spoon sampler was retrieved and immediately opened. Portions of sample aliquots were quickly removed from the split-spoon sampler and placed into two, pre-labeled, airtight plastic bags. Sample handling was executed carefully in an effort to reduce the loss of the volatile organics. The bags were sealed and placed in a warm location.

- After approximately 10 minutes, the headspace gas in one of the two bags was tested with the PID and the peak value was recorded. This procedure was conducted for the soil sample collected at each sample-depth interval.

- From the soil samples collected from the borings, the two samples that exhibited the highest PID reading were targeted for chemical analysis. For those samples, the paired sample was transferred to a laboratory-supplied glass container, placed into a cooler, packed on ice and shipped to the laboratory for chemical analysis. Law Engineering maintained custody of the samples until shipment at the end of each day.

4.2.4 Results of the Soil Sampling

A summary of headspace analyses are presented in Table 4.1. Results show that volatile organics were detected in samples collected from 19 of the 24 boreholes. In general, concentrations of contamination were greatest in the samples collected at depths of 8.5 to 10 feet, near or just below the water table. Therefore, we suspect that lateral movement of the dissolved-phase plume and seasonal fluctuations of the water table has resulted in adsorbed-hydrocarbon contamination in the capillary-fringe area.

A summary of the results of laboratory analyses of the soil samples are presented in Table 4.2. The laboratory analyses are included in Appendix H. The soil samples were tested for total petroleum hydrocarbons (TPH) using EPA Methods 3550 (semi-volatile) and 5030 (volatile) and for lead using EPA Method 6010. We also analyzed 10 soil samples for ignitability using EPA Method 1010. Although the headspace testing indicated the presence of volatile organics in a majority of the boreholes, laboratory testing for total petroleum hydrocarbons (TPH) indicated the presence of primarily high-boiling-point hydrocarbons in samples from 13 of the boreholes. We have combined the measured values of both high- and low-boiling-point hydrocarbons from samples collected above the water table and presented these data in an isopleth map of total petroleum hydrocarbons (Drawing 4.3). This map illustrates three areas of soil contamination, all of which correlate to areas of known or suspected USTs or transmission lines. These areas are:

- the vicinity of boring no. B-4, which was installed near the location of the UST adjacent to the site of the former mess hall;
- the vicinity of the UST behind Building No. 480 and extending to the northeast towards the ponded stormwater (the area of contamination documented in the NUS report); and
- the AST and fuel-dispensing area of the Fuel Farm, in support of the results of the tracer testing discussed in Section 4.1 and in concurrence with the verbal report of the 4-year-old release of gasoline. However, soil contamination in this area appears to be concentrated at depths below the water table.

Based on this data, it appears that there have been releases of fuel in at least three separate locations within the study area. The plume of contamination originating behind Building No. 480 may have resulted from two releases, one from the UST system at Building No. 480 and one from a possible surface release, northeast of that site, which was investigated by NUS (Section 1.3). The pattern of soil contamination corresponds with the direction of ground-water flow. Therefore, it appears that petroleum fuel was released at these source locations and subsequently migrated through the soil towards Brinson Creek partly as a free-phase liquid hydrocarbon prior to dispersion, adsorption and dissolution into the ground water.

Law Engineering also analyzed each soil sample for lead. There was one sample (HA-4) which exhibited concentrations of lead in excess of the laboratory detection limit. This sample was collected from a location adjacent to the pump house. Because this sample was not contaminated with petroleum hydrocarbons, it appears that this lead did not originate from a discharge of leaded fuel.

Law Engineering also analyzed 10 soil samples for ignitibility. Based on the laboratory results, we determined that the flashpoint of each of the ten samples is in excess of 200°F.

4.3 Occurrence of Free Product

The monitoring wells were constructed to allow for detection of free product in the capillary-fringe area. As indicated on the Monitoring-well Casing and Water-elevation Worksheets (Appendix E), we did not detect free product using probe measurement in the wells. Therefore, Law Engineering has no evidence to indicate that free product remains in the subsurface in the study area. However, our experience reveals that, given ample time, free product can accumulate in wells which initially showed no signs of free product.

4.4 Dissolved Ground-Water Contamination

4.4.1 Hydropunch Ground-water Sampling

From August 5-7, 1991, as the initial phase of our investigation, Law Engineering collected ground-water samples using the Hydropunch ground-water sampling system, utilizing the materials and installation procedures described in the CSA Workplan. We collected these ground-water samples at locations indicated on Drawing 4.4 to evaluate the lateral extent of ground-water contamination and to determine the optimal locations for the monitoring wells. This initial phase of investigation indicated two areas of ground-water contamination, one near the Fuel Farm and one northeast of Building No. 480.

4.4.2 Monitoring-well Sampling Procedures

As stated in Section 3.4, Law Engineering installed 18 wells during the investigation to complement the seven installed during previous investigations. Prior to sampling each well, Law Engineering measured and recorded the depth to ground water using an electronic, water-level probe. We recorded the data collected and observations made on the Monitoring Well and Sampling Field Data Worksheets (Appendix I).

We evacuated all monitoring wells prior to collecting ground-water samples in order to remove stagnant water from the well casing and sand pack. We performed this task in an effort to collect samples representative of the water quality in the surficial aquifer. To evacuate the wells, we used decontaminated, Teflon bailers attached to new nylon cord. We measured and recorded specific conductance, pH, and water temperature throughout the evacuation process. We evacuated the wells of at least three standing well volumes and until indicator parameters had stabilized (or until the well exhibited dryness).

We collected ground-water samples from the 18 monitoring wells installed by Law Engineering, 17 of which were "paired" wells, and from the seven "single-cased" wells that had been installed during previous investigations. Prior to sampling the wells, Law Engineering personnel donned laboratory-grade gloves. We collected the water samples and immediately decanted the samples from the bailer into pre-labeled sample containers.

We sealed the containers, stored the containers in chilled coolers, and maintained custody of the samples until shipment at the end of each day. Chain-of-custody forms are included in Appendix J.

4.4.3 Results of the Ground-water Sampling

We have presented a summary of laboratory analyses of the ground-water samples from the Hydropunch sampling in Table 4.3. Reports of laboratory analyses are included in Appendix H. The ground-water samples were tested for purgeable aromatics by EPA Method 602, modified to include methyl tertiary butyl ether (MTBE).

We have presented isopleth maps for the combined total concentrations of benzene, toluene, ethylbenzene and total xylenes (BTEX) (Drawing 4.5) and for MTBE concentrations (Drawing 4.6) documented in the Hydropunch ground-water samples. This map shows two plumes of contamination, one in the vicinity of the Fuel Farm and one extending from the area just north of Building No. 480 to the northeast. This preliminary identification of contaminant plumes allowed us to effectively place permanent monitoring wells.

We have presented a summary of laboratory analyses of the ground-water samples collected from the monitoring wells in Table 4.4 for the shallow screened intervals and in Table 4.5 for the deep screened intervals. The laboratory analyses are included in Appendix H. We tested these ground-water samples for purgeable halocarbons by EPA Method 601, for purgeable aromatics by EPA Method 602 modified to include MTBE, and for lead by EPA Method 7000. We also tested samples from four wells (MW-8S, MW-14S, MW-24S and MW-25S) for polynuclear aromatic hydrocarbons by EPA Method 610.

The laboratory results, when compared with the results of the soil analyses, show what appears to be at least two separate plumes of ground-water contamination. We have presented an isopleth map (Drawing 4.7) for the combined total concentrations of benzene, toluene, ethylbenzene and total xylenes (BTEX) in the shallow screened interval which shows these two plumes. We have presented a second isopleth map

(Drawing 4.8) for the combined total concentrations of BTEX in the deep screened interval. The isopleth map of the lower screened interval shows significantly lower levels of ground-water contamination, in the areas which generally correspond to the plumes observed in the shallow screened interval.

The first plume of the shallow screened interval is in the vicinity of the Fuel Farm. The ground water has been contaminated with hydrocarbons typically related to petroleum fuel including BTEX. The hydrocarbon contamination appears to be originating within the fuel storage and transmission area, in agreement with the results of the Tracer study, which indicated petroleum vapors beneath the Fuel Farm. Contaminants appear to be migrating to the northeast, the predominant direction of ground-water flow.

The second plume of the shallow screened interval is in the vicinity of the UST located behind Building No. 480 and extends to the northeast, towards the ponded stormwater. The ground water has been contaminated with BTEX and other petroleum-related constituents (heavier hydrocarbons) including fluorene, naphthalene, 1-methylnapthalene and 2-methylnapthalene.

Law Engineering has also identified three areas of ground water contaminated with chlorinated compounds from samples collected over the shallow screened interval. The first is in the vicinity of MW-10 and EMW-5, the second is in the vicinity of EMW-7 and MW-19 and the third is in the vicinity of MW-14 (Drawing 4.9). Laboratory analyses of the ground-water samples from these wells document contamination by trichloroethene and tetrachloroethane, constituents commonly found in solvents and degreasers.

The source of contamination in MW-10 is apparently outside the study area and is unknown at this time. The contamination found in and downgradient of MW-14 may be related to the gasoline station formerly located adjacent to the ice house. Solvents and degreasers are commonly used at gasoline stations and maintenance facilities, and it is possible that the waste solvents from these sites were disposed of onto the ground. Over an extended period of time, continual disposal of these solvents in this manner could result in ground-water contamination.

Law Engineering could not identify a source of the chlorinated compounds detected in samples collected from EMW-7 and MW-19, although these compounds may be related to activities of the former automotive maintenance shop in Building No. TC-474, south of the study area. Law Engineering recommends identifying the source of this contamination.

Law Engineering also identified ground water contaminated with chlorinated compounds in the deep screened interval (Drawing 4.10). The areas of contamination generally correspond to those observed in the shallow screened intervals of wells.

Law Engineering cannot identify a consistent pattern of lead concentrations in either the shallow or deep screened intervals at the study area (Drawings 4.11 and 4.12). The well with the highest concentration of lead, EMW-5, is upgradient of known or suspected contaminant sources, while wells within the two contaminant plumes (for example, MW-20, MW-21, MW-22, MW-25) often exhibit relatively low levels of lead contamination. We also observed wells near the boundaries of the BTEX plumes with low levels of contamination (for example, MW-17, MW-23, MW-14) and levels of lead contamination similar to those wells with high levels of contamination. In summary, we are not able to draw any conclusions regarding the probable relationship between lead concentrations detected at the Fuel Farm and migration patterns of water-borne lead resulting from petroleum-fuel releases.

Law Engineering has documented concentrations of MTBE, an unleaded gasoline additive, below the state interim standard in five wells, four in the shallow screened interval (Drawing 4.13) and one (MW-18) in the deep screened interval. MTBE is highly soluble in water, and often is the first contaminant observed at the leading edge of a plume. The levels of MTBE documented in EMW-6, MW-17 and MW-18, all of which are downgradient of the Fuel Farm, are likely the result of the leaking gasoline line referenced in Section 2.2.1. Law Engineering has not identified a likely source for the MTBE documented in MW-9.

Law Engineering documented ground water containing levels of chloroform in excess of the state ground-water quality standard in MW-14. Law Engineering collected a sample of the potable water at the base from the spigot adjacent to Building No. TC-364 and tested the sample for purgeable halocarbons and purgeable aromatic hydrocarbons. The laboratory analysis of this water sample (identified as "potable water" in Table 4.4) revealed concentrations of chloroform, bromoform, bromodichloromethane, and dibromochloromthane in excess of the laboratory detection limits and of state ground-water standards. These compounds may often be found in municipal water supplies as a result of the chlorination process.

In summary, Law Engineering has documented ground-water contamination both in the upper portion of the surficial aquifer and, to a lesser extent, at depths 10 to 15 feet below the water table. We have identified a confining layer within the surficial aquifer which may act as a barrier to the vertical migration of these contaminants.

The rate at which these contaminants migrate through the subsurface is affected by several geohydrochemical processes including molecular diffusion, mechanical mixing, sorption-desorption, ion-exchange, hydrolysis and biodegradation. Because the resources involved in attempting to model the effects of these processes at the project site are significant, we have chosen to apply a relatively simple analytical technique (USEPA, 1985b) with which to arrive at conservative (greater than anticipated) estimates of contaminant-migration rates at the study area. This analytical technique takes into account only sorption-desorption of the contaminant constituent (expressed in terms of the "retardation factor") and the average, linear velocity of ground-water flow at the site.

For purposes of these calculations, we selected an average linear velocity of ground-water flow of 1.33 feet/day (the mean value of those reported in Section 3.5). The resulting calculations, contained in Appendix K, show that the rate of benzene movement is estimated at 0.44 feet/day. By comparison, naphthalene (a relatively hydrophobic compound) is estimated to migrate at a rate of 0.029 feet/day. With the exception of MTBE, the migration rates of remaining organic constituents detected in the study area are likely to fall within the range bounded by benzene and naphthalene. Please note that these migration rates are only gross estimates which may vary considerably from actual field-migration rates.

5.0 PROCEDURES FOR QUALITY CONTROL

5.1 Decontamination of Equipment

The CSA Workplan details the quality-control procedures followed for handling and decontaminating equipment in the field. As outlined in the Workplan, we decontaminated our drilling equipment in an open area just south of Fourth Street, opposite the Fuel Farm.

5.2 Collection and Shipment of Samples

The CSA Workplan details the quality-control procedures followed for collecting, handling and shipping samples. We employed three quality-control measures to provide checks on the integrity and quality of our ground-water sampling program: rinse blanks, trip blanks and duplicate samples.

Law Engineering submitted equipment rinse blanks to the laboratory for evaluation of procedures which we used to decontaminate the Teflon bailers. Law Engineering also submitted trip blanks to the laboratory to check the integrity of the sample containers, to determine if contaminants may have entered the sample containers during shipment to and from the job site, and to check for laboratory-induced contamination. Each of the blanks was analyzed for purgeable aromatics. The two rinse blanks and four trip blanks submitted with the Hydropunch ground-water samples did not contain contaminant levels above the laboratory detection limit. Six of the ten blanks submitted with the monitoring-well ground-water samples exhibited contamination with xylenes and, in one instance, MTBE in excess of, but near, the laboratory detection limits (Table 5.1).

Law Engineering collected two duplicate ground-water samples as a check on our sampling technique and on the reproducibility of laboratory-testing procedures. For this test, we collected a sample from MW-14S, which we labelled as MW-26S, and a sample from MW-24S, which we labelled as MW-27S. Laboratory analyses of these duplicates are included in Table 4.4.

Analysis of our procedures revealed that bailer decontamination was successful in eliminating the introduction of contaminants through the sampling equipment. Based on the relatively low concentrations of xylenes (2.0 ug/l) detected in the blanks, Law Engineering believes that no significant petroleum-hydrocarbon contamination of ground-water samples occurred as a result of contaminated sampling equipment.

5.3 Evaluation of Chemical Data

In order to assess the quality of laboratory-produced data, our laboratory performed an evaluation of the chemical data. This evaluation included reviews of surrogate failures, calibration verification, holding times, organic-blank contamination, documentation and sample condition. In summary, the evaluation results indicate that reported discrepancies between actual results/procedures and standard results/procedures are not considered to have major impact on the data reported. A copy of the analytical data review report is included in Appendix L.

6.0 SURVEY OF POTENTIAL RECEPTORS

Fuel contamination in any one of four physical states or "phases"' (residual, vapor, liquid, dissolved) may be transmitted to receptors through ingestion, inhalation, or absorption. As petroleum fuel seeps into the subsurface, it will undergo a transformation process that results in adsorption of hydrocarbons onto soil particles (residual phase) and release of volatile hydrocarbons into pore spaces (vapor phase). If any product remains after adsorption and volatilization take place, it will continue to move vertically downward (in the absence of preferred lateral routes of migration) until reaching the capillary-fringe area or a relatively impermeable barrier if one is located above the capillary fringe. At this point, the fuel (liquid phase) will tend to spread throughout the capillary fringe and the transformation process will continue with the dissolution of hydrocarbons into ground water (dissolved phase). An evaluation of the relationship between contaminated media and exposure pathways at the project site is summarized in Table 6.1.

Receptors may be potentially exposed to the hydrocarbons found in the soil primarily through inhalation of volatilized compounds and dermal contact with soil at sites contaminated with hydrocarbons. However, based on headspace and laboratory tests results, petroleum contamination is not generally present in near-surface soil at the Fuel Farm. As indicated in Section 4.2, soil contamination is generally present only at depths below approximately 4 feet. As a result, exposure to these soils is contingent upon site disturbance through construction or remediation activities.

In the event that soil remediation is required, there may be some inhalation exposure from volatilization of the hydrocarbons found in the soil. Volatile components will be released and the potential for exposure will occur at this time. Dermal exposure from soil contact by personnel may also occur if remediation activities include excavation. Since this is an occupational exposure, the receptor analysis for these exposure pathways should be considered as part of the design plan for site remediation.

Exposure through ingestion most commonly occurs from consumption of drinking water obtained from contaminated wells or contaminated public-water supplies. The active water-supply wells at Camp Geiger supply water from the Castle Hayne aquifer and are located to the west of the Fuel Farm, upgradient of the documented contamination. Due to the presence of an apparent confining unit separating the contaminated surficial aquifer from the Castle Hayne, and the distance between the Fuel Farm and the supply wells, it is unlikely that contamination in the surficial aquifer at the Fuel Farm has affected the water-supply wells at Camp Geiger. The study by Harned et al (1989) did not include chemical testing of water samples from the water-supply wells.

Subsurface contaminants have been known to find their way into buried water-supply lines primarily through direct contact with free product. Law Engineering did not receive a complete set of site maps showing the locations of all the water lines in the study area. However, because free product was not observed in the study area, potential exposure to contaminants in this manner is unlikely.

Law Engineering observed three access points to the subsurface. The first is the manway providing access to the sanitary sewer, which is located just southeast of the Fuel Farm. The second is the storm sewer and oil/water separator which collects stormwater on the concrete pad adjacent to the ASTs. The third is a collapsing storm-sewer manway behind the former site of the filling station; due to its condition, this manway appeared inaccessible. Law Engineering performed a vapor-phase survey at these access points using the PID and did not detect volatile organics. Inspection of Building No. 480 revealed no means of access to the subsurface (manways, vaults, etc.) within the buildings. This was confirmed by Mr. Blake, who fills the UST behind this building and who is familiar with its design.

The results of the survey of potential receptors indicate that the presence of contaminants in the subsurface at the Fuel Farm does not constitute an imminent or near-future health threat to potential receptors. However, it is possible that organic vapors may be present along portions of subsurface utilities which may possibly result in exposure during maintenance and repair activities.

7.0 REMEDIAL ALTERNATIVES AND RECOMMENDATIONS

This discussion of remedial alternatives and preliminary recommendations is directed primarily toward the contamination by petroleum hydrocarbons encountered at the Camp Geiger Fuel Farm. However, these alternatives and recommendations may also be applicable to chlorinated hydrocarbon contamination.

Due to the spatial distribution of petroleum-hydrocarbon contamination in the soil (adsorbed phase) and water samples (dissolved phase) collected from the Fuel Farm, it appears that at least two separate releases of petroleum fuel have occurred at the project site. The first release occurred approximately four years ago from the gasoline line in the vicinity of the Fuel Farm. Contamination of the soil and ground-water remain in this area from this release. The second release, from the UST behind Building No. 480, may still be occurring and has resulted in soil and ground-water contamination. Therefore, as an initial step in the remedial process, we recommend thoroughly evaluating the integrity of this UST system.

7.1 Soil Remediation

7.1.1 Overview and Objectives of Soil Remediation

Protection of public health and ground-water quality are the primary reasons for soil remediation at sites involving leaking UST systems. As discussed in Section 6.0 of this report, the potential for exposure to contaminated soil at the Camp Geiger Fuel Farm is minimal as long as the subsurface remains undisturbed. However, guidelines for remediation of soil contaminated by petroleum have been established by the Groundwater Section of the Division of Environmental Management, DEHNR (1990).

Within these guidelines, the Groundwater Section has set an "action level" of 10 mg/kg of TPH and a maximum contaminant concentration of 85 mg/kg of TPH. Therefore, the objectives for remediation of contaminated soil at the project site should focus on 1) eliminating the adsorbed hydrocarbons as an ongoing source of ground-water contamination through leaching and desorption and 2) complying with NCDEHNR guidelines which require remediation of all soil containing greater than 85 mg/kg of TPH. At sites where ground water is particularly vulnerable to contamination through leaching or where contaminated soil is in direct contact with ground water, required cleanup levels may be as stringent as 10 mg/kg of TPH, depending on the depths and characteristics of the contamination.

7.1.2 Survey of Remediation Technologies for Petroleum-Contaminated Soil

This section of the report serves to provide a brief introduction to the technologies considered for treatment of contaminated soil at the Camp Geiger Fuel Farm. The technologies may be conveniently separated into in-situ methods and non in-situ methods.

In-situ technologies involve remedial methods in which contaminated soil is treated in place. In-situ technologies do not require the removal of contaminated soil.

However, limited excavation may be required to install and operate an in-situ technology. Our survey includes consideration of the following in-situ technologies:

- enhanced bioreclamation;
- isolation/containment;
- leaching and chemical reaction;
- natural attenuation;
- vitrification; and
- volatilization (vacuum extraction).

These technologies are introduced in Sections 7.1.2.1 through 7.1.2.6. The primary advantages of in-situ technologies include minimal site disturbance, minimal exposure during remediation activities and avoidance of potential liabilities associated with off-site transport and disposal.

Non in-situ technologies involve remedial methods which require the excavation and removal of contaminated soil. Soil treatment may be conducted on site and/or off site depending on the requirements of the particular technology. This survey includes consideration of the following non in-situ technologies:

- low-temperature thermal reduction;
- incineration;
- land application; and
- enhanced volatilization (surface treatment) and/or composting.

These technologies are introduced in Sections 7.1.2.7 through 7.1.2.10. Disposal of untreated soil by landfilling is mentioned in Section 7.1.2.11. The primary advantages of non in-situ technologies include 1) immediate or short-term resolution of the problem at the contamination site, 2) ability to meet target cleanup levels with a higher degree of certainty (assuming all contaminated material is capable of being excavated), and 3) the popularity of the practice within the remediation industry (except for landfilling of untreated soil).

7.1.2.1 Enhanced Bioreclamation

Enhanced bioreclamation is a process in which measures are taken to aid the growth and metabolism of microorganisms in degrading petroleum constituents which are present in the soil.

Although the organisms occur naturally, effective use of this technology often requires the addition of nutrients and oxygen to enhance the degradation of the petroleum.

Enhanced bioreclamation is often used in conjunction with ground-water remediation efforts. Typically, ground water is extracted from the subsurface using recovery wells and a pumping system. The ground water is mixed with nutrients and an oxygen source, then re-introduced into the subsurface through an infiltration gallery which is located above or upgradient of the contaminated area. The nutrient-rich water percolates through the contaminated soil under the influence of gravity until it reaches the ground-water table, where it then migrates toward the ground-water extraction system. As the nutrient-rich water percolates through the petroleum-contaminated soil, the metabolism of the petroleum-consuming microorganisms is stimulated to increase consumption of the petroleum hydrocarbons.

7.1.2.2 Isolation/Containment

Isolation/containment typically involves the installation of subsurface walls to preclude further migration of the contaminants. The walls are usually constructed of slurry or grout and may be located upgradient and/or downgradient of the contaminated soil.

These walls may be used in conjunction with a "cap" which is located upon the land surface above the contaminated soils. This cap is intended to impede the migration of contaminants resulting from the infiltration of precipitation.

It is important to note that this technology does not actively destroy or reduce hydrocarbon concentrations in the soil.

7.1.2.3 In-Situ Leaching and Chemical Reaction

This process entails flushing hydrocarbons from the soil with water or, more typically, a water-surfactant mixture. The water-surfactant mixture is applied by spray irrigation (or similar technique) upon the land surface above the soil contaminated by petroleum. As the mixture leaches through the soil, adsorbed hydrocarbons are extracted from the soil. The water-surfactant and hydrocarbon mixture leach through the soil under the influence of gravity until the mixture reaches the ground-water table or a confining layer. The infiltration water or mixture is extracted from the subsurface by means of a pumping system. The extracted ground water will require treatment to remove the hydrocarbons and the surfactant prior to discharge.

7.1.2.4 In-Situ Passive Treatment/Natural Attenuation

This technology involves "no action" to address petroleum contamination of the soil. This remedial method relies on naturally-occurring processes such as dispersion and biodegradation to reduce the concentrations of the hydrocarbons.

7.1.2.5 In-Situ Vitrification

In-situ vitrification entails the use of electricity to change the soil contaminated by hydrocarbon from its natural, semi-solid phase into a molten, liquid phase which ultimately cools to a glass-like, solid phase. Most hydrocarbons within the soil are volatilized during the phase change and any remaining hydrocarbons are encapsulated within the glass-like end product which results from this technique.

7.1.2.6 In-Situ Volatilization (Vacuum Extraction)

This technology exploits the natural tendency of some hydrocarbon compounds to volatilize. Pressurized, volatile, free air is introduced through vapor-introduction wells into the zone of contaminated soil. The volatile hydrocarbons migrate from the areas of high concentration (on the soil particles) to areas of low concentration (towards the fresh, volatile, free air injected into the subsurface). As the concentrations of volatiles within the injected air increase, the air is extracted through vapor-extraction wells from the subsurface, ultimately reducing the concentration of volatile hydrocarbons within the subsurface. The extracted air, laden with volatile hydrocarbons, may require treatment.

7.1.2.7 Low-temperature Thermal Reduction

Low-temperature thermal reduction (LTTR) is a process in which petroleum hydrocarbons are driven from the soil through enhanced volatilization by the application of heat. The excavated soil may be treated by LTTR either on or off the site. The treated soil may be used as backfill as a raw material in asphalt- or brick-manufacturing operations.

7.1.2.8 Incineration

Incineration is a non in-situ technology which employs high-temperature combustion (at least 1000° Celsius for a minimum of two seconds) of organics such as petroleum hydrocarbons which are present in the soil. The incineration process can be conducted on site or off site. The end products of this treatment alternative include ash and scrubber water (a by-product of the cooling process), both of which may require disposal permits.

7.1.2.9 Land Application

Land application of petroleum-contaminated soil involves the distribution of the excavated soil over the land surface. The petroleum-contaminated soil is spread to a thickness of one to twelve inches and is mixed with the natural soil using earth-moving and conventional farm equipment. Nutrients are typically incorporated into the treated soil. Hydrocarbon concentrations are attenuated primarily by volatilization and biodegradation.

7.1.2.10 Enhanced Volatilization (Surface Treatment) and/or Composting

This technology is similar to land application (Section 7.1.2.9). However, the excavated, contaminated soil is spread upon an impermeable layer (e.g., plastic) to prevent contact between contaminated soil and native soil. In addition to the tilling that is required to enhance volatilization, the soil can be composted to enhance the reduction of hydrocarbons. As with land application, hydrocarbon concentrations are attenuated primarily by volatilization and biodegradation.

7.1.2.11 Landfilling

Landfilling simply requires the excavation of contaminated soil and transportation to a landfill. Hydrocarbons are not actively removed from soil when this disposal method is used exclusive of treatment. This method is not recommended due to the possibility of cross-contamination at the disposal site, thereby creating potential future liabilities for cleanup at the disposal site.

7.1.3 Preliminary Recommendation for Soil Remediation

The eleven technologies introduced in Section 7.1.2 were briefly evaluated for their application to the Camp Geiger Fuel Farm and with respect to technical, institutional, environmental, health and economical considerations. Because of the widespread presence of soil contamination in the capillary fringe area and the near surface seasonal fluctuations in the water table, remediation of contaminated soil in the unsaturated zone caused by near-surface releases may be most effectively accomplished by a combination of land application (Section 7.1.2.9), enhanced bioreclamation (Section 7.1.2.1) and in-situ soil washing.

The first step in the soil-remediation process will be to further identify the extent of vadose-zone contamination in the areas of suspected releases. These suspected areas are discussed in Section 4.2. Once the extent of vadose soil contamination is identified in these areas, the feasibility of infiltration gallery construction should be evaluated to remediate these areas. Discharge of treated ground water through infiltration galleries may enhance removal of adsorbed hydrocarbons from the soil matrix, thereby producing a soil-washing effect. Contaminated soil removed during gallery or trench construction may be treated/disposed through land application.

In conjunction with evaluation of the engineering design, a biofeasibility study should be performed to determine if site conditions are conducive to enhanced bioreclamation. Study results should provide information related to potential toxicity and geochemistry of site conditions that may inhibit effective growth and metabolism of necessary microorganisms. Should study results prove favorable, treated ground water may be augmented with nutrients and oxygen prior to discharge.

7.2 Ground-Water Restoration

7.2.1 Overview and Objectives of Ground-water Remediation

As indicated by data presented in Section 4.4, dissolved hydrocarbon plumes have apparently developed as a result of leaks, spills, discharges, etc. at the Fuel Farm and appear to be extending in a northeasterly direction. The necessity of remediation efforts designed to restore ground water is often not an easy decision to rationalize. The decision ultimately rests upon regulatory requirements, the measured and/or perceived present and future utility of the ground-water resource, the risks associated with the potential exposure to the contaminants, and the availability of resources with which to implement and operate a ground-water restoration project. Obviously, remediation is warranted in a situation where the risk to public health or welfare is unavoidable and unacceptable as a result of exposure to ground-water contaminants. As indicated in Section 6.0 and Table 6.1 of this report, present exposure to ground-water contaminants in the vicinity of the Fuel Farm is considered unlikely.

With respect to regulatory requirements, the North Carolina Environmental Management Commission (EMC) has adopted maximum allowable concentrations for contaminant constituents in ground water. For compounds detected in ground water beneath the Fuel Farm, the maximum concentrations are listed in Table 4.4. For compounds which do not have a numerical standard (e.g., 1-methylnapthalene, 2-methylnapthalene, and naphthalene), a petition may be filed with the North Carolina Division of Environmental Management (DEM) in order to establish such a standard. As indicted in Tables 4.4 and 4.5, Law Engineering has documented levels of contamination of the following constituents in excess of the maximum allowable concentrations: benzene, ethylbenzene, xylenes, lead, trichloroethene, 1- and 2-methylnapthalene, chloroform, 1,2-dichloroethane, 1,1,2,2-tetrachloroethane, tetrachloroethane, trichlorofluoromethane, acenapthene, fluorene, and naphthalene. Rules adopted by the EMC and enforced by DEM require that "any person conducting or controlling an activity which results in an increase in the concentration of a substance in excess of the groundwater standard shall.....submit a plan for eliminating the source of contamination and for restoration of ground-water quality....". Therefore, compliance with North Carolina Administrative Code (15 NCAC 2L) necessitates the restoration of ground waters beneath the Camp Geiger Fuel Farm to a quality as near to the standards as is technologically feasible.

7.2.2 Survey of Technologies for Ground-water Extraction

7.2.2.1 Overview

The majority of available technologies associated with the restoration of aquifers contaminated by hydrocarbons implement "pump-and-treat" techniques in which ground water is pumped from the subsurface. Ground water is treated by aboveground physical, chemical and/or biological means prior to discharge. The following discussion will address the three basic tasks involved with the restoration of an aquifer when using "pump-and-treat" methodologies. These tasks include (1) the extraction of the ground water from the aquifer; (2) the treatment technology(ies) implemented to reduce the concentrations of the contaminants within the extracted ground water; and (3) the disposal of the treated water.

In order to implement a "pump-and-treat" technology, the adversely-impacted ground water must be extracted from the aquifer. The extraction process serves three purposes. First, it provides a means of removing contaminated ground water from the subsurface. Second, it delivers the contaminated ground water from the aquifer to the treatment equipment. Third, it controls, reduces or eliminates further migration of the contaminant plume within the aquifer.

7.2.2.2 Extraction Wells

Extraction wells are essentially hollow pipes installed in boreholes which extend vertically downward, penetrating the aquifer which contains contaminated ground water. The hollow pipe, referred to as casing, is generally constructed of PVC or stainless steel and may vary in diameter from two inches to two feet, or larger (wells within large casings are often referred to as sumps). The casing diameter is less than the borehole diameter and the annular space between the two is filled with a hydraulically-conductive material (such as sand or gravel) over and slightly above the screened section. The remainder of the annular space between the sand pack and land surface is grouted to prevent entry of contaminants from land surface. Typically the portion of the casing which penetrates the aquifer is slotted casing. This permits ground water to accumulate within the casing. The accumulated fluids can be extracted by means of a pump and delivered to the treatment system.

Continuous pumping from the well lowers the elevation of the static water level in the vicinity of the well. The pumping produces a cone of depression upon the water table around the well which alters normal patterns of ground-water flow. Fluids tend to flow towards the well being pumped. Thus, the fluids targeted for recovery and treatment can be captured by judicious use of pumping wells.

The effectiveness of pumping wells is dependent upon site- specific conditions. The characteristics of the impacted aquifer will dictate the effectiveness of ground-water extraction by means of pumping wells.

Advantages of extraction wells:

- Once installed, extraction wells are unobtrusive.
- Extraction wells can be effective in shallow as well as deep aquifers.
- Extraction wells are economical to operate and maintain.

Disadvantage of extraction wells:

- Low aquifer conductivity can severely limit the area influenced by pumping the extraction well.

7.2.2.3 Trenches/Drains

When used in applications for permanent systems, as opposed to temporary or emergency situations, trenches can be thought of as horizontal wells. A trench is excavated to a depth which penetrates the target aquifer. Perforated pipe, which serves as a drain, is placed within the trench and is linked to a vertical standpipe. The entire trench is backfilled with a material characterized by high hydraulic conductivity (sand, gravel, etc.). Contaminated ground water is extracted by means of a pump located in the standpipe, which draws fluids from the trench system.

Trench recovery systems are typically located downgradient of the contaminant source. As the contaminants migrate under the influence of the natural flow of ground-water, they are intercepted by the downgradient trench. These interceptor trenches are useful in situations where the velocity of the contaminant plume requires expedient restoration of the aquifer.

If pumped at sufficient rates, trenches may be used to depress the water table and alter the natural flow of ground water to benefit the restoration of the aquifer in a fashion similar to recovery wells.

Advantages of trenches/drains:

- Recovery trenches may expedite aquifer restoration when compared to other extraction methods under certain circumstances.

- Recovery trenches may be more effective than wells in aquifers of very low yield.
- Recovery trenches are useful to quickly capture migrating free product in emergency situations.

Disadvantages of trenches/drains:

- The contaminated portion of the aquifer must be relatively close to land surface.
- Soil excavated during trench installation may require special disposal, if contaminated.
- Installation of trenches may be obtrusive to normal site activities and underground utilities may present difficulties with trench placement and construction.

7.2.2.4 Pumping Technologies

Pneumatical or electric pumps are typically used for the extraction of ground water and petroleum. They may be used to skim free product from the water table, to pump total fluids (petroleum and ground water) or to operate in pairs (water-table depression pump coupled with a free-product pump). Each of these pump systems may be used in conjunction with extraction wells or trenches.

Advantages of Skimmer Pumps:

- Pumps do not mix water with the petroleum.
- Pumps are inexpensive and may be operated with or without a power source in remote locations.

Disadvantages of Skimmer Pumps:

- Pumps can only be used effectively in open ditches, sumps (large-diameter wells) or trenches.
- The volume of the aquifer influenced by these pumps is limited.

Advantages of Total-fluids Pumps:

- Applicable to wells and trenches.
- Capable of displacing large quantities of fluids over large distances.
- Capable of influencing relatively large aquifer volumes.

Disadvantage of Total-fluids Pumps:

- May emulsify petroleum and water.

Advantages of Pump Pairs:

- Applicable to wells and trenches.
- Capable of displacing large quantities of fluids over large distances.
- Capable of influencing relatively large aquifer volumes.
- Does not emulsify petroleum and water.

Disadvantages of Pump Pairs:

- Pump operation is complicated and sensitive to fluctuations in levels of free product and ground water.
- Pump pairs are expensive.

7.2.3 Survey of Treatment Technologies for Ground Water

7.2.3.1 Oil/Water Separators

Oil/water separators, as the name implies, are used to separate free-phase and suspended petroleum from the extracted ground water. These units are essentially tanks which contain a series of baffles which segregate the fluids. Typically, the oil (petroleum) is decanted from the unit and stored in a separate tank for recycling or disposal. The effluent ground water may undergo further treatment prior to discharge pursuant to regulatory permit.

Advantages:

- Provide effective pre-treatment of ground water which may contain free product (petroleum).
- Help minimize fouling of subsequent treatment equipment.

Disadvantage:

- Treatment by this method alone usually does not reduce concentration of influent contaminants (dissolved phase) sufficiently for disposal (i.e., not effective as a stand-alone treatment).

7.2.3.2 Packed-tower Air Stripping

Packed towers consist of a rigid, cylindrical column or tower which usually extends vertically upward from land surface. The dimensions of the tower depend on the air-to-water ratio required for effective treatment. Typically, towers range from 1.5 to 4 feet in diameter and 10 to 30 feet in height. The tower, which resembles a smoke stack, is often constructed of fiberglass, aluminum or steel. The tower is filled with a packing material designed to provide a large surface area to enhance water-to-air transport (volatilization) of organics.

The extracted ground-water, containing dissolved contaminants, is pumped to the top of the tower and sprayed over the packing material. Concurrently, air is forced from the bottom of the tower upwards through the tower by means of a blower, thus creating a counterflow of ground water and air over the large surface area created by the packing material. The treated water, which collects at the bottom of the tower, is routed for further treatment or direct discharge under regulatory permit. The injected air is typically vented to the atmosphere from the top of the tower.

The petroleum hydrocarbons dissolved within the ground water come into intimate contact with the clean, injected air. The petroleum hydrocarbons have a propensity to move from media of high concentration (ground water) to media of low concentration (air). The transfer of the petroleum hydrocarbons from the ground water to the injected air is enhanced by the high Henry's Law constant which characterizes many petroleum hydrocarbons.

Reductions in petroleum concentrations within the ground water achieved with packed-tower air stripping have been reported as high as 95-99 percent. When necessary, water treatment by oil-water separation or chemical treatment may proceed packed-tower air stripping. Post air-stripping treatment may be required, depending upon limitations of effluent discharge.

Advantages:

- Stripping towers can effectively remove large percentages of dissolved hydrocarbons.
- Stripping towers are a proven technology generally accepted by regulatory agencies.
- Stripping towers are relatively inexpensive.

Disadvantages:

- Large, obtrusive towers may be aesthetically displeasing.
- Treatment of effluent air may be required.
- Further treatment or "polishing" of effluent water may be required prior to discharge.
- Packed towers are subject to fouling by inorganic compounds.

7.2.3.3 Trickle-tray Air Stripping

Trickle-tray air strippers treat petroleum-contaminated ground water with the same technology described for stripping towers. However, the trickle-tray system routes the influent water over a stack of trays which contain a high surface-area media. Air is blown into the system, mass transport occurs across the air-water interface, and the petroleum-laden air is vented to the atmosphere.

Advantages:

- The design is compact and less obtrusive than tower designs.
- The design is capable of producing high removal rates.

Disadvantages:

- Treatment of effluent air may be required.
- Further treatment or "polishing" of effluent water may be required prior to discharge.
- The design is subject to fouling by inorganic compounds.

7.2.3.4 Diffusion Air Stripping

This method also works on the principle of removing petroleum hydrocarbons from the ground water by transport to fresh air. However, the diffusion technique does not implement a counterflow approach as with towers and trays.

Extracted ground water is pumped into a vat (ranging in size from a 55-gallon drum to 200+ gallon concrete vaults). Water within the vat is vigorously aerated by forcing compressed or blower-driven air through a diffuser at the bottom of the vat. As the air rises through the water in the vat, the petroleum-hydrocarbon compounds transfer from the water (high petroleum concentration) to the air bubbles (low petroleum concentration). When the bubbles reach the water surface, the petroleum hydrocarbons are released to the atmosphere. The effluent water may be discharged or further treated, if necessary.

Advantages:

- Equipment is easy to operate and requires little maintenance.
- High removal efficiencies are possible.
- System can be installed below grade, thereby minimizing freeze-up problems and aesthetic concerns.
- System has a relatively low cost.

Disadvantages:

- Treatment of effluent air may be required.

- Method is a new application for an existing technology and may be unfamiliar to the regulatory agencies.
- Further treatment or "polishing" of effluent water may be required prior to discharge.
- If installed below grade, additional regulatory requirements for monitoring may apply.

7.2.3.5 Ultrafiltration/Reverse Osmosis

This method employs a technique by which the petroleum-laden ground water is forced through a semi-permeable membrane. Water passes through the membrane but petroleum and other substances in the water cannot. The petroleum and other substances are decanted off and require disposal. The water which passes through the membrane is usually treated sufficiently for direct discharge under regulatory permit.

Advantages:

- Effectiveness of petroleum removal is high.
- Equipment is generally unobtrusive.

Disadvantages:

- Often up to 10% of influent volume is filtered out and requires special handling for disposal.
- Maintenance is intensive.
- System is expensive.

7.2.3.6 Carbon Adsorption

Granulated-activated carbon (GAC) is used for carbon-adsorption technologies. The extracted ground water is pumped into GAC reactors. The reactors operate at or above atmospheric pressure, depending on equipment design. Within the reactor, the petroleum-laden ground water comes into intimate contact with the GAC. The molecules of petroleum hydrocarbons within the ground water are attracted to the GAC and physically bond to the GAC. Water exiting the reactor or reactor series is typically treated sufficiently for disposal under strict, regulatory-permit requirements.

Advantages:

- System is very effective at removing target compounds.

- System is effective when used to "polish" water treated by other methods.
- System is widely accepted by regulatory agencies.

Disadvantages:

- Disposal/regeneration of spent GAC is required.
- System is expensive, particularly if used as a stand-alone treatment method.

7.2.3.7 Enhanced Bioreclamation

Enhanced bioreclamation is a process in which measures are taken to aid the growth and metabolism of microorganisms which degrade petroleum constituents present in the contaminated ground water. Although the organisms occur naturally, effective use of this technology often requires the addition of nutrients and oxygen to enhance the degradation of the petroleum.

Enhanced bioreclamation is often used in conjunction with soil-remediation efforts. Typically, ground water is extracted from the subsurface, allowed to undergo physical and/or biological treatment in an aboveground "bioreactor", mixed with nutrients, oxygenated, and re-introduced into the subsurface through an infiltration gallery located above or upgradient of the extraction system. The nutrient-rich water percolates through the soil under the influence of gravity until it reaches the water table, where it then migrates toward the ground-water extraction system. As the nutrient-rich water reaches the water table, the metabolism of the petroleum-consuming microorganisms is stimulated and results in consumption of petroleum hydrocarbons.

Advantages:

- System can be used in conjunction with soil-remediation efforts.
- System is a closed loop, eliminating the potential liabilities associated with off-site discharges.
- System does not produce troublesome byproducts of treatment (e.g., off-gases and spent carbon).

Disadvantages:

- System requires pilot or "biofeasibility" study(ies).

- Introduction of limiting nutrients to the ground water may be met with some regulatory resistance.
- Soils with low permeability inhibit effectiveness.
- System requires a high degree of maintenance and close supervision.

7.2.4 Survey of Technologies for Disposal

7.2.4.1 Storm Sewer/Surface Waters

A National Pollutant Discharge Elimination System (NPDES) permit is required in order to dispose of the effluent water of the treatment system to storm sewers or surface waters.

Advantages:

- Storm-sewer systems are often accessible in urban areas and surface waters are often accessible in rural areas.

- Operations are relatively maintenance-free.

Disadvantages:

- Permit processing is lengthy.
- The effluent quality stipulated in the regulatory permit requirements may be difficult to achieve.

7.2.4.2 Sanitary Sewer

Disposal of the effluent water in the treatment system to the sanitary sewer will typically require a discharge permit from the receiving publicly-owned treatment works (POTW).

Advantages:

- Sanitary-sewer systems are often accessible in urban areas.

- Treatment requirements are often less restrictive than those for NPDES permits.
- Operations are relatively maintenance-free.

Disadvantage:

- Permit availability and requirements are subject to the capacity of the local POTW.

7.2.4.3 Land Application/Infiltration Galleries

Land-application disposal (e.g., spray irrigation or infiltration galleries), where the treated water is discharged back into the subsurface, requires a North Carolina "non-discharge" permit.

Advantage:

- Can be used to create a closed-loop system, thus eliminating potential liabilities associated with discharging of wastewater off-site.

Disadvantages:

- System is subject to site soil conditions which affect the required surface and subsurface loading rates.

- Space requirements can be extensive.
- System may require periodic maintenance.

7.2.4.4 Industrial Wastewater Treatment Works

In industrial situations, extracted ground water may be incorporated into industrial wastewater treated by the waste-water treatment facility on the site.

Advantages:

- System is typically an economical disposal method.
- System may eliminate or minimize treatment of extracted groundwater prior to discharge.
- System may eliminate the need for additional regulatory permitting associated with discharge.

Disadvantages:

- System may require modifications to existing waste-water processing methods and monitoring requirements.

- System may require modifications to existing discharge permits.

7.2.4.5 Plant Process Make-up Water

For industrial situations, the extracted ground water can be used as make-up water for the plant process water system.

In these situations, the extracted ground water is used to make up for water lost during ordinary system processes (e.g., boiler blow-down, evaporation, etc.).

Advantages:

- System is typically an economical disposal method.
- System may eliminate or minimize treatment of extracted ground water prior to discharge.
- System may eliminate the need for additional regulatory permitting associated with discharge.
- System will not increase the load on the existing waste-water treatment system.

Disadvantage:

- Make-up water-quality requirements may mandate extensive pretreatment of ground water prior to disposal into a process-water system.

7.2.5 Preliminary Recommendation for Ground-water Restoration

Because conventional pump-treat-discharge systems may not be effective in completely restoring the aquifer and will not directly address residual soil contamination present in the capillary fringe area, consideration should be given to enhanced bioreclamation technology (Section 7.2.3.7). The physical characteristics of the site appear to be well-suited for implementation of this technology in view of the relatively coarse-grained soils, the relatively secure areas for construction of infiltration systems, and the moderately-thick vadose zone upgradient of the contaminant plumes to allow for adequate percolation of treated ground water.

Ground water from recovery wells could be treated by air stripping and then allowed to infiltrate into the ground at contaminated locations, thereby creating a closed-loop system. This system may be designed so that ground water from a combination of recovery wells and trenches is delivered to a central treatment unit with treated effluent discharged through a series of infiltration galleries installed in the contaminant source areas. Further evaluation of this technology involves performing staged biofeasibility studies which will evaluate the presence of natural hydrocarbon-consuming bacteria, the potential toxicity of the site to such bacteria, nutrient availability and the ability of the site to support growth of bacterial populations.

7.3 Additional Data Needs to Develop the Remedial Action Plan

Developing an effective remedial action plan for restoration of subsurface conditions at Camp Geiger Fuel Farm relies upon the following:

- Identification of potential ongoing sources of contamination which includes evaluation of the existing fuel storage and distribution system located behind Building No. 480.

- Definition of spatial extent of soil contamination in the vadose zone along the abandoned fuel-distribution line in the event that such contamination cannot be attributed to releases from the UST behind Building No. 480.

- Results of an aquifer test and sampling to evaluate critical aquifer parameters and to identify critical, inorganic, water-quality parameters, should remedial objectives include ground-water restoration.

- Results of a biofeasibility study to evaluate critical site parameters, should remedial strategy include enhanced bioreclamation.

7.4 Recommendations

- Identifying possible ongoing releases through evaluation of the integrity of fuel system located behind Building No. 480.

- Determine if the UST associated with the former mess hall is still present and whether it presently contains fuel.

- Notifying the North Carolina Division of Environmental Management of the findings and results of this investigation.

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TABLE 4.2 (Page 1 of 3)
SUMMARY OF LABORATORY ANALYSES OF SOIL SAMPLES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft)	TOTAL PETROLEUM HYDROCARBONS		IGNITABILITY (Degrees F)	LEAD (ug/L)
		VOLATILES (mg/kg)	SEMI-VOLATILES (mg/kg)		
HA-3	4	N.D.	17	--	N.D.
HA-4	2	N.D.	N.D.	--	42
HA-7	5	N.D.	5700	--	N.D.
B-1A	1.5 - 3.0	N.D.	N.D.	--	N.D.
B-1B	8.5 - 10.0	N.D.	N.D.	--	N.D.
B-2	5.5 - 6.0	N.D.	N.D.	--	N.D.
B-2	8.5 - 10.5	630	7600	--	N.D.
B-4A	3 - 4.5	N.D.	8400	--	N.D.
B-4B	8.5 - 10	N.D.	5100	--	N.D.
B-5A	3 - 4.5	N.D.	980	--	N.D.
B-5B	8.5 - 10	N.D.	280	--	N.D.
B-6A	3 - 4.5	N.D.	7	--	N.D.
B-6B	8.5 - 10	N.D.	6200	--	N.D.
MW-8	6.0 - 8.0	N.D.	9100	>200	N.D.
MW-8	14.0 - 16.0	N.D.	14,600	>200	N.D.
MW-9	6.0 - 8.0	N.D.	N.D.	>200	N.D.
MW-9	16.0 - 18.0	N.D.	N.D.	>200	N.D.
MW-10	0 - 1.5	N.D.	N.D.	--	N.D.

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TABLE 4.2 (Page 2 of 3)
SUMMARY OF LABORATORY ANALYSES OF SOIL SAMPLES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft)	TOTAL PETROLEUM HYDROCARBONS		IGNITABILITY (Degrees F)	LEAD (ug/L)
		VOLATILES (mg/kg)	SEMI-VOLATILES (mg/kg)		
MW-10	1.5 - 3.0	N.D.	N.D.	--	N.D.
MW-11	4.0 - 6.0	N.D.	2100	>200	N.D.
MW-11	8.5 - 10.5	N.D.	4	>200	N.D.
MW-12	0 - 1.5	N.D.	N.D.	--	N.D.
MW-12	3.0 - 4.5	N.D.	N.D.	--	N.D.
MW-13	8.5 - 10.0	N.D.	N.D.	--	N.D.
MW-13	18.5 - 20.5	N.D.	N.D.	--	N.D.
MW-14	3.0 - 4.5	0.3	N.D.	--	N.D.
MW-14	18.5 - 20.0	N.D.	N.D.	--	N.D.
MW-15	4.0 - 6.0	N.D.	N.D.	--	N.D.
MW-15	8.5 - 10.5	N.D.	3500	--	N.D.
MW-16	3.0 - 4.5	N.D.	N.D.	--	N.D.
MW-16	18.5 - 20.0	1	8	--	N.D.
MW-17	4.0 - 6.0	N.D.	N.D.	--	N.D.
MW-17	18.5 - 20.5	N.D.	N.D.	--	N.D.
MW-18	3.0 - 4.5	N.D.	N.D.	--	N.D.
MW-18	8.5 - 10.0	N.D.	N.D.	--	N.D.
MW-19	2.0 - 4.0	N.D.	N.D.	--	N.D.

TABLE 4.2 (Page 3 of 3)
SUMMARY OF LABORATORY ANALYSES OF SOIL SAMPLES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft)	TOTAL PETROLEUM HYDROCARBONS		IGNITABILITY (Degrees F)	LEAD (ug/L)
		VOLATILES (mg/kg)	SEMI-VOLATILES (mg/kg)		
MW-19	8.5 - 10.5	N.D.	N.D.	--	N.D.
MW-20	3.0 - 4.5	N.D.	14	--	N.D.
MW-20	8.5 - 10.0	N.D.	22,000	>200	N.D.
MW-21	2.0 - 4.0	N.D.	5,200	>200	N.D.
MW-21	4.0 - 6.0	N.D.	21,000	>200	N.D.
MW-22	3.0 - 4.5	N.D.	5	--	N.D.
MW-22	9.5 - 11.0	540	8900	>200	N.D.
MW-23	0 - 2.0	N.D.	N.D.	--	N.D.
MW-23	13.5 - 15.5	N.D.	N.D.	--	N.D.
MW-24	2.0 - 4.0	N.D.	N.D.	--	N.D.
MW-24	8.5 - 10.5	N.D.	21	--	N.D.
MW-25	2.0 - 4.0	N.D.	8700	--	N.D.
MW-25	4.0 - 6.0	N.D.	5700	--	N.D.

TABLE 4.3 (Page 1 of 2)
SUMMARY OF LABORATORY ANALYSES
HYDROPUNCH GROUND-WATER SAMPLES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER FUEL FORM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	DATE SAMPLED	LABORATORY RESULTS (ug/l)				
		BENZENE	ETHYLBENZENE	TOLUENE	XYLENES (TOTAL)	METHYL TERT BUTYL ETHER
HP-1	8/5/91	N.D.	N.D.	N.D.	N.D.	N.D.
HP-2	8/7/91	N.D.	N.D.	N.D.	N.D.	N.D.
HP-3	8/7/91	0.7	N.D.	N.D.	N.D.	0.6
HP-4	8/6/91	0.2	1	N.D.	13	N.D.
HP-5	8/6/91	610	520	130	1900	N.D
HP-6	8/7/91	240	14	N.D.	N.D.	410
HP-7	8/6/91	8	1	N.D.	1	83
HP-8	8/7/91	N.D.	N.D.	N.D.	N.D.	N.D.
HP-9	8/7/91	N.D.	N.D.	N.D.	N.D.	3
HP-10	8/7/91	11	0.6	N.D.	2	N.D.
HP-11	8/6/91	350	350	N.D.	540	N.D.
HP-12	8/6/91	100	350	170	820	N.D.
HP-13	8/6/91	N.D.	N.D.	N.D.	N.D.	N.D.
HP-14	8/6/91	0.4	32	N.D.	24	N.D.
HP-15	8/6/91	N.D.	N.D.	N.D.	N.D.	N.D.
HP-16	8/6/91	N.D.	N.D.	N.D.	N.D.	N.D.
HP-17	8/6/91	N.D.	N.D.	2	N.D.	N.D.
HP-18	8/6/91	260	310	N.D.	740	N.D.

TABLE 4.3 (Page 2 of 2)
SUMMARY OF LABORATORY ANALYSES
HYDROPUNCH GROUND-WATER SAMPLES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER FUEL FORM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	DATE SAMPLED	LABORATORY RESULTS (ug/l)				
		BENZENE	ETHYLBENZENE	TOLUENE	XYLENES (TOTAL)	METHYL TERT BUTYL ETHER
HP-19	8/6/91	N.D.	N.D.	N.D.	N.D.	N.D.
HP-20	8/6/91	N.D.	N.D.	N.D.	N.D.	N.D.
HP-21	8/7/91	N.D.	N.D.	N.D.	N.D.	N.D.

TABLE 4.4 (Page 1 of 3)
SUMMARY OF LABORATORY ANALYSES
MONITORING WELL GROUND-WATER SAMPLES
SHALLOW SCREENED INTERVAL

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

	WELL NUMBER	NC GROUND WATER STANDARD	EMW-1 (CGMW-1)	EMW-2 (CGMW-2)	EMW-3 (CGMW-3)	EMW-4 (CGMW-4)	EMW-5 (35GW-4)	EMW-6 (35GW-5)	EMW-7 (35GW-6)	MW-8S	MW-9S	MW-10S
	DATE SAMPLED		9/3/91	9/5/91	9/5/91	9/5/91	9/4/91	9/5/91	9/5/91	9/4/91	9/3/91	9/3/91
PARAMETER (ug/l)	SCREENED INTERVAL (Feet)		8.5-17.5	1.87-10.87	3.06-12.06	2.61-11.61	10.5-24.5	10.5-24.5	10.5-24.5	4.5-13.5	3.5-12.5	4.5-13.5'
BENZENE		1	ND	40	ND	13	0.4	0.3	ND	52	45	3
TOLUENE		1000	ND	12	ND	ND	ND	ND	ND	ND	ND	5
ETHYLBENZENE		29	ND	41	ND	0.7	ND	ND	ND	73	ND	7
XYLENES TOTAL		400	ND	76	ND	2	ND	ND	ND	420	4	ND
METHYL TERTIARY BUTYL ETHER (MTBE)		50**	ND	ND	ND	ND	ND	3	ND	ND	46	ND
LEAD		50	14	ND	2	28	75	ND	12	5	ND	3
TRANS-1,2-DICHLOROETHENE		70	ND	ND	2	ND	0.7	ND	18	ND	ND	17
TRICHLOROETHENE		2.8	ND	ND	8	0.6	3	0.6	59	ND	ND	170
1-METHYLNAPTHALENE		*	-	-	-	-	-	-	-	450	-	-
2-METHYLNAPTHALENE		*	-	-	-	-	-	-	-	460	-	-

LAW ENGINEERING

TABLE 4.4 (Page 2 of 3)
SUMMARY OF LABORATORY ANALYSES
MONITORING WELL GROUND-WATER SAMPLES
SHALLOW SCREENED INTERVAL

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

	WELL NUMBER	NC GROUND WATER STANDARD	MW-11S	MW-12S	MW-13S	MW-14S	MW-15S	MW-16S	MW-17S	MW-18S	MW-19S	MW-20S
	DATE SAMPLED		9/4/91	9/4/91	9/4/91	9/4/91	9/4/91	9/5/91	9/5/91	9/5/91	9/4/91	9/4/91
PARAMETER (ug/l)	SCREENED INTERVAL (Feet)		4.5'-13.5'	5'-14'	5.5'-14.5'	3.5'-12.5'	4.5'-13.5'	5.0'-14.0'	7.5'-16.5'	3.0'12.0'	4.5'-13.5'	3.0'-12.0'
BENZENE		1	ND	ND	ND	0.6	4	40	0.5	52	ND	140
TOLUENE		1000	ND	ND	ND	ND	ND	230	ND	ND	ND	280
ETHYLBENZENE		29	80	ND	ND	ND	3	76	ND	ND	ND	320
XYLENES TOTAL		400	170	ND	ND	ND	29	800	ND	ND	ND	830
METHYL TERTIARY BUTYL ETHER (MTBE)		50**	ND	ND	ND	ND	ND	ND	1	32	ND	ND
LEAD		50	ND	16	7	2	5	6	6	9	36	ND
CHLOROFORM		0.19	ND	ND	ND	3	ND	ND	ND	ND	ND	ND
TRANS-1,2-DICHLOROETHENE		70	ND	ND	ND	44	ND	ND	ND	ND	5	ND
TRICHLOROETHENE		2.8	ND	ND	ND	110	ND	ND	0.6	ND	31	ND
1,2-DICHLOROETHANE		*	ND	ND	ND	ND	ND	ND	1	ND	ND	ND
1,1,2,2-TETRACHLOROETHANE		*	ND	ND	ND	ND	ND	ND	ND	ND	12	ND
TETRACHLOROETHENE		*	ND	ND	ND	ND	ND	ND	ND	ND	1	ND

LAW ENGINEERING

TABLE 4. e 3 of 3)
SUMMARY OF LABORATORY ANALYSES
MONITORING WELL GROUND-WATER SAMPLES
SHALLOW SCREENED INTERVAL

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

	WELL NUMBER	NC GROUND WATER STANDARD	MW-21S	MW-22S	MW-23S	MW-24S	MW-25S	MW-26S (MW-14S)	MW-27S (MW-24S)	POTABLE WATER
	DATE SAMPLED		9/4/91	9/4/91	9/5/91	9/5/91	9/4/91	9/4/91	9/5/91	5/29/91 8/5/91
PARAMETER (ug/l)	SCREENED INTERVAL (Feet)		4.5-13.5	5.5'-14.5'	2.5-9.5	8.5-17.5	4.5-13.5	3.5-12.5	8.5-17.5	-
BENZENE		1	220	2300	ND	11	26	0.6	12	ND
TOLUENE		1000	ND	ND	ND	ND	160	ND	ND	ND
ETHYLBENZENE		29	590	560	ND	10	190	ND	10	ND
XYLENES TOTAL		400	1100	740	ND	43	500	ND	43	ND
METHYL TERTIARY BUTYL ETHER (MTBE)		50**	ND	ND	ND	ND	ND	ND	ND	ND
LEAD		50	4	3	2	5	1	2	7	ND
CHLOROFORM		0.19	ND	ND	ND	ND	ND	3	ND	9
TRANS-1,2-DICHLOROETHENE		70	ND	ND	ND	ND	ND	51	ND	ND
TRICHLOROETHENE		2.8	ND	ND	0.6	ND	ND	120	ND	ND
TRICHLOROFLUOROMETHANE		*	ND	ND	0.9	ND	ND	ND	ND	ND
BROMODICHLOROMETHANE		*	ND	ND	ND	ND	ND	ND	ND	14
BROMOFORM		0.19	ND	ND	ND	ND	ND	ND	ND	16
DIBROMOCHLOROMETHANE		*	ND	ND	ND	ND	ND	ND	ND	27
ACENAPTHENE		*	-	-	-	ND	ND	ND	0.7	-
FLUORENE		*	-	-	-	1	ND	ND	ND	-
1-METHYLNAPTHALENE		*	-	-	-	64	190	ND	42	-
2-METHYLNAPTHALENE		*	-	-	-	63	270	ND	42	-
NAPTHALENE		*	-	-	-	41	220	ND	31	-

TABLE 4.5 (Page 1 of 2)

SUMMARY OF LABORATORY ANALYSES
MONITORING WELL GROUND-WATER SAMPLES
DEEP SCREENED INTERVAL

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

	WELL NUMBER	NC GROUND WATER STANDARD	MW-8D	MW-9D	MW-10D	MW-11D	MW-12D	MW-13D	MW-14D	MW-15D
	DATE SAMPLED		9/4/91	9/3/91	9/3/91	9/4/91	9/4/91	9/4/91	9/4/91	9/4/91
PARAMETER (ug/l)	SCREENED INTERVAL (Feet)		20.5-29.5	25.5-29.5	25.5-29.5	25.5-29.5	24-28	25.5-29.5	24.5-28.5	25.5-29.5
BENZENE		1	1	0.3	3	ND	ND	ND	0.8	ND
TOLUENE		1000	3	ND	2	ND	ND	ND	ND	ND
ETHYLBENZENE		29	26	ND	1	ND	ND	ND	ND	ND
XYLENES (TOTAL)		400	52	ND	ND	9	ND	ND	ND	ND
METHYL TERTIARY BUTYL ETHER (MTBE)		50**	ND	ND	ND	ND	ND	ND	ND	ND
LEAD		50	8	14	11	10	9	3	14	5
TRANS-1,2-DICHLOROETHENE		70	ND	0.9	110	ND	ND	ND	7	ND
TRICHLOROETHENE		2.8	0.7	14	810	ND	ND	ND	13	ND
VINYL CHLORIDE		*	ND	ND	6	ND	ND	ND	ND	ND

LAW ENGINEERING

TABLE 4.5 (Page 2 of 2)

SUMMARY OF LABORATORY ANALYSES
MONITORING WELL GROUND-WATER SAMPLES
DEEP SCREENED INTERVAL

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

	WELL NUMBER	NC GROUND WATER STANDARD	MW-16D	MW-17D	MW-18D	MW-19D	MW-21D	MW-22D	MW-23D	MW-24D	MW-25D
	DATE SAMPLED		9/5/91	9/5/91	9/5/91	9/4/91	9/4/91	9/4/91	9/5/91	9/5/91	9/4/91
PARAMETER (ug/l)	SCREENED INTERVAL (Feet)		24.5'-28.5'	25-29	20.5-24.5	22.5-24.5	25.5-27	32'-35'	17.5-20	26.5-29	27.5-30
BENZENE		1	12	ND	ND	ND	0.4	50	ND	0.7	ND
TOLUENE		1000	23	ND	ND	ND	13	1	ND	ND	33
ETHYLBENZENE		29	21	ND	ND	ND	17	10	ND	1	110
XYLENES (TOTAL)		400	100	ND	ND	ND	93	8	ND	3	290
METHYL TERTIARY BUTYL ETHER (MTBE)		50**	ND	ND	1	ND	ND	ND	ND	ND	ND
LEAD		50	9	7	5	9	3	10	2	7	ND
TRANS-1,2-DICHLOROETHENE		70	ND	0.6	ND	92	2	ND	ND	ND	ND
TRICHLOROETHENE		2.8	ND	ND	0.9	630	6	ND	0.7	0.6	ND

TABLE 5.1
SUMMARY OF LABORATORY ANALYSES RINSE AND TRIP BLANKS

REPORT OF UNDERGROUND FUEL INVESTIGATION COMPREHENSIVE SITE ASSESSMENT

CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE NUMBER	TYPE OF BLANK	DATE COLLECTED	DATE SUBMITTED	RESULTS (mg/l)
HYDROPUNCH SAMPLES				
AA11637	Trip		8/6	ND
AA11677	Trip		8/8	ND
AA11685	Rinse	8/6	8/8	ND
AA11686	Trip		8/8	ND
AA11740	Rinse	8/7	8/9	ND
AA11741	Trip		8/9	ND
MONITORING WELL SAMPLES				
AA12927	Trip		9/6	ND
AA12939	Rinse	9/4	9/6	Total Xylenes 2 MTBE 1
AA12940	Trip		9/6	Total Xylenes 2
AA12951	Rinse	9/4	9/6	Total Xylenes 2
AA12952	Trip		9/6	Total Xylenes 2
AA12985	Rinse	9/5	9/6	Total Xylenes 1
AA12986	Rinse	9/5	9/6	ND
AA12987	Trip		9/6	ND
AA12992	Rinse	9/5	9/6	Total Xylenes 1
AA12993	Trip		9/6	ND

TABLE 6.1
SUMMARY OF EXPOSURE PATHWAYS

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

CONTAMINATED MEDIUM	INGESTION (EATING)	INGESTION (DRINKING)	INHALATION	ABSORPTION
Free Product	NA	No Exposure (1)	NA	No Exposure (1)
Soil	Contingent Exposure (2)	NA	NA	Contingent Exposure (2)
Ground Water	Exposure Unlikely (3)	Exposure Unlikely (3)	NA	Exposure Unlikely (3)
Surface Water	No Exposure (4)	No Exposure (4)	NA	No Exposure (4)
Vapor	NA	NA	Possible Exposure (5)	NA

Notes:

(1) No free product detected in surface waters; water supply wells draw from Castle Hayne aquifer.
(2) Potential for exposure only if subsurface below 8 feet BLS is disturbed.
(3) Through use of Camp Geiger water-supply wells for drinking, cooking, and bathing.
(4) Ground-water sampling results indicate that plume does not extend to surface waters.
(5) Potential for exposure during maintenance/repair work in subsurface utility confinements.

KEY TO SYMBOLS

SUMMARY OF LABORATORY ANALYSES

* Numerical standard has not been established; substances not allowed in detectable concentrations.

** Interim standard

N.D. = Not detected: see laboratory reports for applicable detection limits.

\- = Sample not analyzed for this parameter.

TABLE 4.1
SUMMARY OF HEADSPACE ANALYSES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft.)	PID READING (ppm)	SAMPLE SELECTED FOR LABORATORY ANALYSIS
SB-3 (formerly MW-18)	27.5 - 29	<1	
	29 - 30.5	<1	
	30.5 - 32	<1	
	32 - 33.5	<1	
	33.5 - 35	<1	
	35 - 36.5	<1	
	36.5 - 38	200	
	38 - 39	155	
HAND-AUGER BORINGS			
HA-3	2′	2	•
	4′	5	
HA-4	2′	4	•
	5′	3	
HA-7	3′	10	
	5′	60	•
HA-8	5′	8	
HA-9	3′	<1	
	5′	8	

TABLE 4.1
SUMMARY OF HEADSPACE ANALYSES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft.)	PID READING (ppm)	SAMPLE SELECTED FOR LABORATORY ANALYSIS
B-6	2" - 1.5′	2	
	1.5 - 3	<1	
	3 - 4.5	<1	•
	8.5 - 10	50	•
	13.5 - 15	8	
STRATIGRAPHIC BORINGS			
SB-1	0 - 20	See MW-8	
	23.5 - 25	<1	
	28.5 - 30	150	
	33.5 - 35	<1	
	38.5 - 40	200	
SB-3 (formerly MW-18)	0 - 1.5	<1	
	1.5 - 3	<1	
	3 - 4.5	9	•
	8.5 - 10	10	•
	13.5 - 15	5	
	17 - 18	<1	
	18.5 - 20	<1	
	20 - 21.5	<1	
	21.5 - 23	<1	
	23 - 24.5	<1	
	24.5 - 26	<1	
	26 - 27.5	<1	

TABLE 4.1
SUMMARY OF HEADSPACE ANALYSES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft.)	PID READING (ppm)	SAMPLE SELECTED FOR LABORATORY ANALYSIS
SOIL BORINGS			
B-1	0 - 1.5	200	
	1.5 - 3	160	*
	3 - 4.5	40	
	8.5 - 10	140	*
	13.5 - 15	4	
B-2	2 - 2.5	3	
	3 - 3.5	2	
	4 - 4.5	8	
	5 - 5.5	7.5	
	5.5 - 6	12	*
	8.5 - 10	51	*
	13.5 - 15	6.2	
B-3	ATTEMPTED 6 TIMES, ABANDONED		
B-4	0 - 1.5	0	
	1.5 - 3	11	
	3 - 4.5	22	*
	8.5 - 10	50	*
	13.5 - 15	18	
B-5	2" - 1.5'	<1	
	1.5 - 3	0	
	3 - 4.5	20	*
	8.5 - 10	2	*
	13.5 - 15	0	

TABLE 4.1
SUMMARY OF HEADSPACE ANALYSES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft.)	PID READING (ppm)	SAMPLE SELECTED FOR LABORATORY ANALYSIS
MW-22	0 - 1.5	10	
	1.5 - 3	2	
	3 - 4.5	150	•
	9.5 - 11	90	•
	14.5 - 16	5	
	19.5 - 21	4	
	24.5 - 26	0	
	29.5 - 31	0	
MW-23	1.5 - 2	<1	•
	3.5 - 4	<1	
	5.5 - 6	<1	
	10 - 10.5	<1	
	15 - 15.5	<1	•
	20 - 20.5	<1	
MW-24	1.5 - 2	<1	
	3.5 - 4	<1	•
	5.5 - 6	0	
	10 - 10.5	3	•
	15 - 15.5	0	
	20 - 20.5	<1	
MW-25	1.5 - 2	22	
	3.5 - 4	45	•
	5.5 - 6	45	•
	10 - 10.5	2.5	
	15 - 15.5	25	

TABLE 4.1
SUMMARY OF HEADSPACE ANALYSES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft.)	PID READING (ppm)	SAMPLE SELECTED FOR LABORATORY ANALYSIS
MW-19	1.5 - 2	<1	
	3.5 - 4	<1	*
	5.5 - 6	<1	
	10 - 10.5	<1	*
	15 - 15.5	<1	
	20 - 20.5	<1	
	25 - 25.5	<1	
MW-20	0 - 1.5	40	
	1.5 - 3	65	
	3 - 4.5	300	*
	8.5 - 10	220	*
	13.5 - 15	75	
	18.5 - 20	55	
	23.5 - 25	110	
MW-21	1.5 - 2	<1	
	3.5 - 4	60	*
	5.5 - 6	75	*
	10 - 10.5	35	
	15 - 15.5	17	
	20 - 20.5	<1	
	25 - 25.5	<1	

TABLE 4.1
SUMMARY OF HEADSPACE ANALYSES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft.)	PID READING (ppm)	SAMPLE SELECTED FOR LABORATORY ANALYSIS
MW-14	0 - 1.5	<1	
	1.5 - 3	3	
	3 - 4.5	60	*
	8.5 - 10	16	
	13.5 - 15	3	
	18.5 - 20	145	*
MW-15	1.5 - 2	<1	
	3.5 - 4	<1	
	5.5 - 6	<1	*
	10 - 10.5	65	*
	15 - 15.5	<1	
	20 - 20.5	<1	
MW-16	0 - 1.5	30	
	1.5 - 3	110	
	3 - 4.5	200	*
	8.5 - 10	155	
	13.5 - 15	200	
	18.5 - 20	250	*
MW-17	1.5 - 2	<1	
	3.5 - 4	<1	
	5.5 - 6	<1	*
	10 - 10.5	<1	
	15 - 15.5	<1	
	20 - 20.5	<1	*

TABLE 4.1
SUMMARY OF HEADSPACE ANALYSES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft.)	PID READING (ppm)	SAMPLE SELECTED FOR LABORATORY ANALYSIS
MW-10	1.5 - 2	>2000	•
	3.5 - 4	220	•
	5.5 - 6	105	
	10 - 10.5	40	
	15 - 15.5	6	
	20 - 20.5	<1	
MW-11	1.5 - 2	0	
	3.5 - 4	1.5	
	5.5 - 6	30	•
	10 - 10.5	31	•
	15 - 15.5	7.3	
	20 - 20.5	<1	
MW-12	0 - 1.5	>2000	•
	1.5 - 3	75	
	3 - 4.5	200	•
	8.5 - 10	45	
	13.5 - 15	<1	
	18.5 - 20	0	
MW-13	1.5 - 2	<1	
	3.5 - 4	<1	
	5.5 - 6	<1	
	10 - 10.5	<1	•
	15 - 15.5	<1	
	20 - 20.5	<1	•

TABLE 4.1
SUMMARY OF HEADSPACE ANALYSES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER AREA FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

SAMPLE LOCATION	SAMPLE DEPTH (ft.)	PID READING (ppm)	SAMPLE SELECTED FOR LABORATORY ANALYSIS
MONITORING WELL SOIL BORINGS			
MW-8	1.5 - 2	8	
	3.5 - 4	3	
	5.5 - 6	55	
	7.5 - 8	85	*
	9.5 - 10	42	
	11.5 - 12	4	
	13.5 - 14	32	
	15.5 - 16	65	*
	17.5 - 18	5	
	19.5 - 20	2.5	
MW-9	1.5 - 2	0	
	3.5 - 4	0	
	5.5 - 6	0	
	7.5 - 8	0	*
	9.5 - 10	0	
	11.5 - 12	0	
	13.5 - 14	0	
	15.5 - 16	0	
	17.5 - 18	0	*
	19.5 - 20	0	
	25 - 25.5	0	

TABLE 3.2
SUMMARY OF DEVELOPMENT OF "DEEP" MONITORING WELLS

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

MONITORING WELL IDENTIFICATION NUMBER	FINAL TURBIDITY (SUBJECTIVE)*	APPROXIMATE VOLUME OF WATER REMOVED (GAL)
MW-8D	1	70
MW-9D	1	60
MW-10D	1	60
MW-11D	1	50
MW-12D	1	50
MW-13D	1	55
MW-14D	1	50
MW-15D	1	60
MW-16D	1	50
MW-17D	1	55
MW-18D	1	50
MW-19D	1	60
MW-21D	1	55
MW-22D	1	60
MW-23D	1	60
MW-24D	1	50
MW-25D	1	50

Note:

* (1) Clear; (2) Slight; (3) Moderate; (4) High

TABLE 3.1
SUMMARY OF DEVELOPMENT OF "SHALLOW" MONITORING WELLS

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

MONITORING WELL IDENTIFICATION NUMBER	FINAL TURBIDITY (SUBJECTIVE)*	APPROXIMATE VOLUME OF WATER REMOVED (GAL)
MW-8S	1	50
MW-9S	1	50
MW-10S	1	45
MW-11S	1	40
MW-12S	1	50
MW-13S	1	60
MW-14S	1	45
MW-15S	1	30
MW-16S	1	40
MW-17S	1	40
MW-18S	1	45
MW-19S	1	45
MW-20S	1	30
MW-21S	1	60
MW-22S	1	30
MW-23S	1	35
MW-24S	1	30
MW-25S	1	25

Note:

* (1) Clear; (2) Slight; (3) Moderate; (4) High

TABLE 2.3
LIST OF WATER-SUPPLY WELLS

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

LAW ENGINEERING JOB NO. J47590-6014

USGS WELL NO.	CAMP GEIGER WELL LETTER	TOTAL WELL DEPTH (Ft.)	CASING LENGTH (Ft.)	CASING DIAMETER (INCHES)	APPROX. DISTANCE FROM FUEL FARM (FEET)	STATUS
TC104	A	Unknown	Unknown	Unknown	2600	Abandoned
TC100	B	Unknown	Unknown	Unknown	2600	Abandoned
TC202	I	Unknown	Unknown	Unknown	2600	Abandoned
TC325	C	70'	20'	18"	2600	Abandoned
TC502	D	184'	110'	10"	2600	Drinking
TC600	E	170'	21'	20"	2600	Drinking
TC700	F	76'	27.5'	18"	3300	Drinking
TC901	G	76'	25'	18"	3900	Abandoned

TABLES

TABLE 2.1
LIST OF DRAWINGS

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

DRAWING NUMBER	DESCRIPTION	DATE
2816	Filling Station/Fire Station Plans	11/12/47
161813	Ice Storage House	6/26/41
161814	Ice Storage House	6/26/41
161821	Mess Hall UST Fuel Line	10/28/41
161870	Drinking Water Well Locations	8/25/41
161873	Fuel Farm/Mess Hall UST	7/17/41
162072	Fuel Farm	2/2/42
267402	Storm Sewer/Fire Hydrant/Sanitary Sewer Lines	Unknown
267403	Barracks Plan	10/29/43
4009116	Building No. 480	6/18/75
4714380	Piping Plan/Fuel Farm	Not Dated
4174381	Demolition Plan/Fuel Farm	Not Dated
4174383	Fuel Farm	Not Dated
417439?	Electrical Plan/Fuel Farm	Not Dated
Unnumbered	Steam Lines	7/31/84
Unnumbered	Wastewater Lines	7/31/84
Unnumbered	Electrical Lines	7/31/84

TABLE 2.2
INVENTORY OF POTENTIAL CONTAMINANT SOURCES

REPORT OF UNDERGROUND FUEL INVESTIGATION
COMPREHENSIVE SITE ASSESSMENT

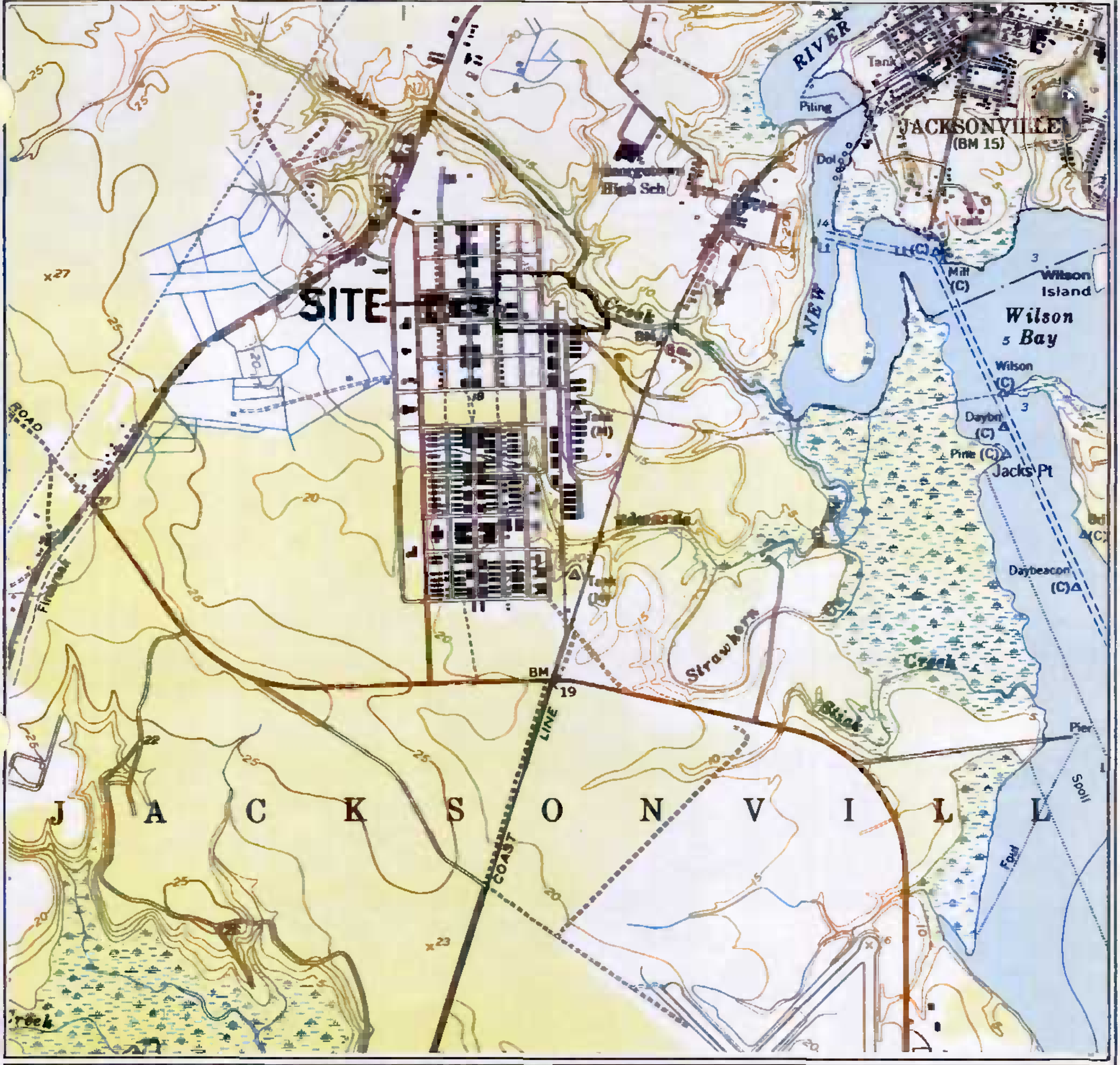
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA
LAW ENGINEERING JOB NO. J47590-6014

TANK LOCATION	PRODUCT TYPE	TANK TYPE	INSTALL DATE	SIZE OF TANK	TANK STATUS
Building No. 480	No. 2 Fuel Oil	UST	1976	550 Gallons	Active
Former Mess Hall	No. 6 Fuel Oil	UST	1941?	Unknown	Abandoned
Building No. 474	Waste Oil	UST	1946	550 Gallons	Abandoned

Underground lines associated with these tanks, the aboveground tanks and the oil-water separator located southeast of the Fuel Farm are also potential contaminant sources.

DRAWINGS

01985 F01



NORTH

JACKSONVILLE SOUTH, N.C.
NW/4 NEW RIVER 15' QUADRANGLE
N3437.5—W7722.5/7.5
1952
PHOTOINSPECTED 1971
AMS 5553 III NW—SERIES V 842

CONTOUR INTERVAL 5 FEET

GRAPHIC SCALE FEET
2000 1000 0 2000 4000

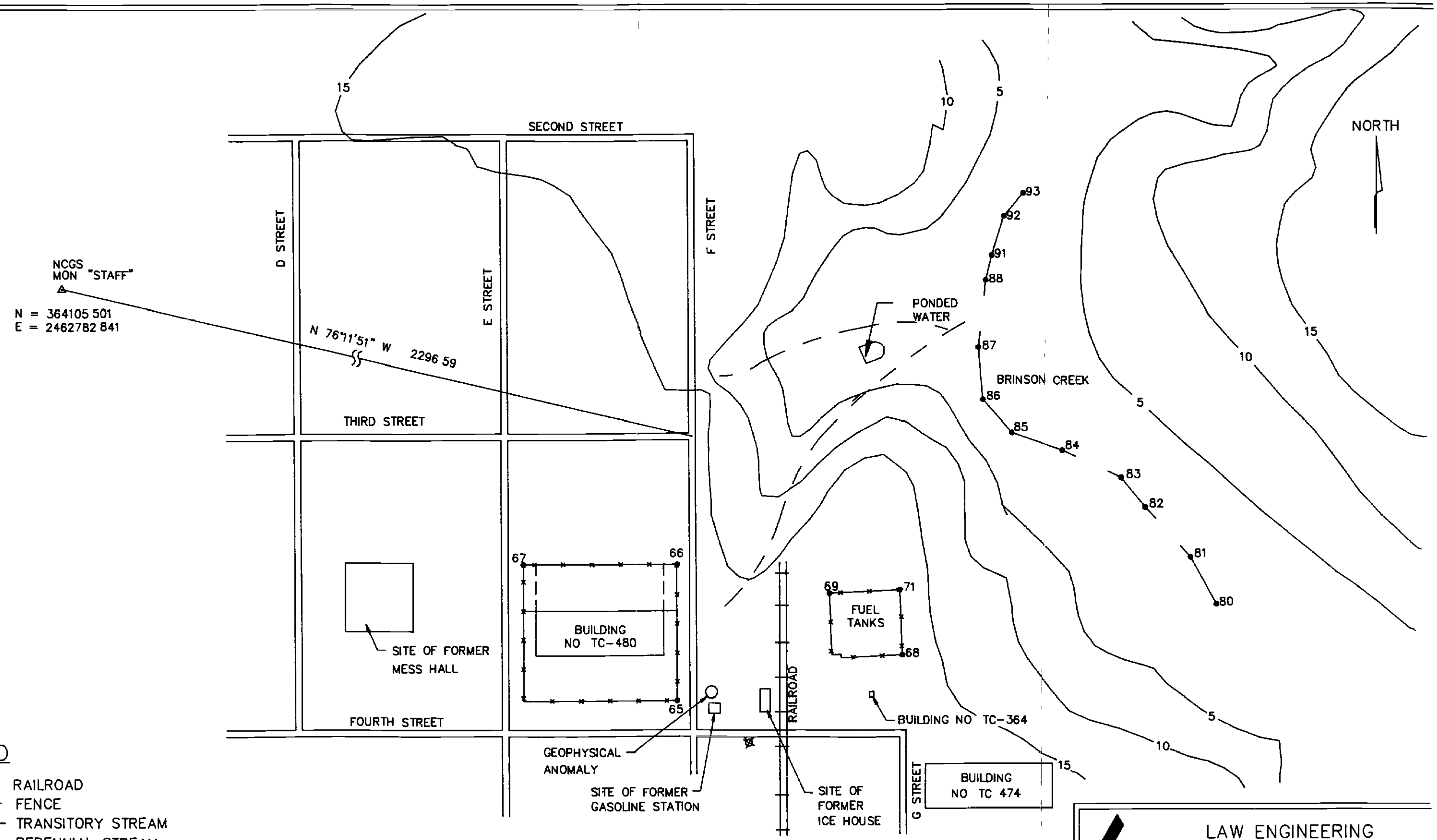
QUADRANGLE LOCATION

NOTE: SITE LOCATIONS ARE APPROXIMATE.

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

TOPOGRAPHIC SITE MAP
UNDERGROUND FUEL INVESTIGATION
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE: OCT. 1991
DFT CHECK:	SCALE: 1:24000
ENG CHECK: WDDixon	JOB: J47590-6014
APPROVAL: WDDixon	DWG: 1.1



LEGEND

- ╪═╪ RAILROAD
- —×—×— FENCE
- — — — TRANSITORY STREAM
- —— —— PERENNIAL STREAM
- •67 POINTS OF REFERENCE
- ☒ SITE B M – TOP OF FLANGE BOLT THAT HAS I D. NUMBER ATTACHED ELEV = <u>18.08</u>
- —10— TOPOGRAPHIC CONTOUR (FEET ABOVE MSL)

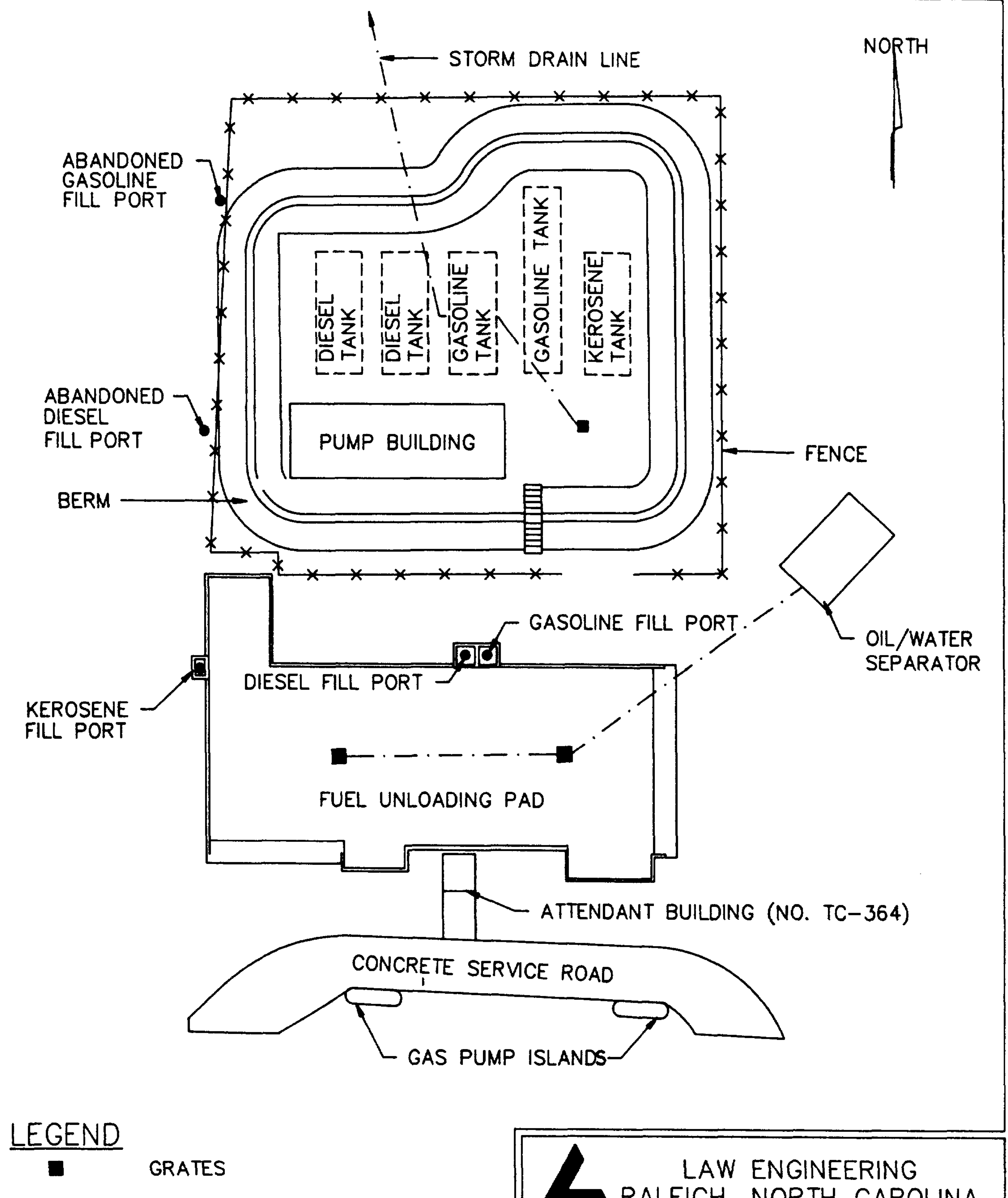
NOTE. CONTOUR INTERVAL 5 FEET

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

DRAWN DCC	DATE OCT. 1991
DFT CHECK. DCC	SCALE 1"=150'
ENG CHECK WADixon	JOB J47590-6014
APPROVAL WADixon	DWG 21

BASE MAP
CAMP GEIGER FUEL FARM STUDY AREA
CAMP LEJEUNE, NORTH CAROLINA

REFERENCE JAMES E STEWART AND ASSOC ,SHT 1&2 OF 2,9/13/91 USGS JACKSONVILLE SOUTH,N C

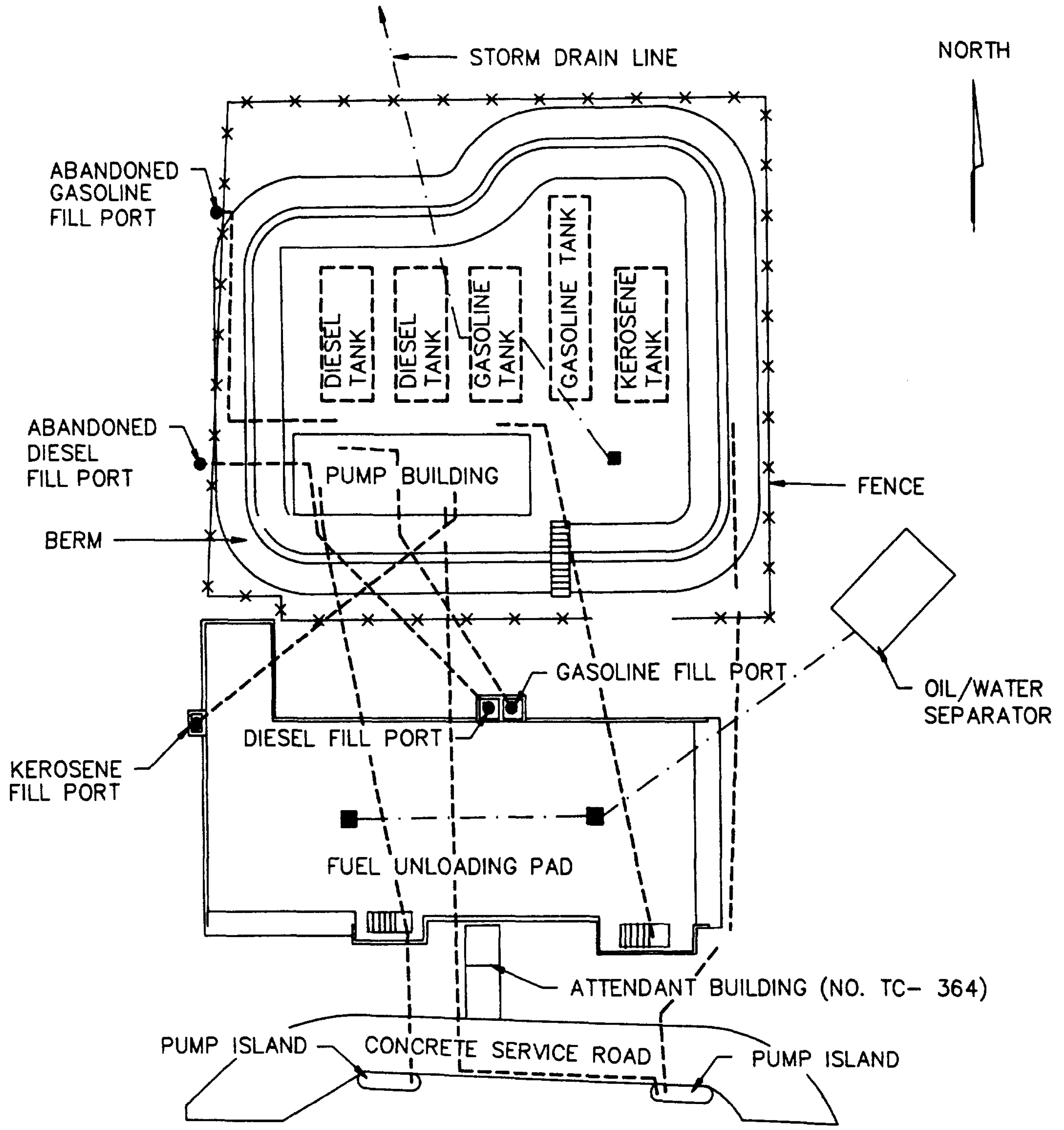


LAW ENGINEERING
RALEIGH, NORTH CAROLINA

BASE MAP
FUEL FARM AREA
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE: OCT. 1991
DFT CHECK: DCC	SCALE: 1"=30'
ENG CHECK:	JOB: J47590-6014
APPROVAL: W Dixon	DWG: 2.2

REFERENCE: NAVFAC DWG. NO. 4174383



LEGEND

■ GRATES

-------- LOCATION OF UNDERGROUND FUEL LINES

6014BZ6A 1:3

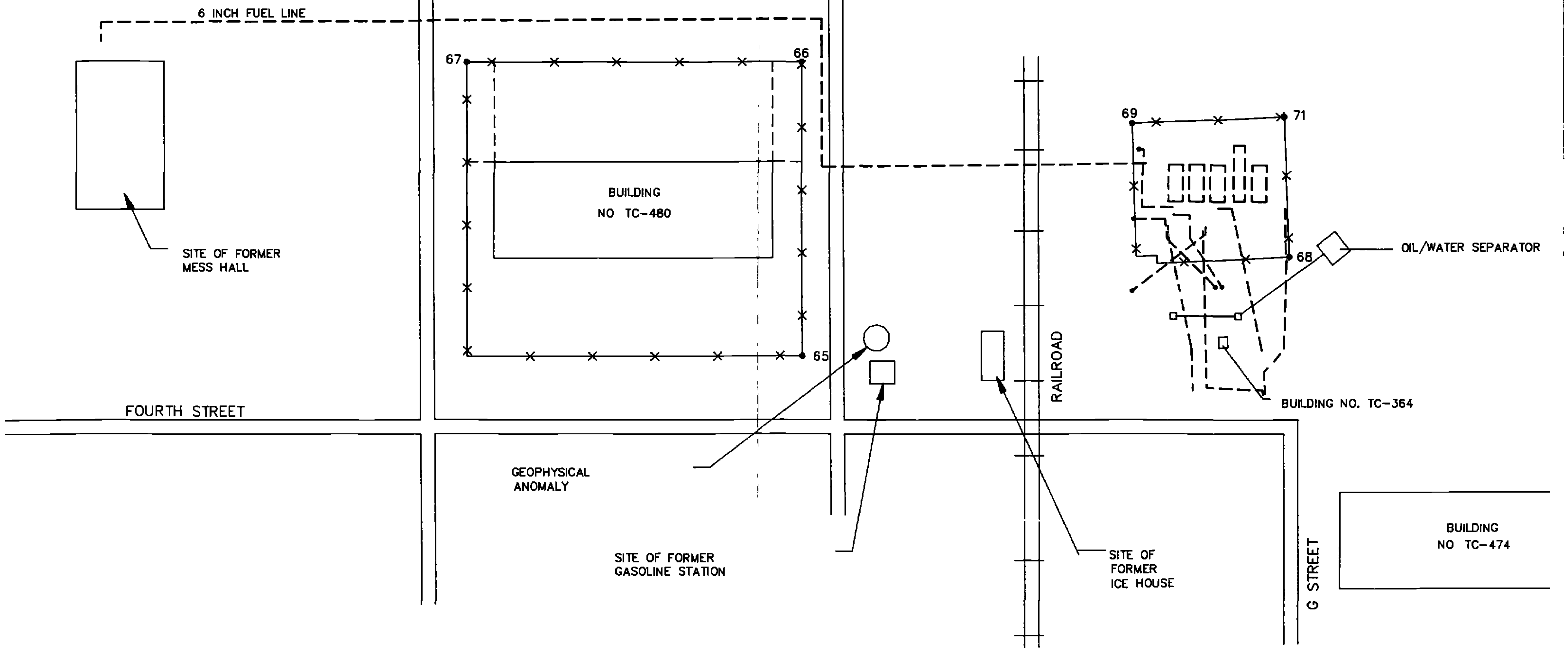
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

UNDERGROUND FUEL LINES
FUEL FARM AREA
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE: OCT. 1991
DFT CHECK: DCC	SCALE: 1"=30'
ENG CHECK:	JOB: J47590-6014
APPROVAL: WDD	DWG: 2.3

REFERENCE: NAVFAC DWG. NO. 4174383; TRACER RES. CORP. REPORT NO. 2-91-425T.

01985F032



J6014Z23

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

LEGEND

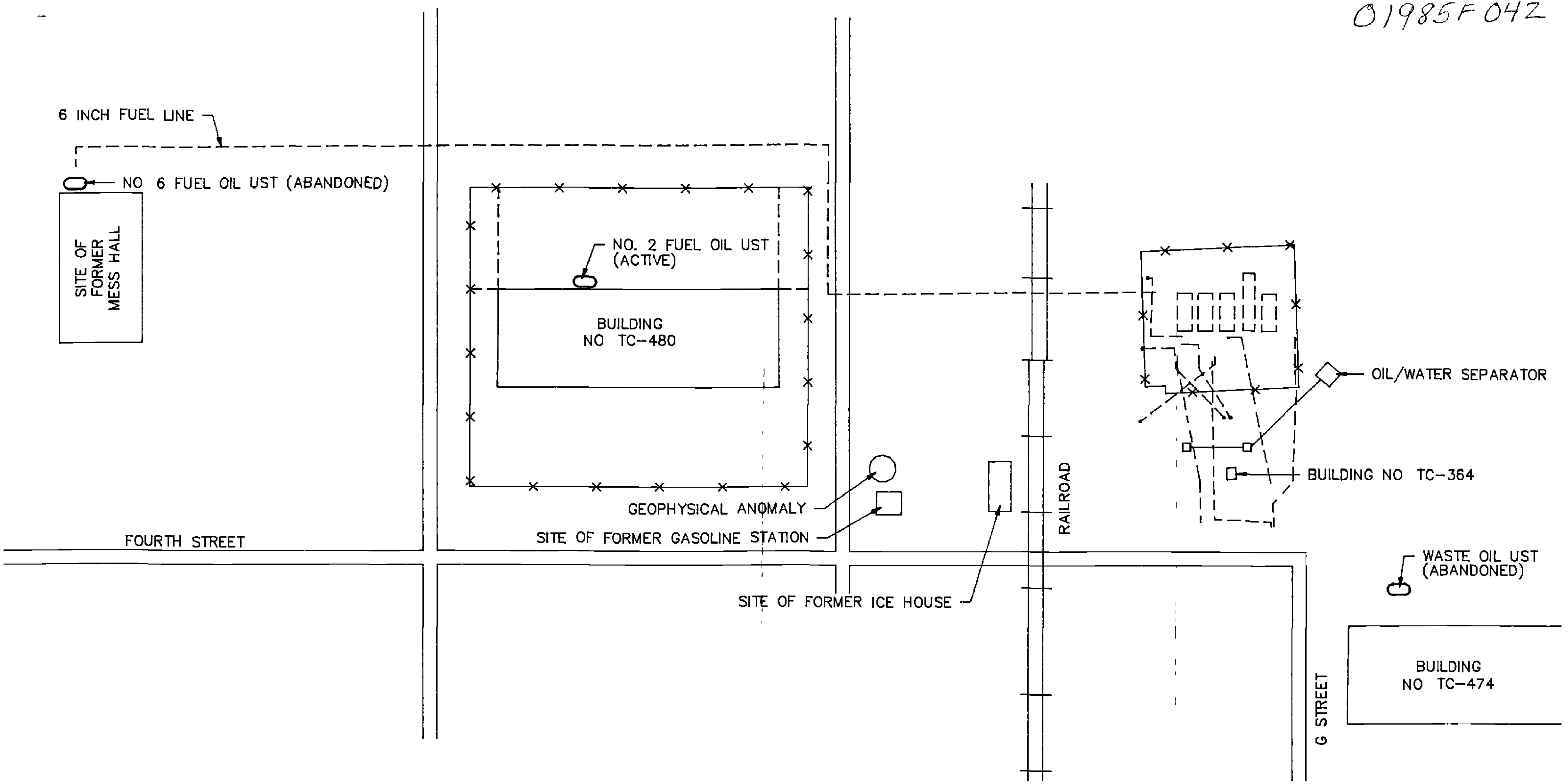
– – – – – – LOCATION OF UNDERGROUND FUEL LINES

UNDERGROUND FUEL LINES
CAMP GEIGER FUEL FARM STUDY AREA
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCG	DATE: NOV 1991
DFT CHECK:	SCALE: 1"=70'
ENG CHECK: WADixon	JOB 47590-6014
APPROVAL: WADixon	DWG 2.4

REFERENCE JAMES E STEWART & ASSOC SHT 1&2 OF 2; NAVFAC DWG 4174383, TRACER RES #2-91-425T

01985F042



J6014Z24

LEGEND

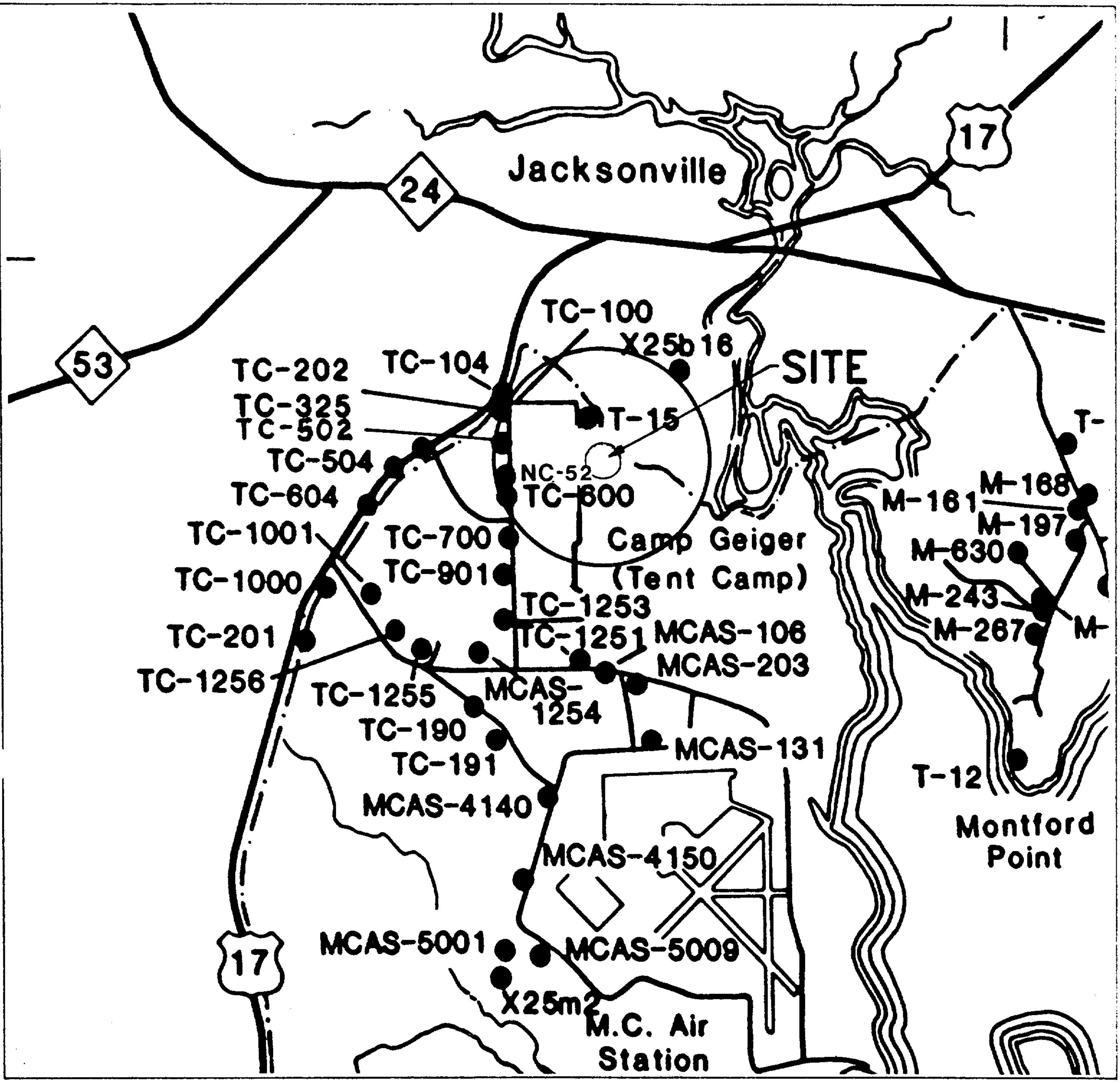
– – – – – –	LOCATION OF UNDERGROUND FUEL LINES
⬭	APPROXIMATE LOCATION OF UNDERGROUND STORAGE TANKS

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

LOCATION OF POTENTIAL CONTAMINANT SOURCES
CAMP GEIGER FUEL FARM STUDY AREA
CAMP LEJEUNE, NORTH CAROLINA

DRAWN		DATE	FEB 1992
DFT CHECK		SCALE	1"=70'
ENG CHECK	RDKall	JOB	475-06014-01
APPROVAL		DWG	2.5

REFERENCE JAMES E STEWART & ASSOC SHT 1&2 OF 2, NAVFAC DWG 4174383, TRACER RES #2-91-425T



NORTH

LEGEND

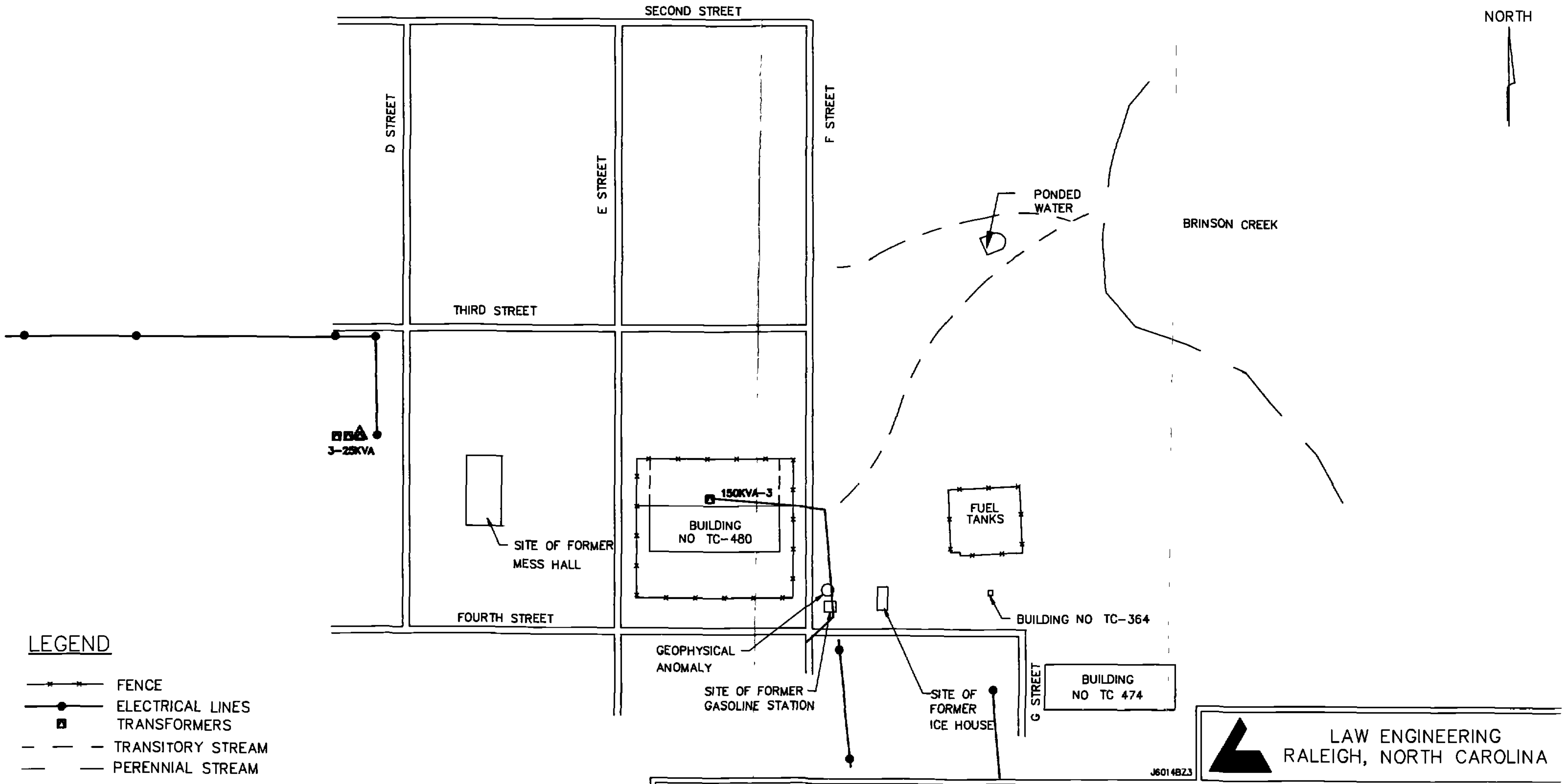
● TC-202 LOCATION OF WATER-SUPPLY WELL AND WELL NUMBER

○ 1/2 MILE RADIUS AROUND SITE

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

LOCATIONS OF WATER-SUPPLY WELLS
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE: OCT. 1991
DFT CHECK:	SCALE: 1"=3500'
ENG CHECK:	JOB: J47590-6014
APPROVAL: WD Dixon	DWG: 2.6



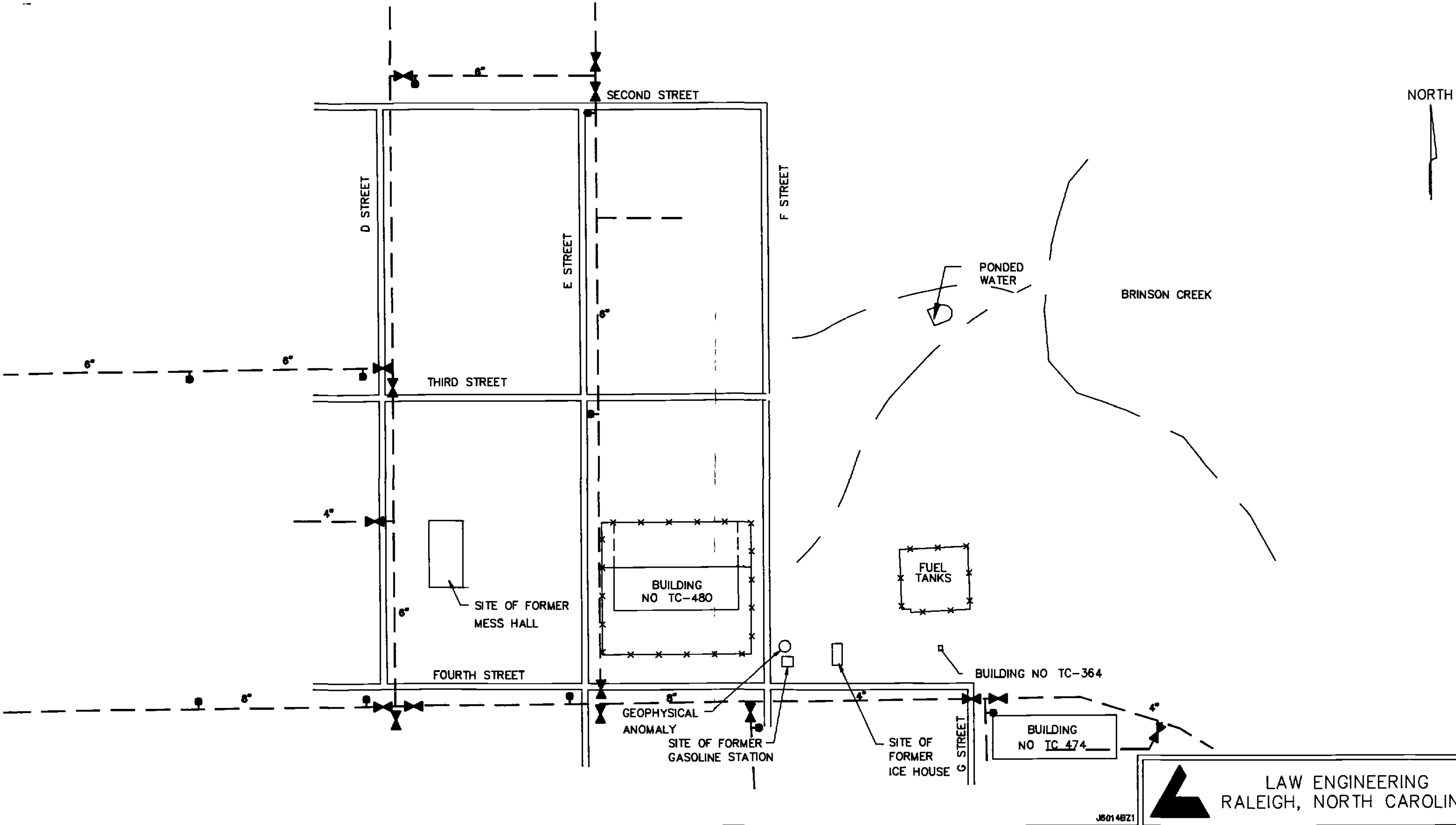
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

LOCATION OF UNDERGROUND ELECTRICAL LINES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN DCC	DATE NOV. 1991
DFT CHECK. DCC	SCALE: 1"=150'
ENG CHECK: WDDixon	JOB: J47590-6014
APPROVAL: WDDixon	DWG 2.7

REFERENCE. JAMES E STEWART AND ASSOC, SHT 1 AND 2 OF 2, 9-13-91, ELEC. SYS SHT A-2 OF 73

01985F052



LEGEND

—×—×— FENCE

— 6" — POTABLE WATER MAIN WITH CORRESPONDING SIZE

— ⋈ — GATE VALVE

— ● — FIRE HYDRANT

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

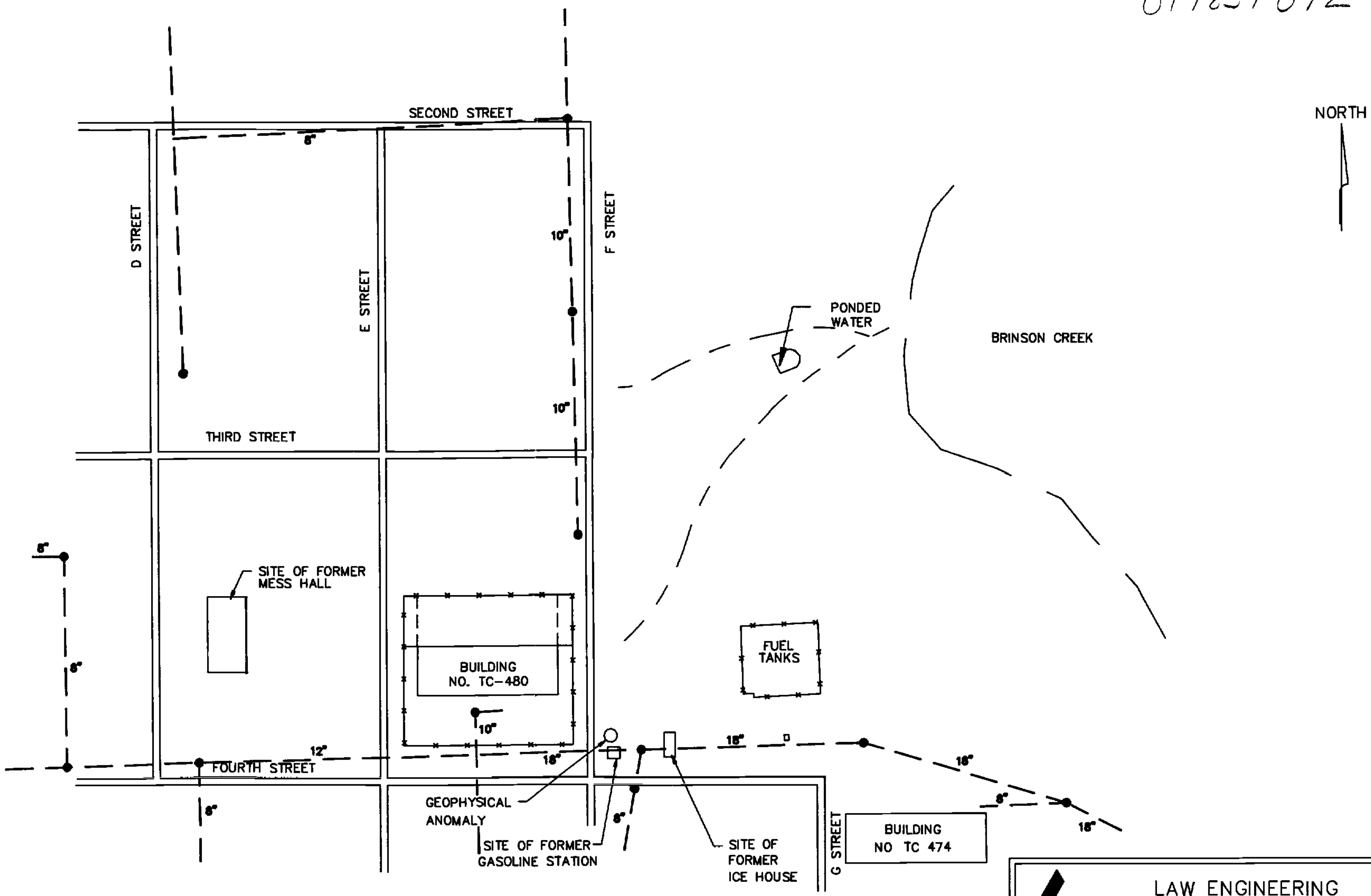
LOCATIONS OF POTABLE WATER LINES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN DCC	DATE NOV 1991
DFT CHECK DCC	SCALE 1"=150'
ENG CHECK:	JOB. J47590-6014
APPROVAL	DWG 28

REFERENCE JAMES E STEWART AND ASSOC, SHT 1 AND 2 OF 2, 9-13-91 EXIST WATER DIST SYS A-2 OF 73

01985F067

01985F072



J60148Z2

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

LEGEND

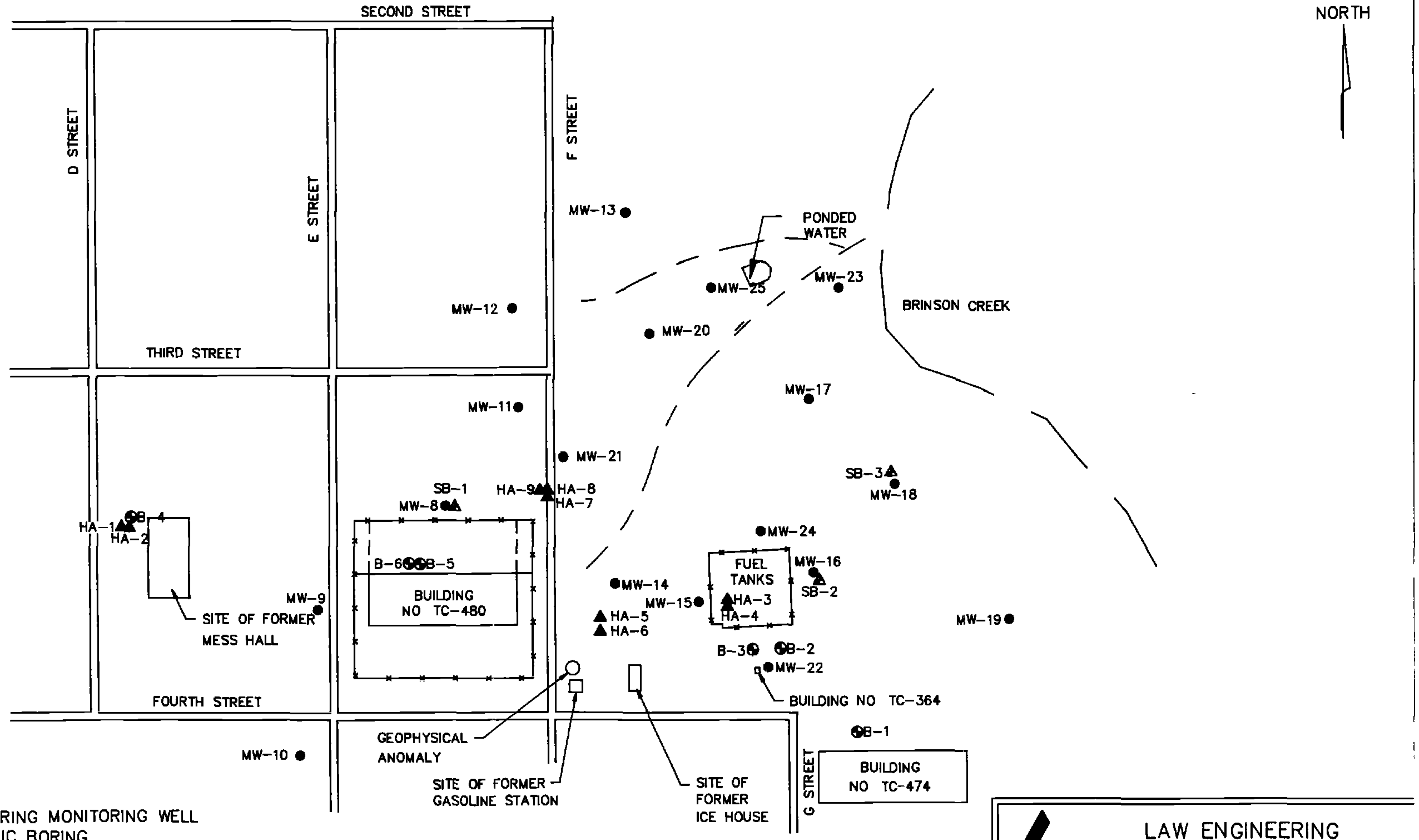
—×—×— FENCE
— 18" — WASTEWATER LINES WITH CORRESPONDING LINE SIZE
— ● — MANHOLE
— — — TRANSITORY STREAM
—— —— PERENNIAL STREAM

LOCATION OF WASTEWATER LINES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE NOV 1991
DFT CHECK DCC	SCALE 1"=150'
ENG CHECK WDDixon	JOB J47590-6014
APPROVAL WDDixon	DWG 29

REFERENCE JAMES E STEWART AND ASSOC., SHT 1 AND 2 OF 2, 9-13-91, EXIST WASTEWATER SYS A-2 OF 73

01985F082



LEGEND

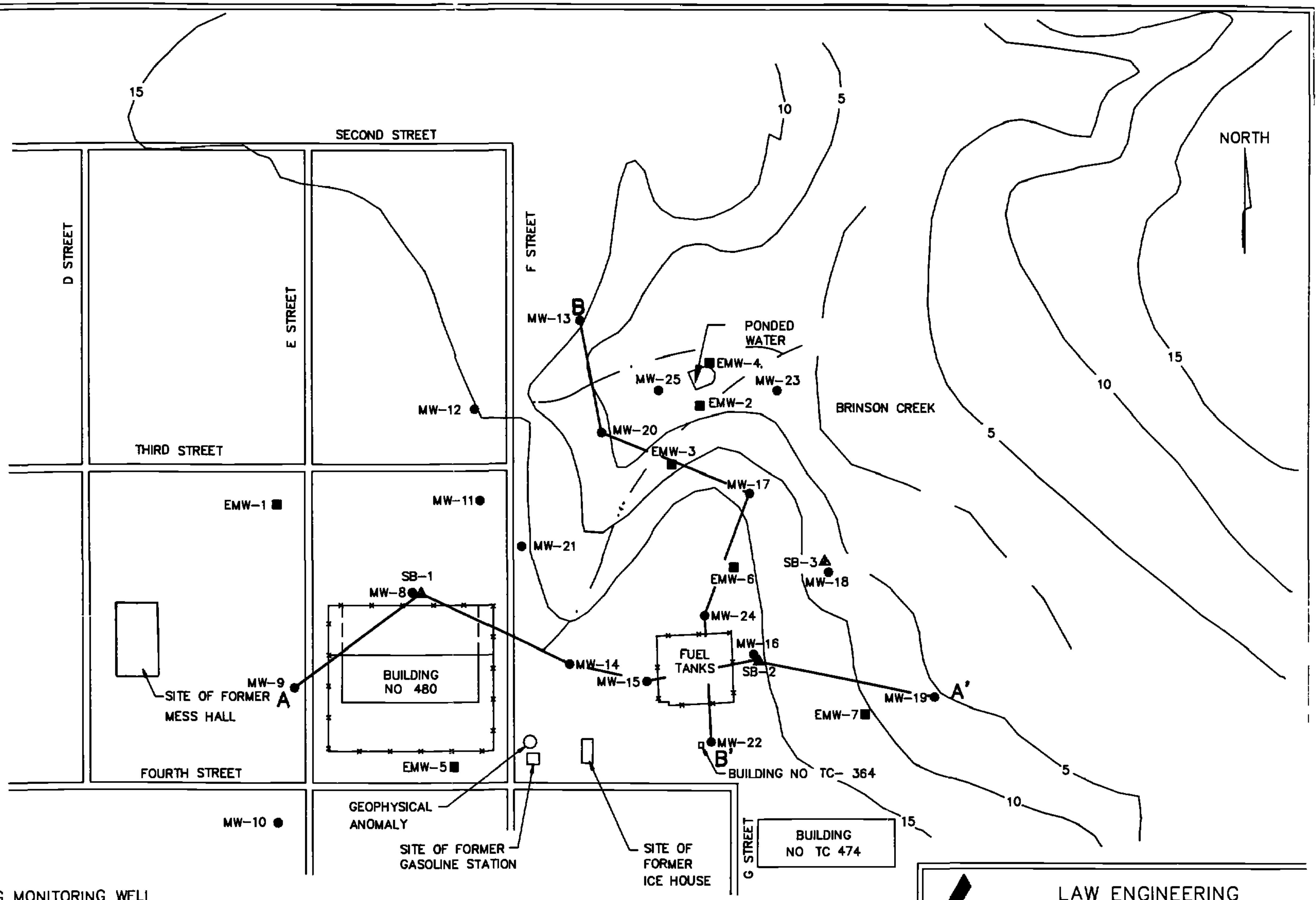
—x—x— FENCE
●MW-1 LOCATION OF LAW ENGINEERING MONITORING WELL
▲SB-1 LOCATION OF STRATIGRAPHIC BORING
⊕B-1 LOCATION OF SOIL BORING
▲HA-1 LOCATION OF HAND-AUGER BORING
— — — TRANSITORY STREAM
—— —— PERENNIAL STREAM

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

LOCATION OF SOIL BORINGS
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN DCC	DATE: NOV. 1991
DFT CHECK: DCC	SCALE 1"=150'
ENG CHECK WDD	JOB J47590-6014
APPROVAL. WDD	DWG. 31

REFERENCE JAMES E STEWART AND ASSOC; SHT 1&2 OF 2, 9/13/91 USGS JACKSONVILLE SOUTH, N C



LEGEND

—×—×— FENCE

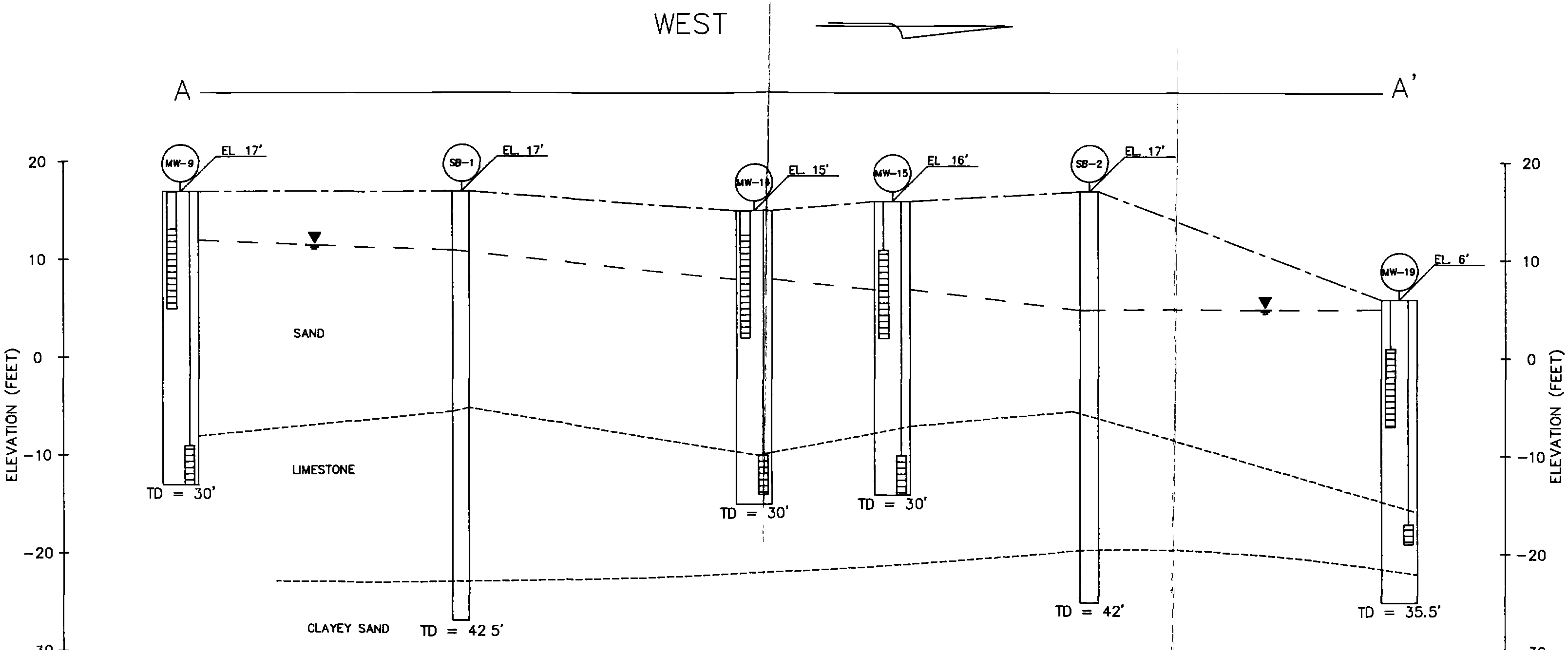
■EMW-1 LOCATION OF PRE-EXISTING MONITORING WELL
●MW-1 LOCATION OF LAW ENGINEERING MONITORING WELL
▲SB-1 LOCATION OF STRATIGRAPHIC BORING
——— LINE OF CROSS SECTION
— — — TRANSITORY STREAM
—— —— PERENNIAL STREAM
—10— TOPOGRAPHIC CONTOUR (FEET ABOVE MSL)

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

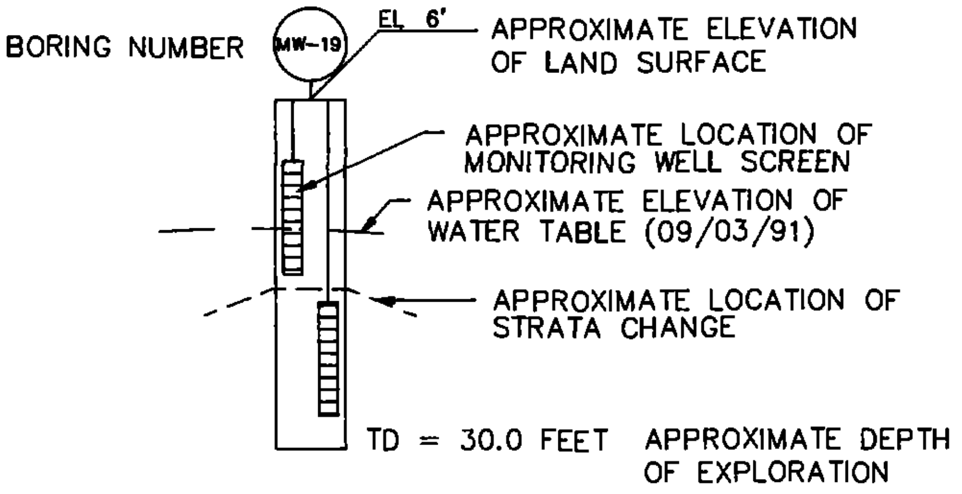
PLAN VIEW OF CROSS SECTIONS
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN. DCC	DATE NOV 1991
DFT CHECK: DCC	SCALE 1"=150'
ENG CHECK:	JOB J47590-6014
APPROVAL:	DWG: 32

REFERENCE JAMES E STEWART AND ASSOC, SHT 1&2 OF 2, 9/13/91 USGS JACKSONVILLE SOUTH, N C



LEGEND



J6014B01

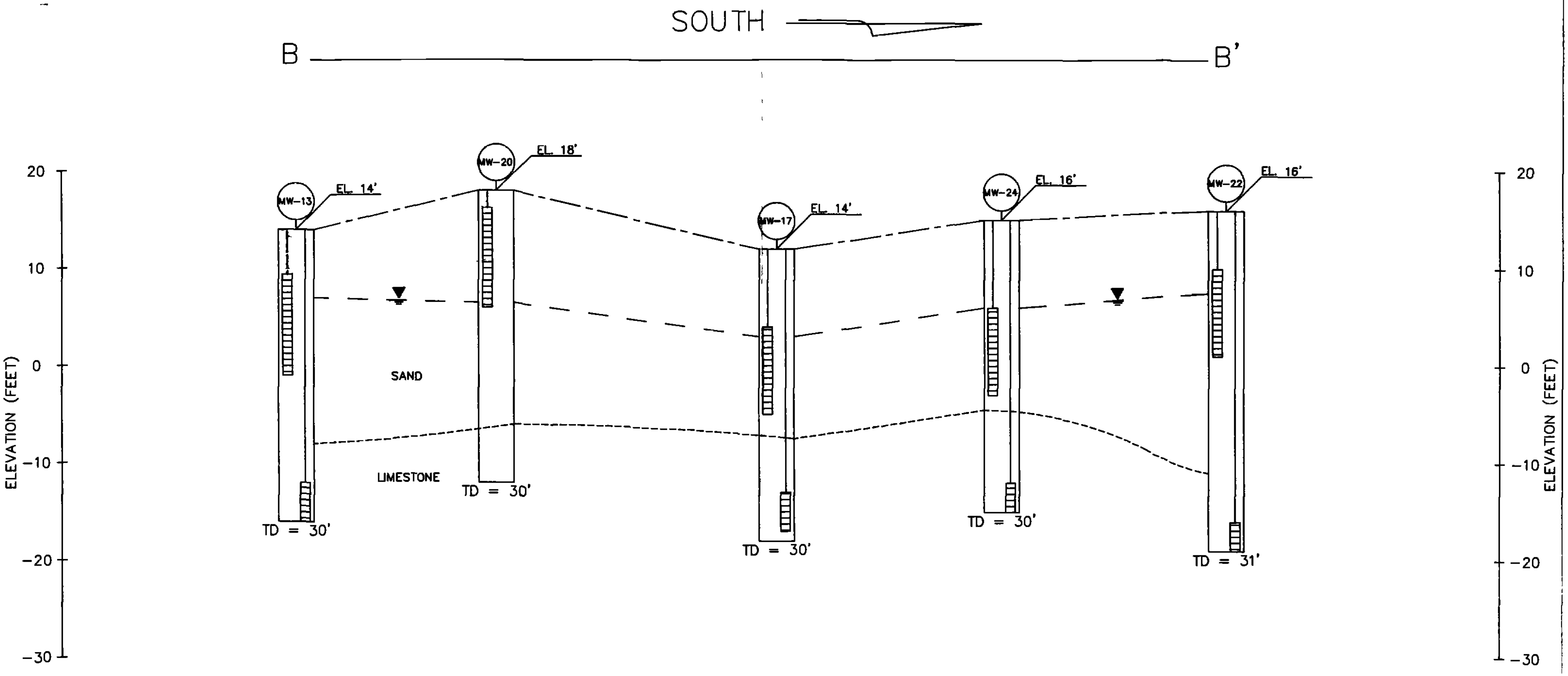
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

CROSS SECTION A–A'
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

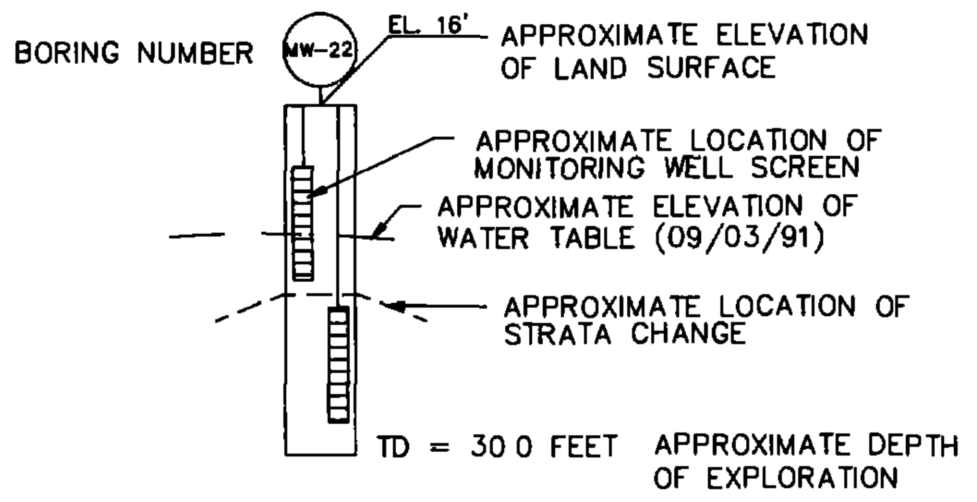
DRAWN: DCG	DATE NOV 1991
DFT CHECK:	SCALE VERT 1"=10' HORIZ 1"=80'
ENG CHECK: WDDixon	JOB J47590-6014
APPROVAL: WDDixon	DWG. 3 3

REFERENCE. FIELD NOTES

01985F10Z



LEGEND



J6014B02

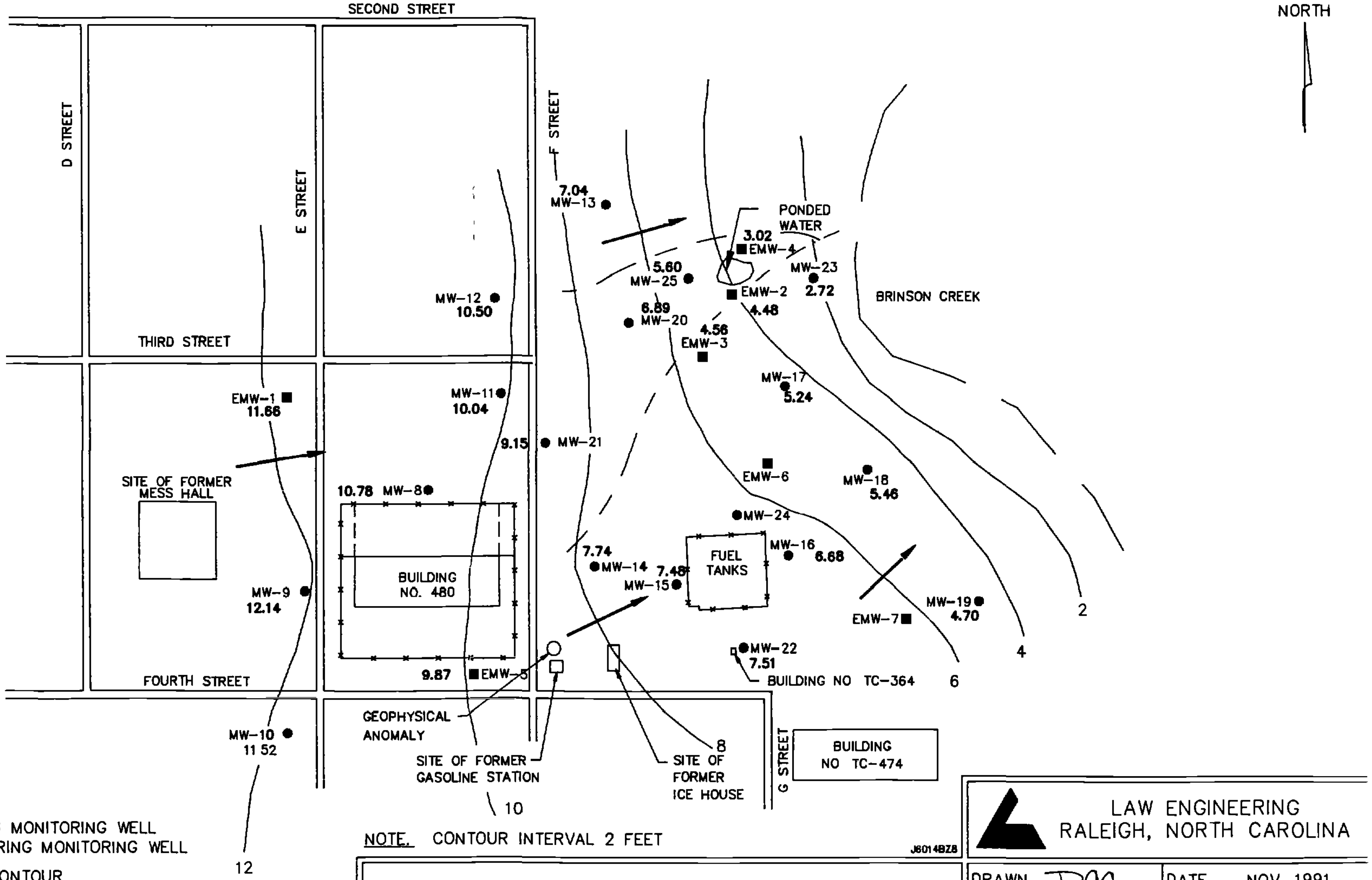
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

CROSS SECTION B-B'
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN DCC	DATE NOV 1991
DFT CHECK· DCC	SCALE. VERT 1"=10' HORIZ 1"=80'
ENG CHECK WAD	JOB J47590-6014
APPROVAL. WAD	DWG: 3.4

REFERENCE FIELD NOTES

01985F112



NOTE. CONTOUR INTERVAL 2 FEET

J6014BZ8

LEGEND

—×—×—	FENCE
■EMW-1	LOCATION OF PRE-EXISTING MONITORING WELL
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
10	ESTIMATED WATER TABLE CONTOUR
5.60	GROUND WATER ELEVATION IN FEET
——→	DIRECTION OF GROUND WATER FLOW
— — —	TRANSITORY STREAM
— —	PERENNIAL STREAM

NOTE: ELEVATIONS OF EMW-6,7,AND 24 NOT USED

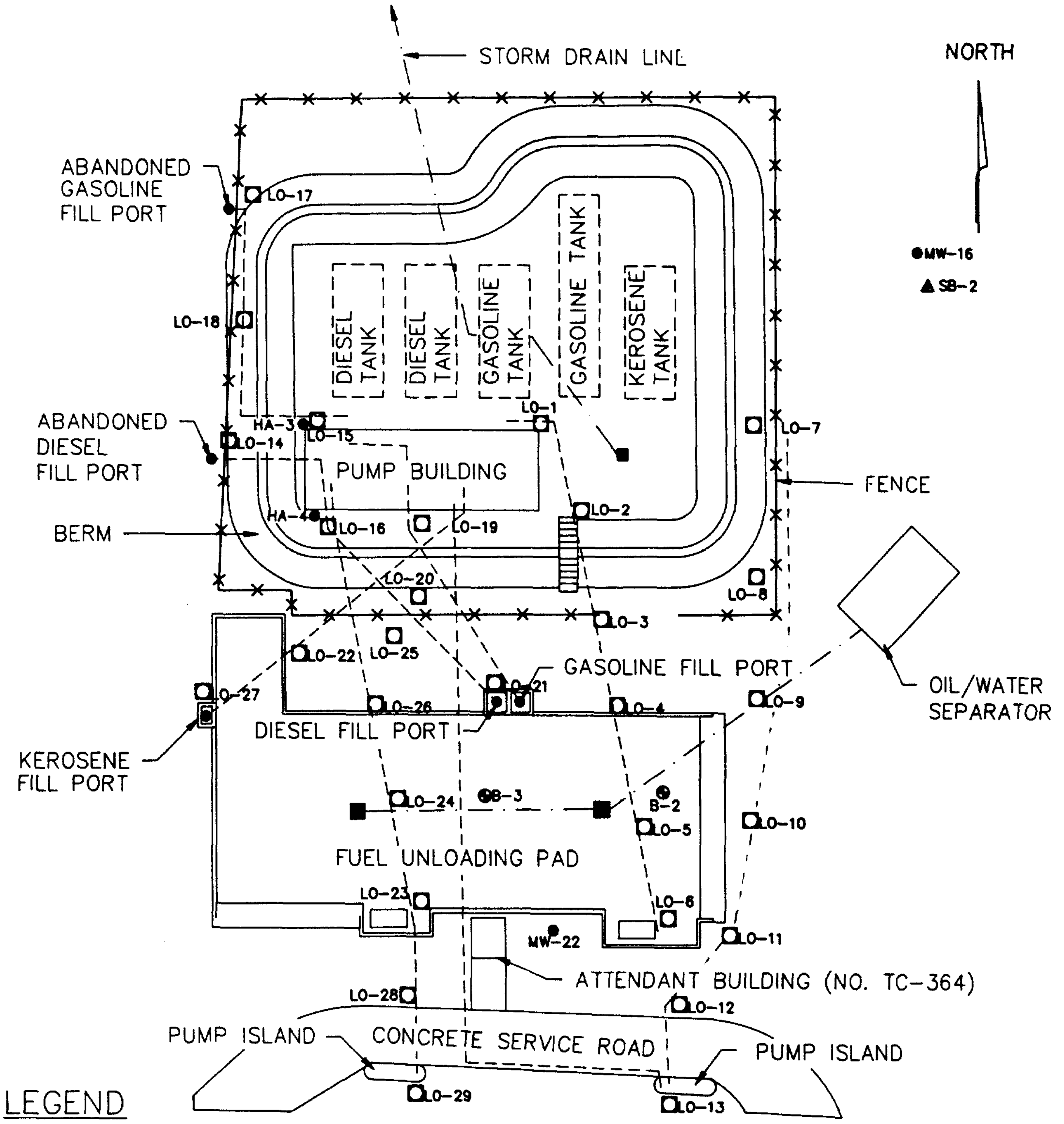
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

WATER-TABLE CONTOUR MAP
SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN DAM	DATE NOV 1991
DFT CHECK:	SCALE. 1"=150'
ENG CHECK. WDDixon	JOB J47590-6014
APPROVAL WDDixon	DWG 35

REFERENCE JAMES E. STEWART AND ASSOC, SHT 1&2 OF 2; 9/13/91

01985F12Z



LEGEND

■	GRATES
◻LO-29	LOCATION OF SOIL-GAS PROBE
▲SB-2	LOCATION OF STRATIGRAPHIC BORING
●MW-16	LOCATION OF MONITORING WELL
⊕B-2	LOCATION OF SOIL BORING
●HA-3	LOCATION OF HAND AUGER BORING
--------	LOCATION OF UNDERGROUND FUEL LINES

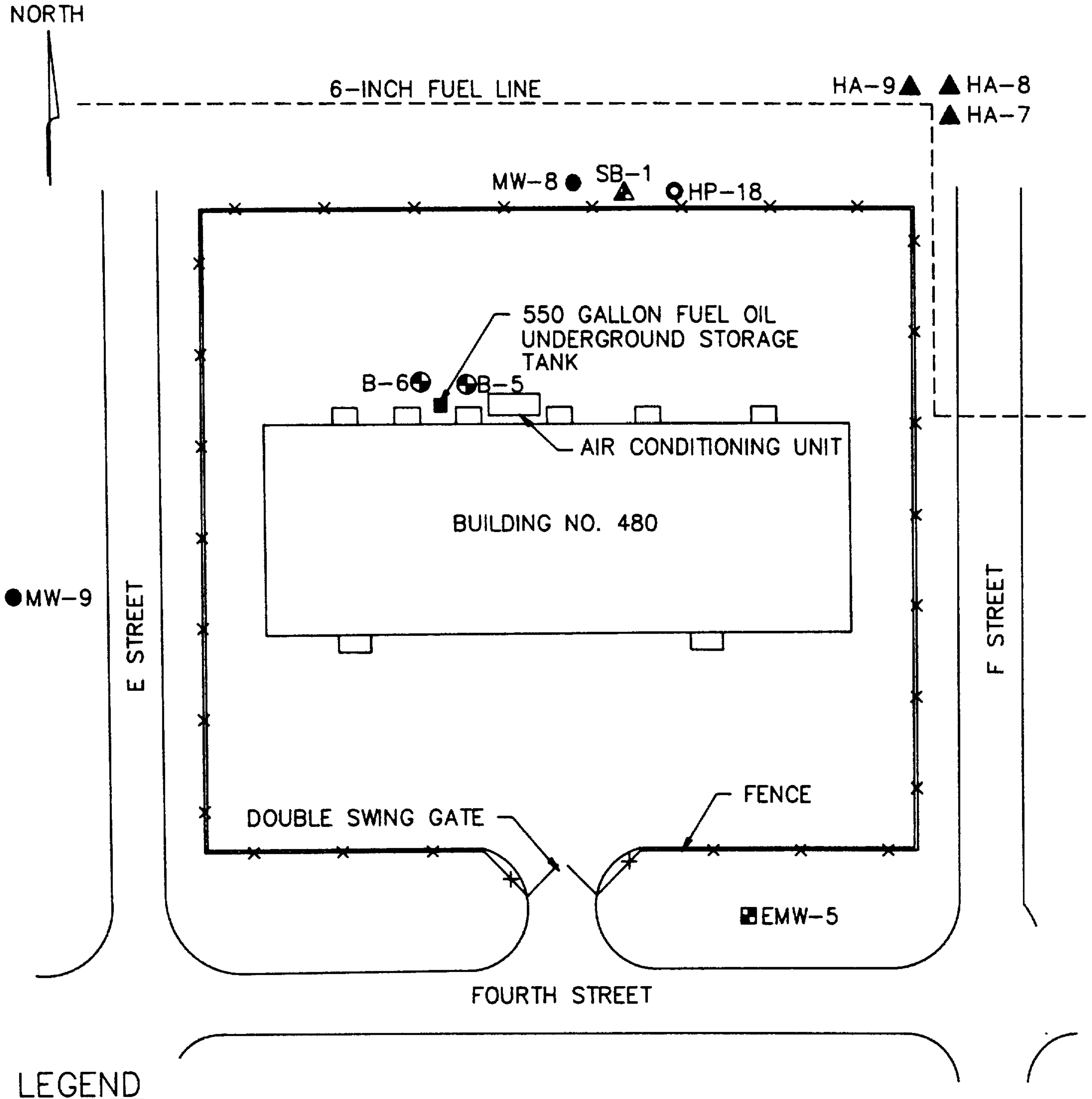
J6014BZ6 1:3

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

LOCATION OF SOIL-GAS PROBES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE: NOV. 1991
DFT CHECK:	SCALE: 1"=30'
ENG CHECK: WDDixon	JOB: J47590-6014
APPROVAL: WDDixon	DWG: 4.1

REFERENCE: NAVFAC DWG. NO. 4174383; TRACER RES. CORP. REPORT NO. 2-91-425T.



LEGEND

▣ EMW-5	LOCATION OF PRE-EXISTING MONITORING WELL
● MW-8	LOCATION OF MONITORING WELL
▲ SB-1	LOCATION OF STRATIGRAPHIC BORING
⊕ B-5	LOCATION OF SOIL BORING
▲ HA-8	LOCATION OF HAND-AUGER BORING
○ HP-18	LOCATION OF HYDROPUNCH BORING

J6014BZ7 1:5

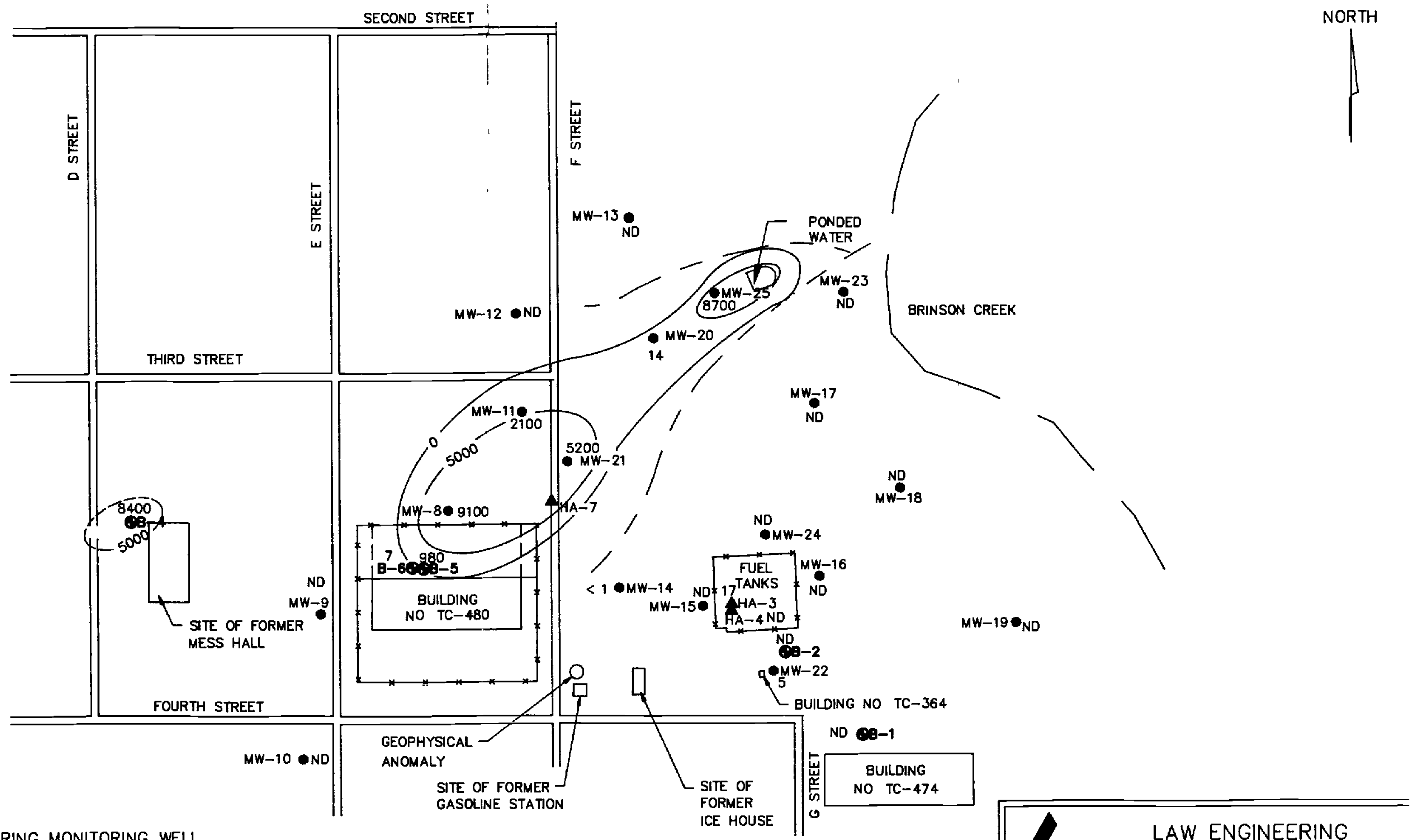
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

BUILDING NO. 480 SITE PLAN
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE: OCT. 1991
DFT CHECK: DCC	SCALE: 1"=50'
ENG CHECK:	JOB: J47590-6014
APPROVAL: WDDixon	DWG: 4.2

REFERENCE: NAVFAC DRAWING NO. 4009116

01985F132



LEGEND

—×—×—	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
SB-1	LOCATION OF SOIL BORING
▲HA-1	LOCATION OF HAND-AUGER BORING
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM
8400	CONCENTRATION OF TPH IN ug/L
ND	NONE DETECTED

NOTE. CONTOUR INTERVAL 5000 ug/L

J6014Z17

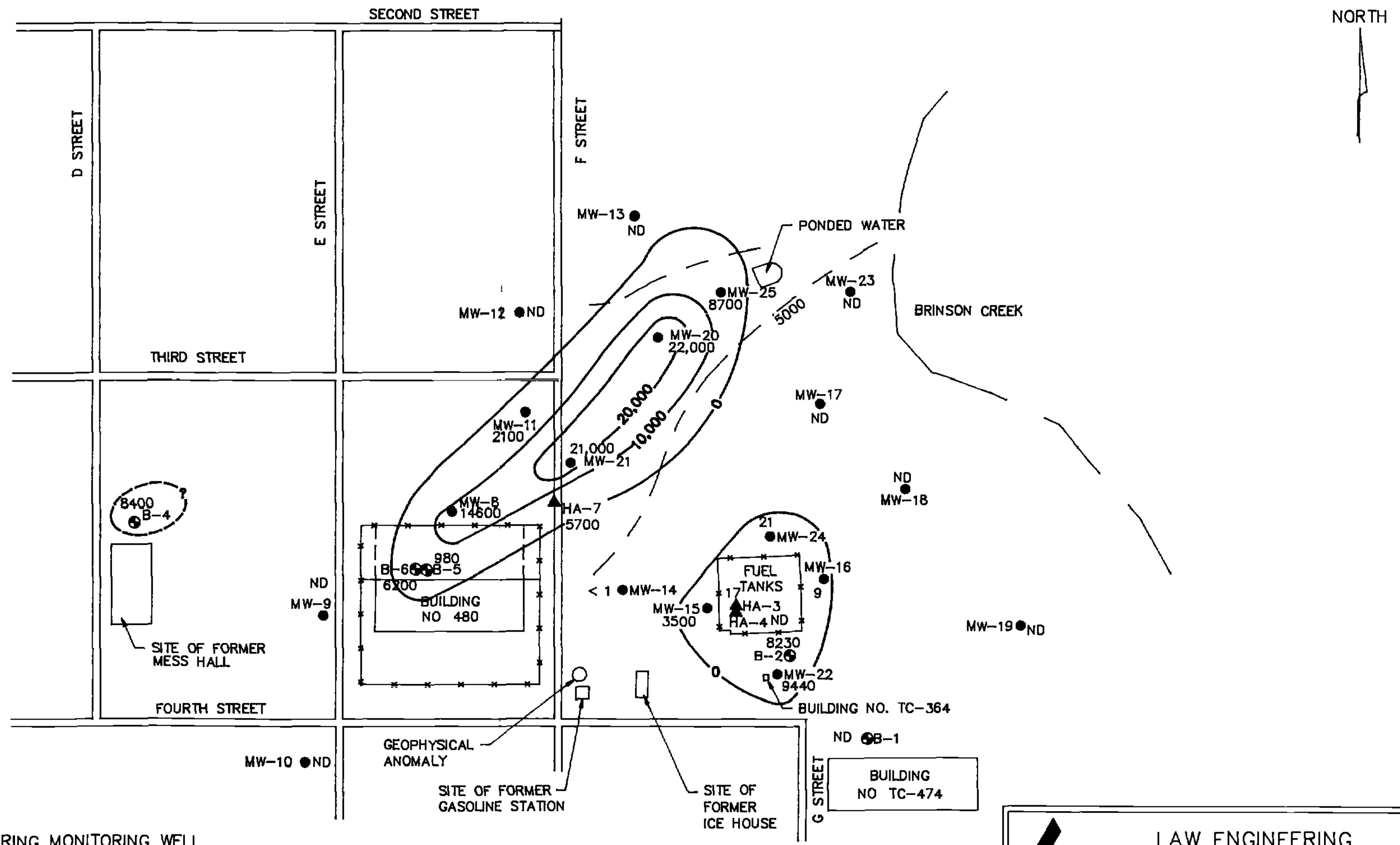
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – TPH CONCENTRATIONS
COMBINED VOLATILES AND SEMI-VOLATILES
SOIL SAMPLES ABOVE THE WATER TABLE
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN DCG	DATE NOV 1991
DFT CHECK	SCALE 1"=150'
ENG CHECK WDD/xw	JOB J47590-6014
APPROVAL WD Dixon	DWG 43

REFERENCE JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91 USGS JACKSONVILLE SOUTH, N C

01985F14Z



LEGEND

—×—×—	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
⊕B-1	LOCATION OF SOIL BORING
▲HA-1	LOCATION OF HAND-AUGER BORING
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM
8400	CONCENTRATION OF TPH IN mg/kg
ND	NONE DETECTED

CONTOUR INTERVAL 10,000 mg/kg

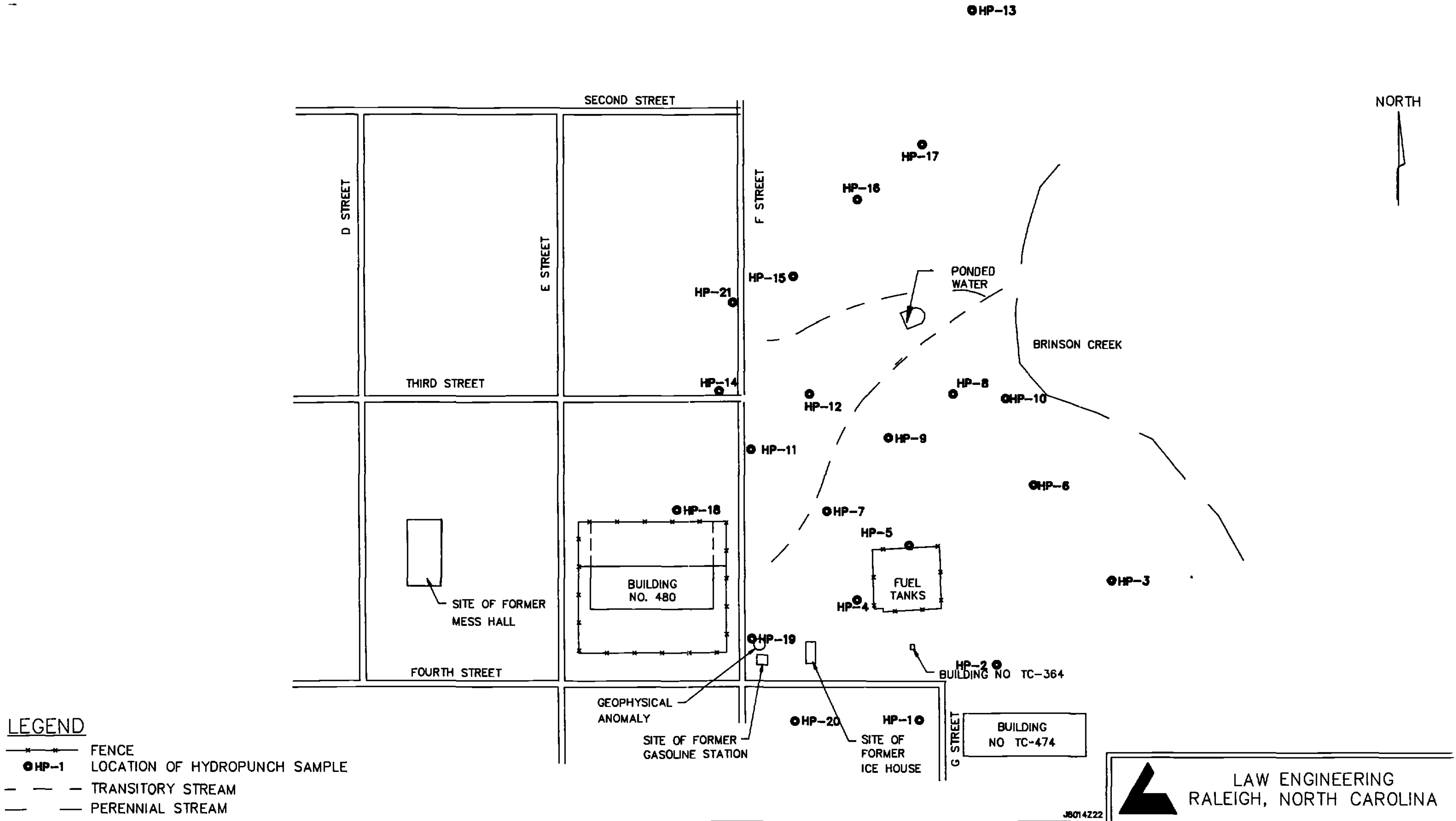
J6014809

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – TPH CONCENTRATIONS
COMBINED VOLATILES AND SEMI-VOLATILES
SOIL SAMPLES WITH HIGHEST TPH CONCENTRATIONS
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE FEB 1992
DFT CHECK. SSL	SCALE 1"=150'
ENG CHECK: DALOW	JOB J47590-6014
APPROVAL. WDDixon	DWG 4.3.1

REFERENCE JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91 USGS JACKSONVILLE SOUTH, N.C



LAW ENGINEERING
RALEIGH, NORTH CAROLINA

LOCATION OF HYDROPUNCH GROUND-WATER SAMPLES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN DCC	DATE: NOV. 1991
DFT CHECK: DCC	SCALE: 1"=150'
ENG CHECK: WDDixon	JOB J47590-6014
APPROVAL: WDDixon	DWG 4 4

REFERENCE JAMES E STEWART AND ASSOC, SHT 1&2 OF 2, 9/13/91

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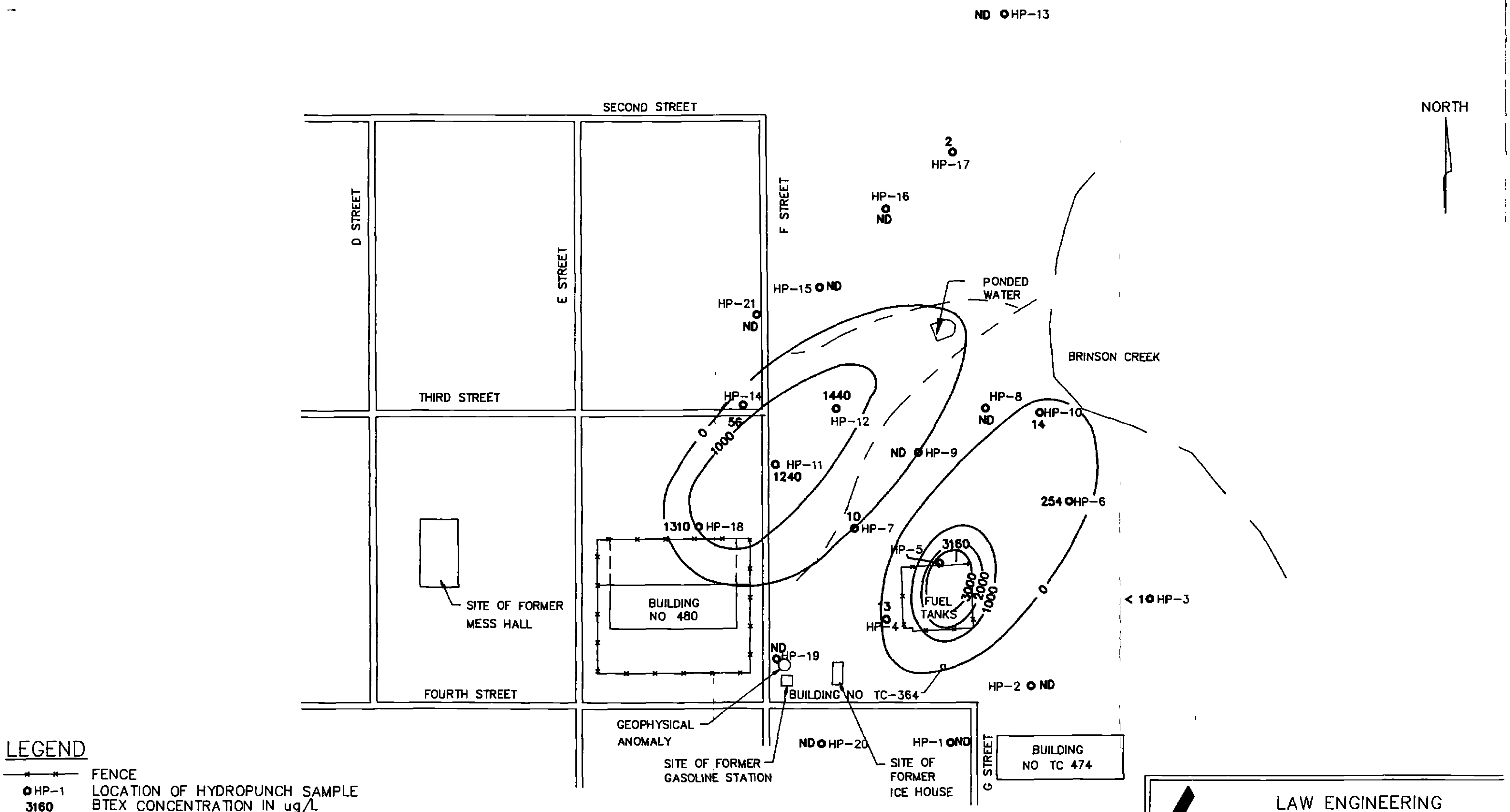

LEGEND

—x—x—	FENCE
○ HP-1	LOCATION OF HYDROPUNCH SAMPLE
3160	BTEX CONCENTRATION IN ug/L
ND	NONE DETECTED
— —— —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

NOTE. CONTOUR INTERVAL 1000 ug/L

J6014BZ0

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP
COMBINED BTEX CONCENTRATIONS
HYDROPUNCH GROUND-WATER SAMPLES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN. DCC	DATE OCT 1991
DFT CHECK	SCALE 1"=150'
ENG CHECK WDD	JOB J47590-6014
APPROVAL WDDixon	DWG 45

REFERENCE JAMES E. STEWART AND ASSOC, SHT 1&2 OF 2, 9/13/91

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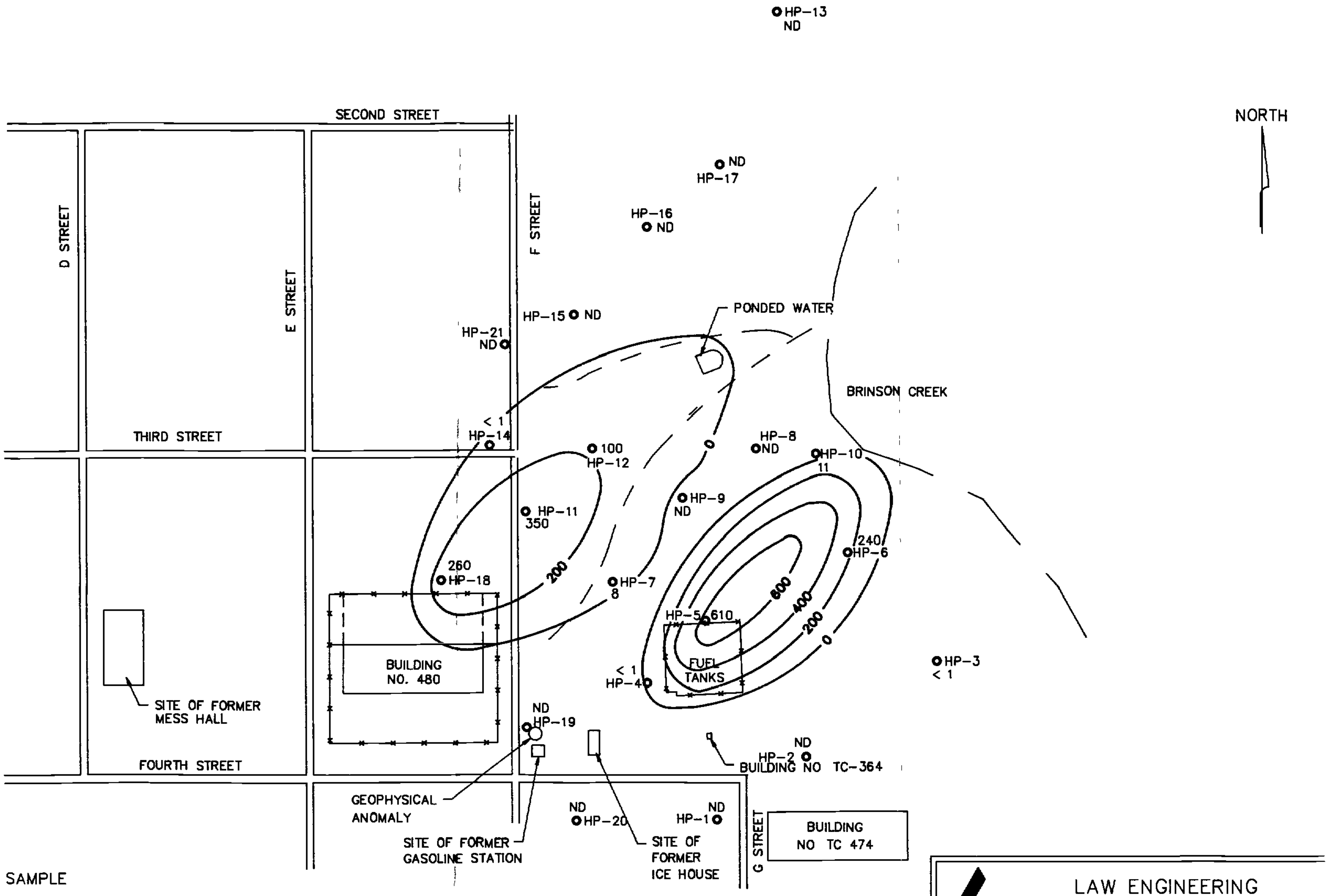

LEGEND

—×—×—	FENCE
○HP-1	LOCATION OF HYDROPUNCH SAMPLE
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM
8905	BENZENE CONCENTRATION IN ug/L
ND	NONE DETECTED

CONTOUR INTERVAL = 200 ug/L

J6014B10

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – BENZENE CONCENTRATIONS
HYDROPUNCH GROUND-WATER SAMPLES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN:	DATE NOV. 1991
DFT CHECK CCC	SCALE 1"=150'
ENG CHECK RAK	JOB J47590-6014
APPROVAL: WDDixon	DWG 4.5 1

REFERENCE. JAMES E STEWART AND ASSOC., SHT 1&2, 9/13/91

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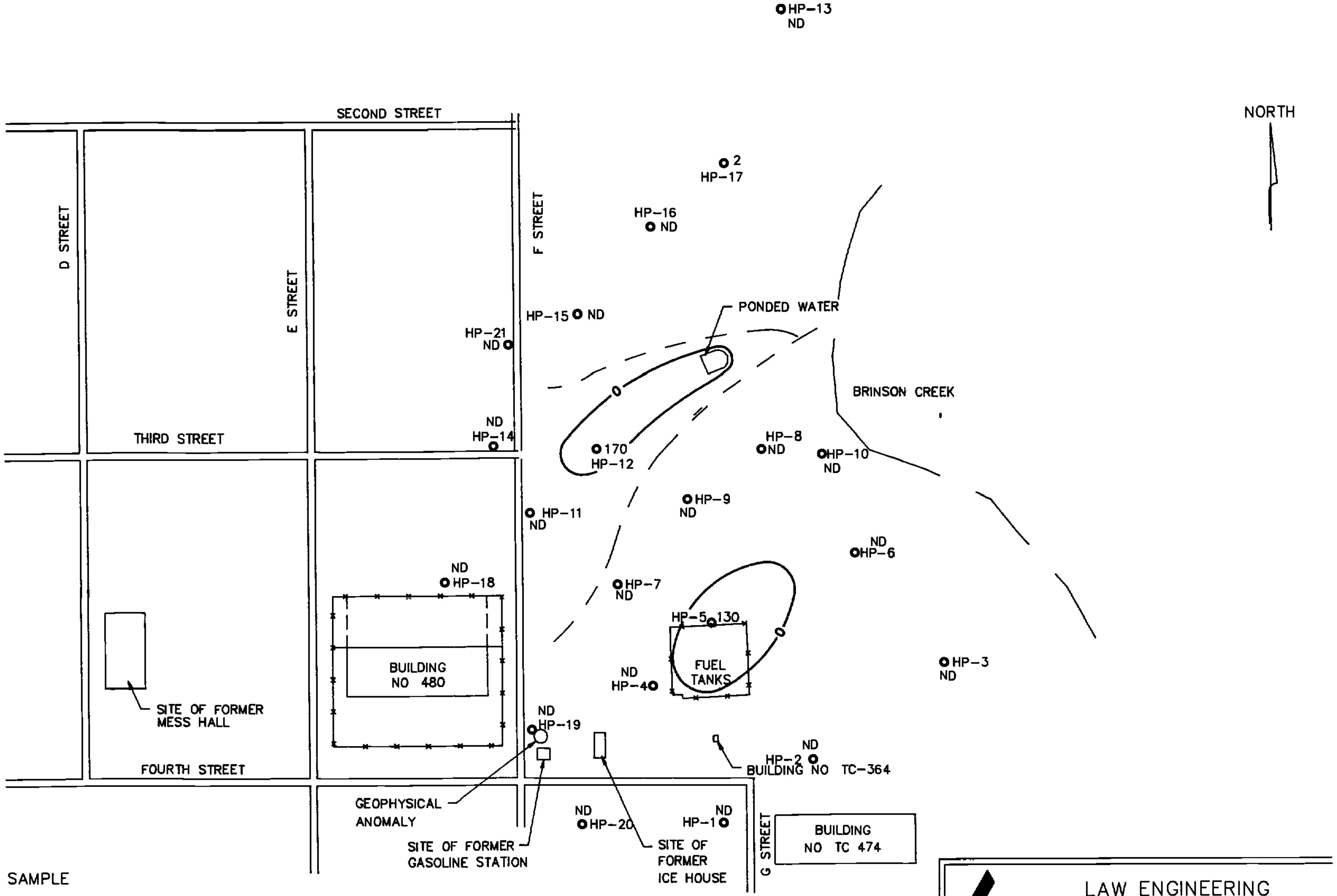

LEGEND

―x―x―	FENCE
○HP-1	LOCATION OF HYDROPUNCH SAMPLE
– — –	TRANSITORY STREAM
——	PERENNIAL STREAM
8905	TOLUENE CONCENTRATION IN ug/L
ND	NONE DETECTED

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – TOLUENE CONCENTRATIONS
HYDROPUNCH GROUND-WATER SAMPLES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN:	DATE NOV 1991
DFT CHECK. CCC	SCALE 1"=150'
ENG CHECK:	JOB: J47590-6014
APPROVAL WDD,W	DWG. 452

REFERENCE JAMES E STEWART AND ASSOC, SHT 1&2, 9/13/91

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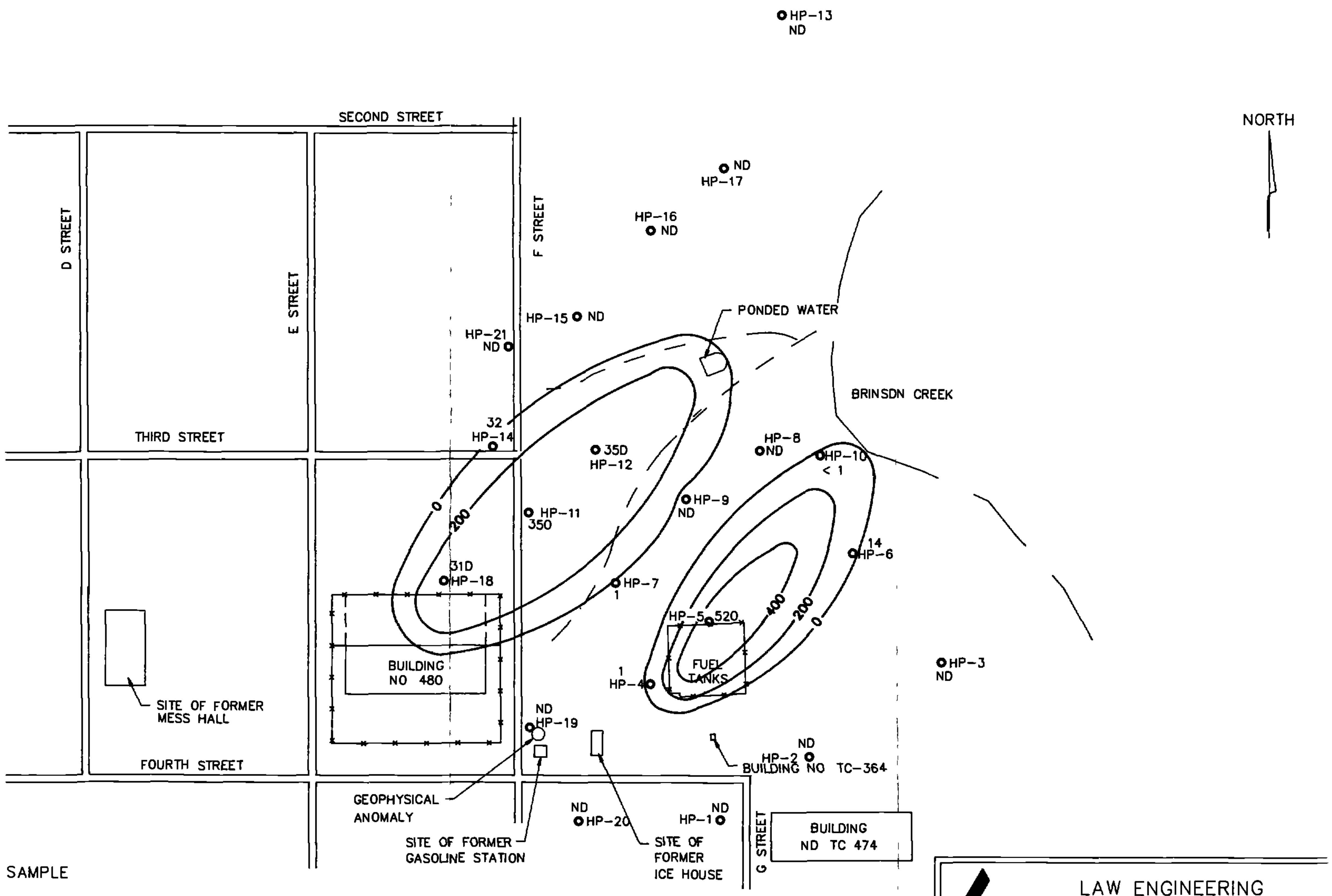

LEGEND

—×—×—	FENCE
○HP-1	LOCATION OF HYDROPUNCH SAMPLE
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM
8905	ETHYLBENZENE CONCENTRATION IN ug/L
ND	NONE DETECTED

CONTOUR INTERVAL = 200 ug/L

J6014B11

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – ETHYLBENZENE CONCENTRATIONS
HYDROPUNCH GROUND-WATER SAMPLES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN	DATE NOV 1991
DFT CHECK CCC	SCALE 1"=150'
ENG CHECK.	JOB J47590-6014
APPROVAL.	DWG 4 5 3

REFERENCE JAMES E STEWART AND ASSOC, SHT 1&2, 9/13/91

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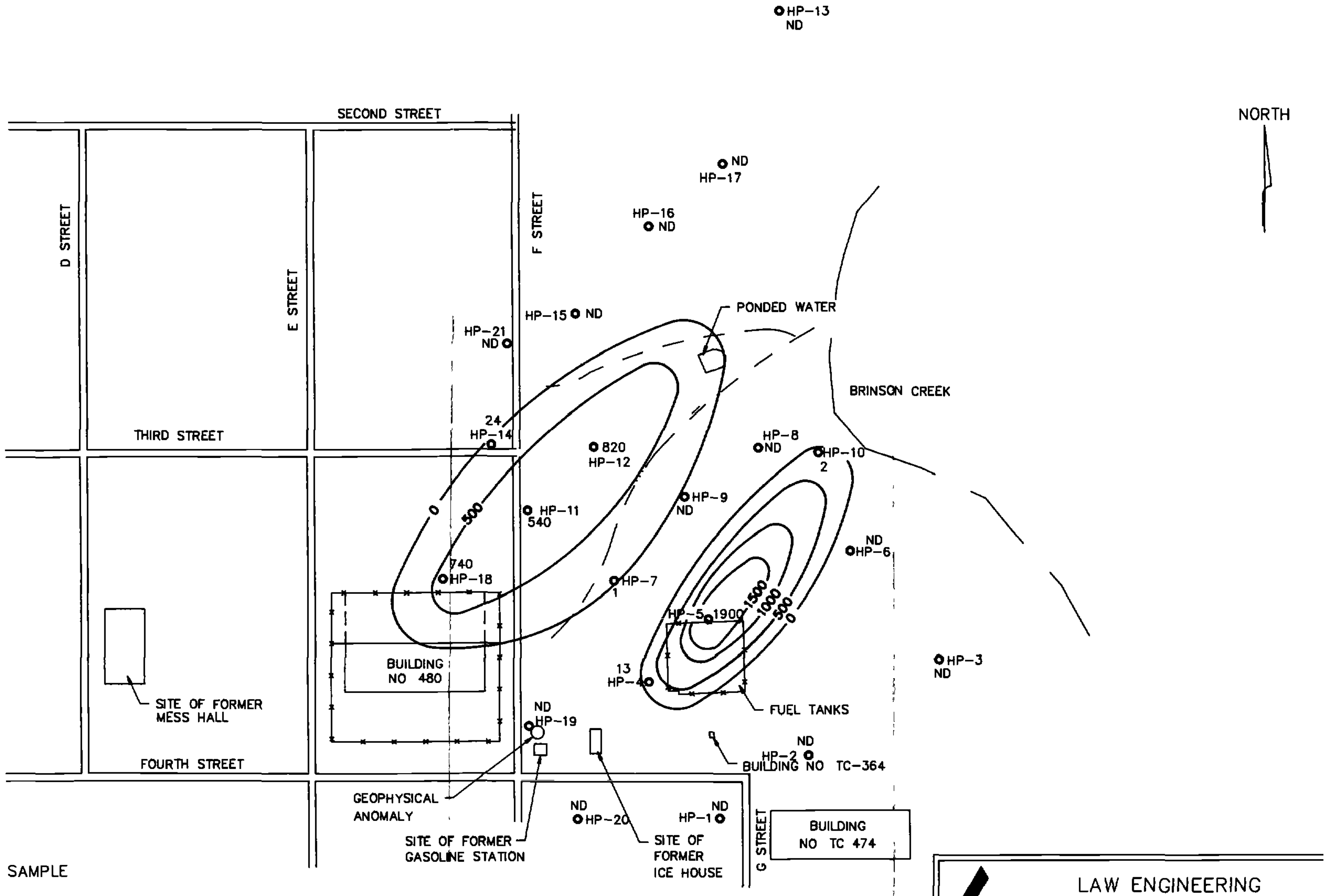

LEGEND

—×—×—	FENCE
○ HP-1	LOCATION OF HYDROPUNCH SAMPLE
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM
8905	XYLENES CONCENTRATION IN ug/L
ND	NONE DETECTED

CONTOUR INTERVAL = 500 ug/L

ISOPLETH MAP – TOTAL XYLENES CONCENTRATIONS
HYDROPUNCH GROUND-WATER SAMPLES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

REFERENCE JAMES E STEWART AND ASSOC, SHT 1&2, 9/13/91

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

DRAWN	DATE. NOV. 1991
DFT CHECK· ccc	SCALE 1"=150'
ENG CHECK· Pbc	JOB J47590-6014
APPROVAL: WD Dixon	DWG. 4 5.4

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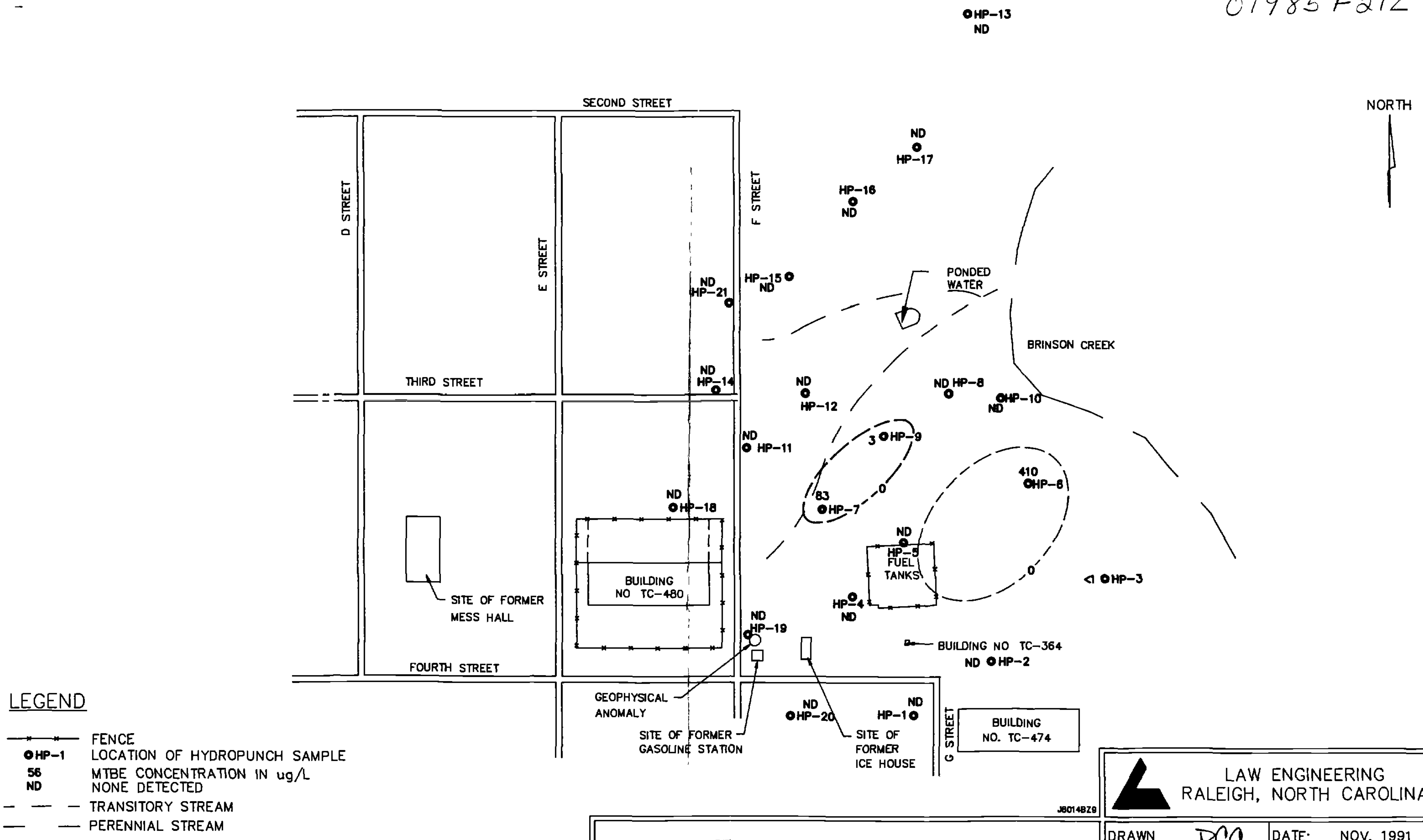

LEGEND

—×—×—	FENCE
● HP-1	LOCATION OF HYDROPUNCH SAMPLE
56	MTBE CONCENTRATION IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP - MTBE CONCENTRATIONS
HYDROPUNCH GROUND-WATER SAMPLES
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN	DATE: NOV. 1991
DFT CHECK.	SCALE 1"=150'
ENG CHECK.	JOB J47590-6014
APPROVAL	DWG. 46

REFERENCE. JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91 USGS JACKSONVILLE SOUTH, N.C

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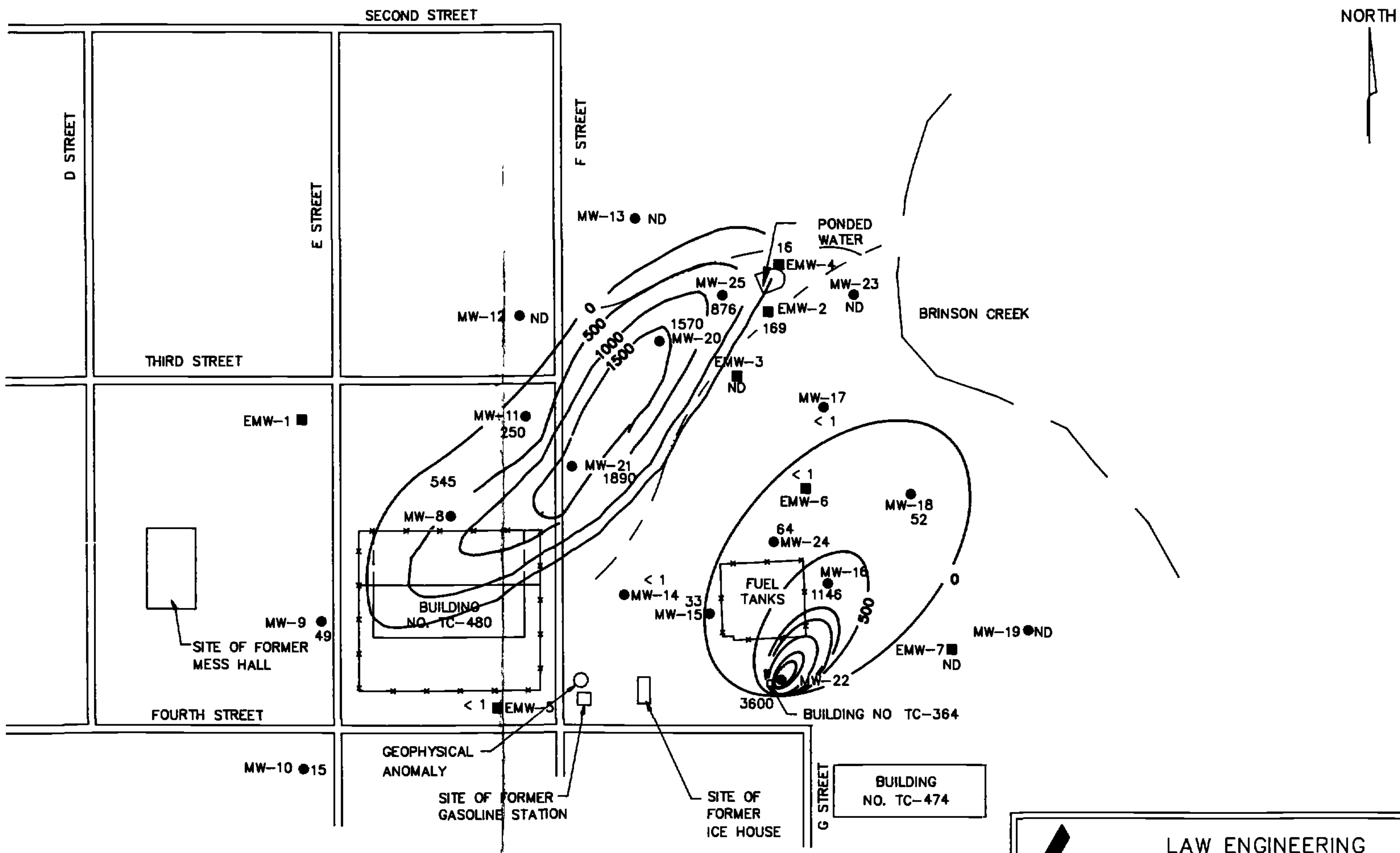


LEGEND

—×—×—	FENCE
■EMW–1	LOCATION OF PRE–EXISTING MONITORING WELL
●MW–1	LOCATION OF LAW ENGINEERING MONITORING WELL
8905	BTEX CONCENTRATION IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

CONTOUR INTERVAL = 500 ug/L

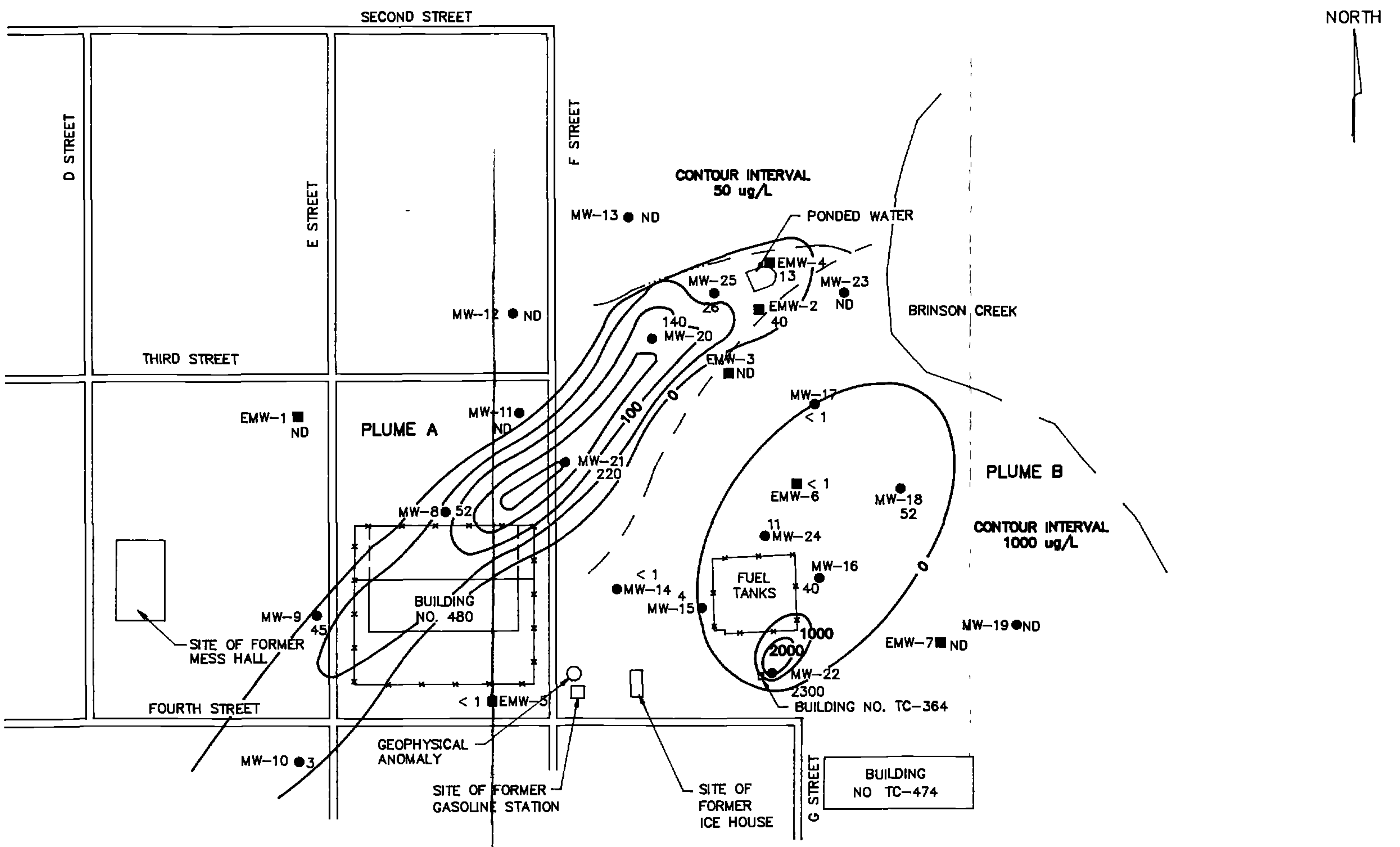
J6019Z19

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – COMBINED BTEX CONCENTRATIONS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN.		DATE:	NOV. 1991
DFT CHECK.		SCALE.	1"=150'
ENG CHECK.	WADixon	JOB·	J47590–6014
APPROVAL	WADixon	DWG·	47

REFERENCE: JAMES E STEWART AND ASSOC, SHT 1&2 OF 2; 9/13/91



LEGEND

—×—×—	FENCE
■EMW-1	LOCATION OF PRE-EXISTING MONITORING WELL
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
8905	BENZENE CONCENTRATION IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

PLUME A CONTOUR INTERVAL 50 ug/L
PLUME B CONTOUR INTERVAL 1000 ug/L

J6014805

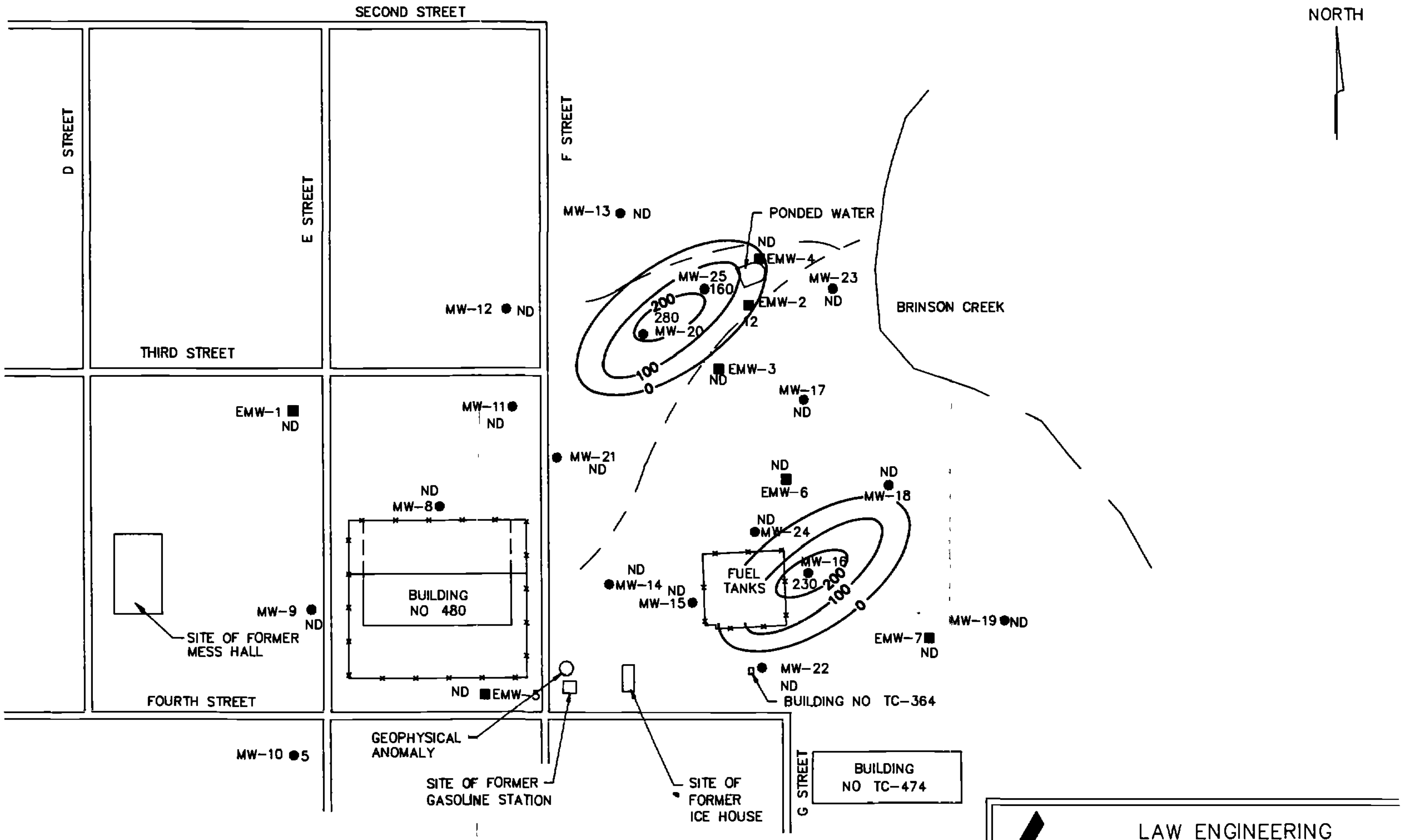
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – BENZENE CONCENTRATIONS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE: FEB 1992
DFT CHECK:	SCALE 1"=150'
ENG CHECK	JOB: J47590-6014
APPROVAL:	DWG. 471

REFERENCE. JAMES E STEWART AND ASSOC, SHT 1&2 OF 2, 9/13/91

01985 F 232



CONTOUR INTERVAL = 100 ug/L

J8014806

LEGEND

—×—×—	FENCE
■EMW-1	LOCATION OF PRE-EXISTING MONITORING WELL
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
8905	TOLUENE CONCENTRATION IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – TOLUENE CONCENTRATIONS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN	DATE. NOV 1991
DFT CHECK· CCC	SCALE. 1"=150'
ENG CHECK	JOB J47590-6014
APPROVAL.	DWG 4.7 2

REFERENCE· JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91

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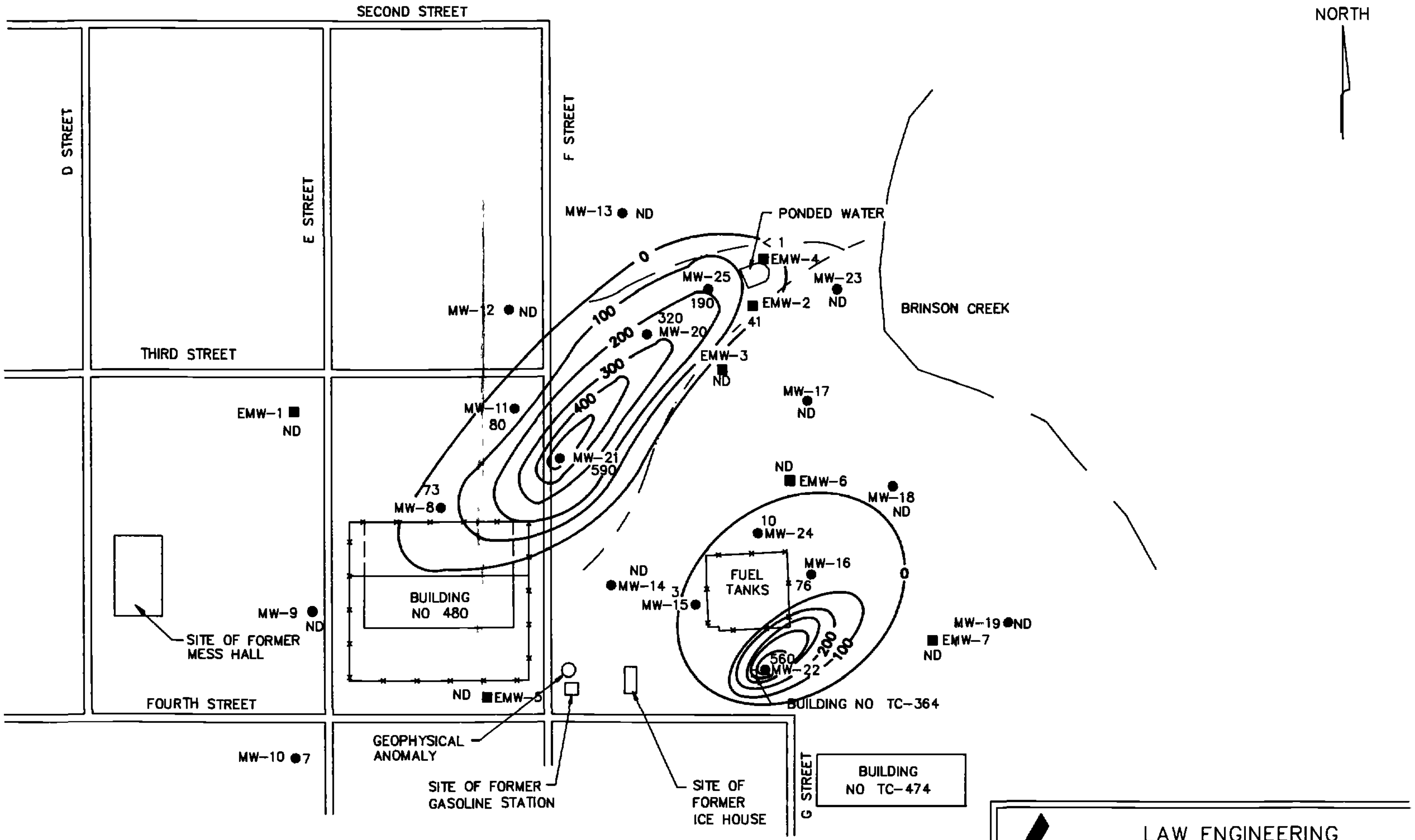

LEGEND

—×—×—	FENCE
■EMW-1	LOCATION OF PRE-EXISTING MONITORING WELL
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
8905	ETHYLBENZENE CONCENTRATION IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

CONTOUR INTERVAL = 100 ug/L

J6014807

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – ETHYLBENZENE CONCENTRATIONS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN	DATE NOV 1991
DFT CHECK CCC	SCALE 1"=150'
ENG CHECK. RAL	JOB J47590-6014
APPROVAL.	DWG 4 7.3

REFERENCE JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91

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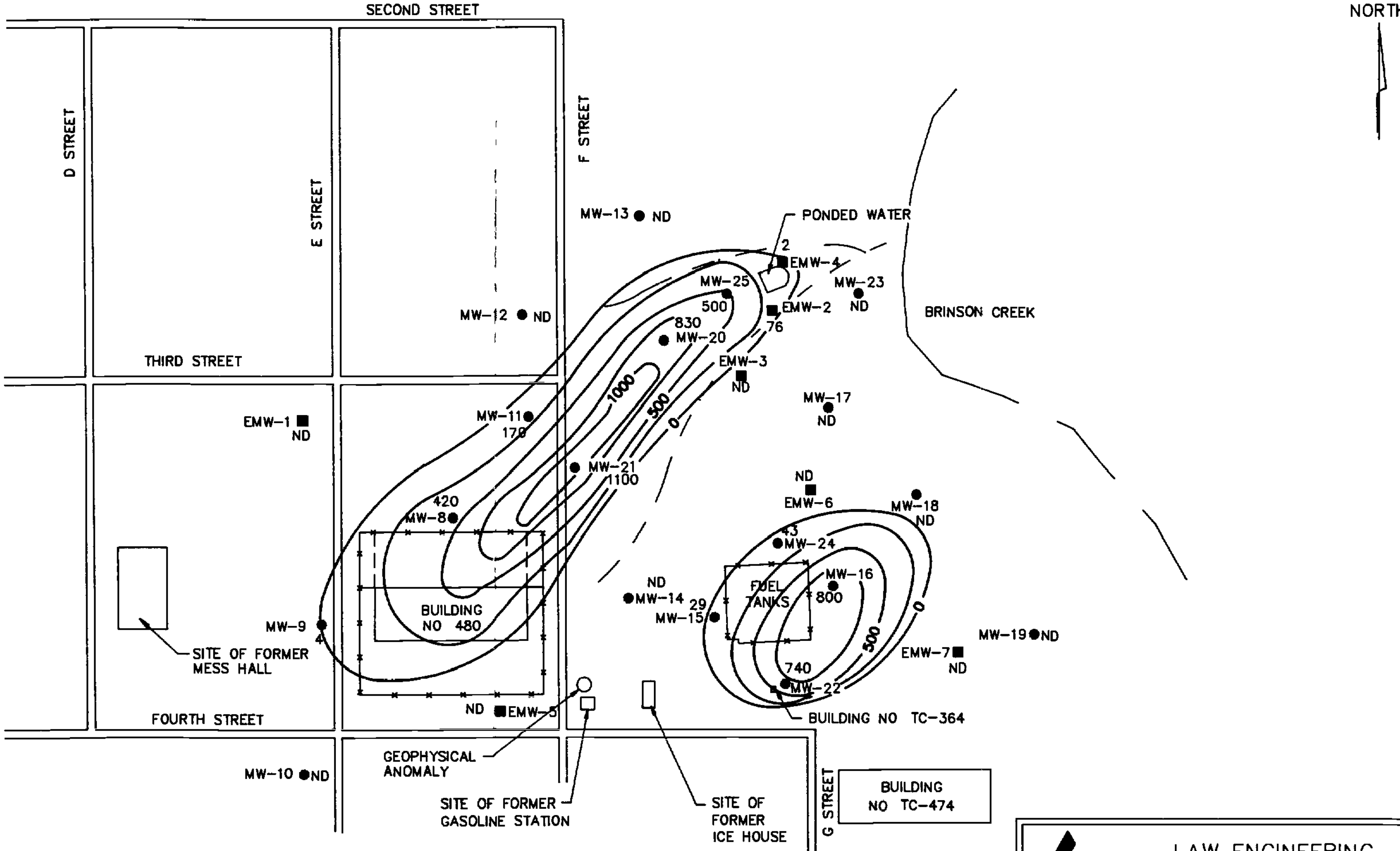

LEGEND

- ─×─×─ FENCE
- ■EMW-1 LOCATION OF PRE-EXISTING MONITORING WELL
- ●MW-1 LOCATION OF LAW ENGINEERING MONITORING WELL
- 8905 XYLENES CONCENTRATION IN ug/L
- ND NONE DETECTED
- — — — TRANSITORY STREAM
- —— —— PERENNIAL STREAM

CONTOUR INTERVAL = 250 ug/L

J6019B06

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP
TOTAL XYLENES CONCENTRATIONS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN	DATE NOV. 1991
DFT CHECK. CCC	SCALE 1"=150'
ENG CHECK: BAK	JOB. J47590-6014
APPROVAL: WADixon	DWG. 474

REFERENCE JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91

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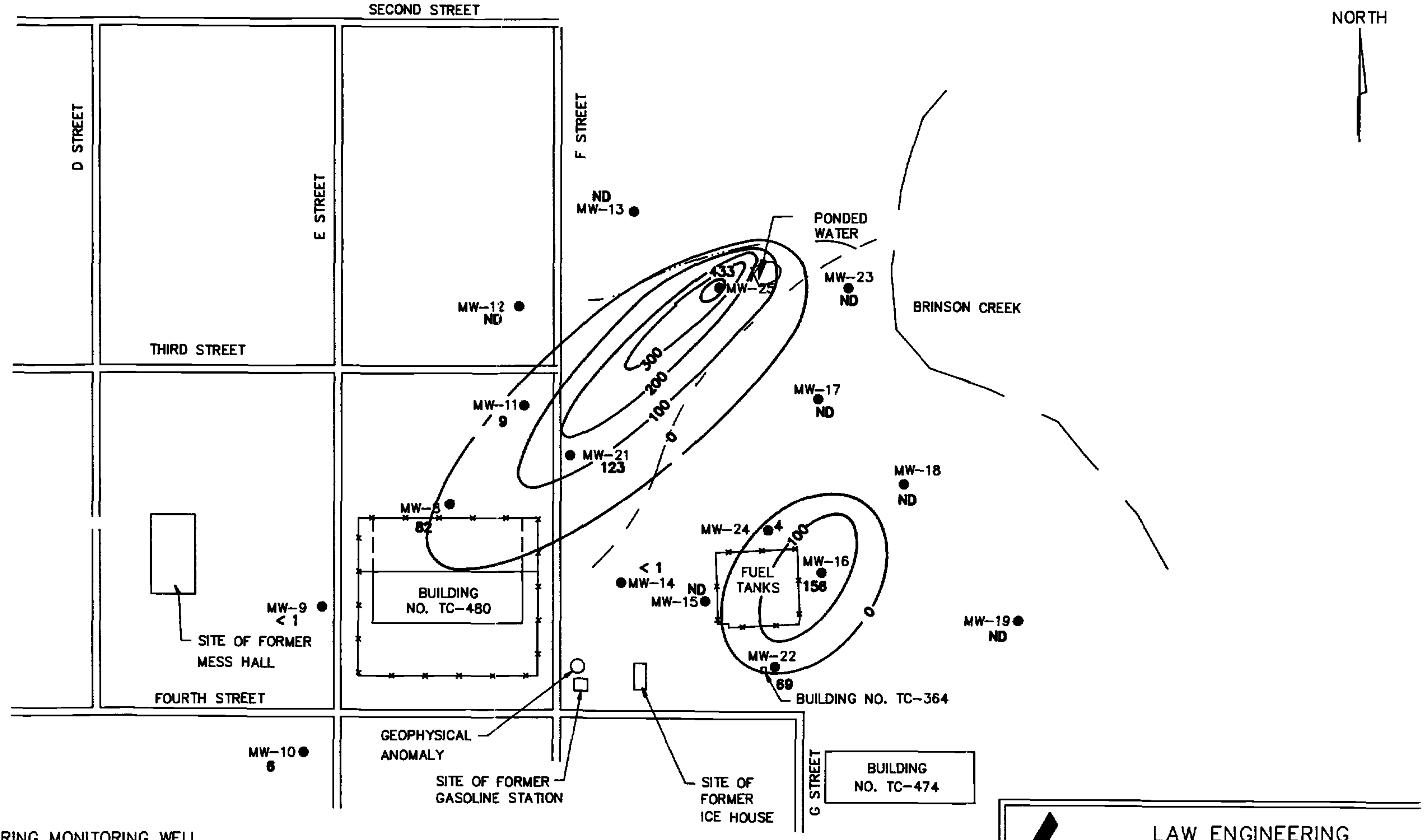

LEGEND

—x—x—	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
123	CONCENTRATION OF BTEX IN ug/L
ND	NONE DETECTED
– — –	TRANSITORY STREAM
— —	PERENNIAL STREAM

NOTE. CONTOUR INTERVAL 100 ug/L.

J8C14Z11

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – COMBINED BTEX CONCENTRATIONS
WATER SAMPLES FROM DEEP SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE· NOV. 1991
DFT CHECK:	SCALE. 1"=150'
ENG CHECK: WDD	JOB J47590-6014
APPROVAL: WDD	DWG 4.8

REFERENCE. JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91 USGS JACKSONVILLE SOUTH, N C

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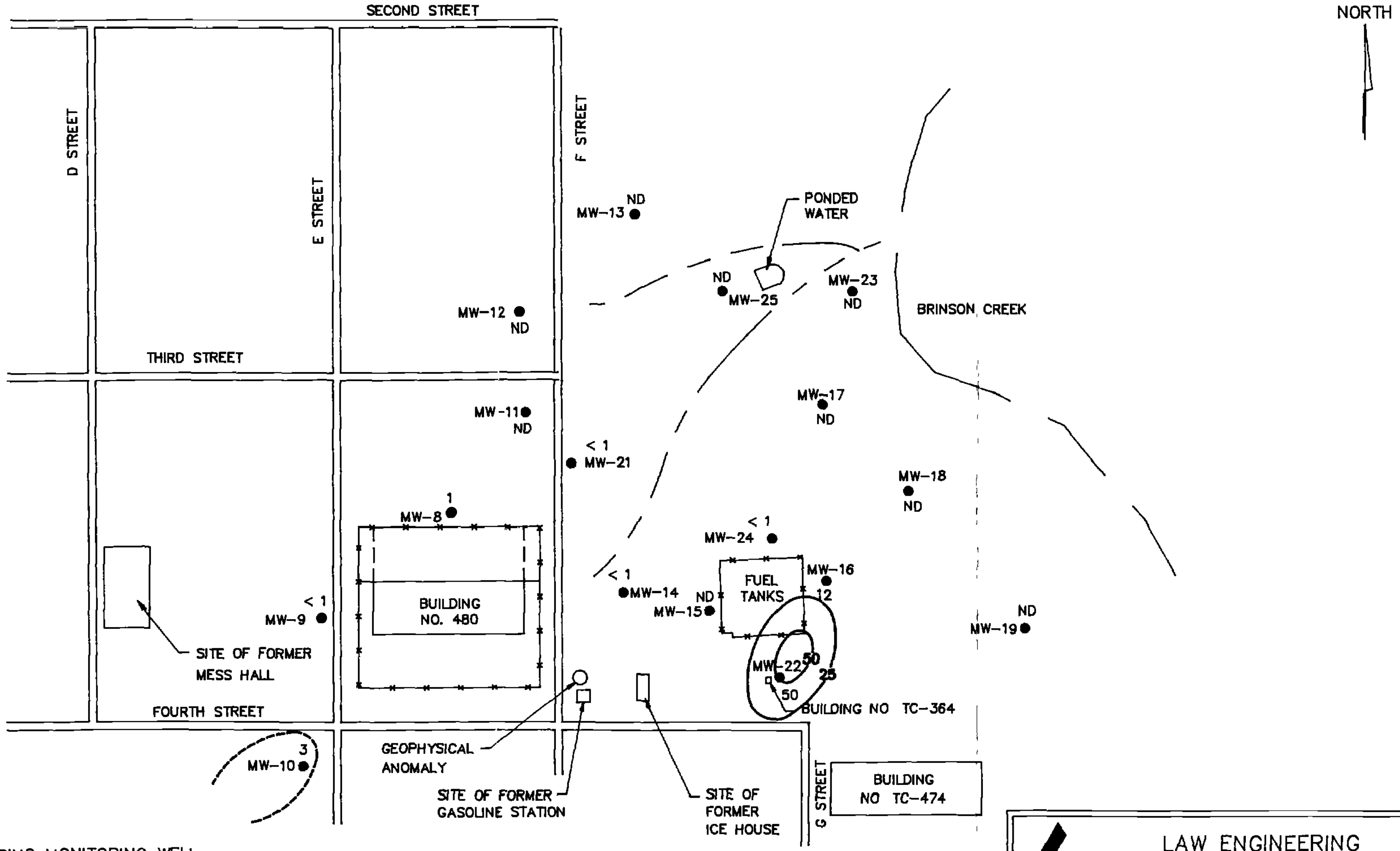

LEGEND

—×—×—	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
123	CONCENTRATION OF BENZENE IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

J6014M01

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – BENZENE CONCENTRATIONS
WATER SAMPLES FROM DEEP SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN. DCG	DATE FEB 1992
DFT CHECK.	SCALE: 1"=150'
ENG CHECK	JOB· J47590-6014
APPROVAL	DWG· 4.8 1

REFERENCE JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91. USGS JACKSONVILLE SOUTH, N.C

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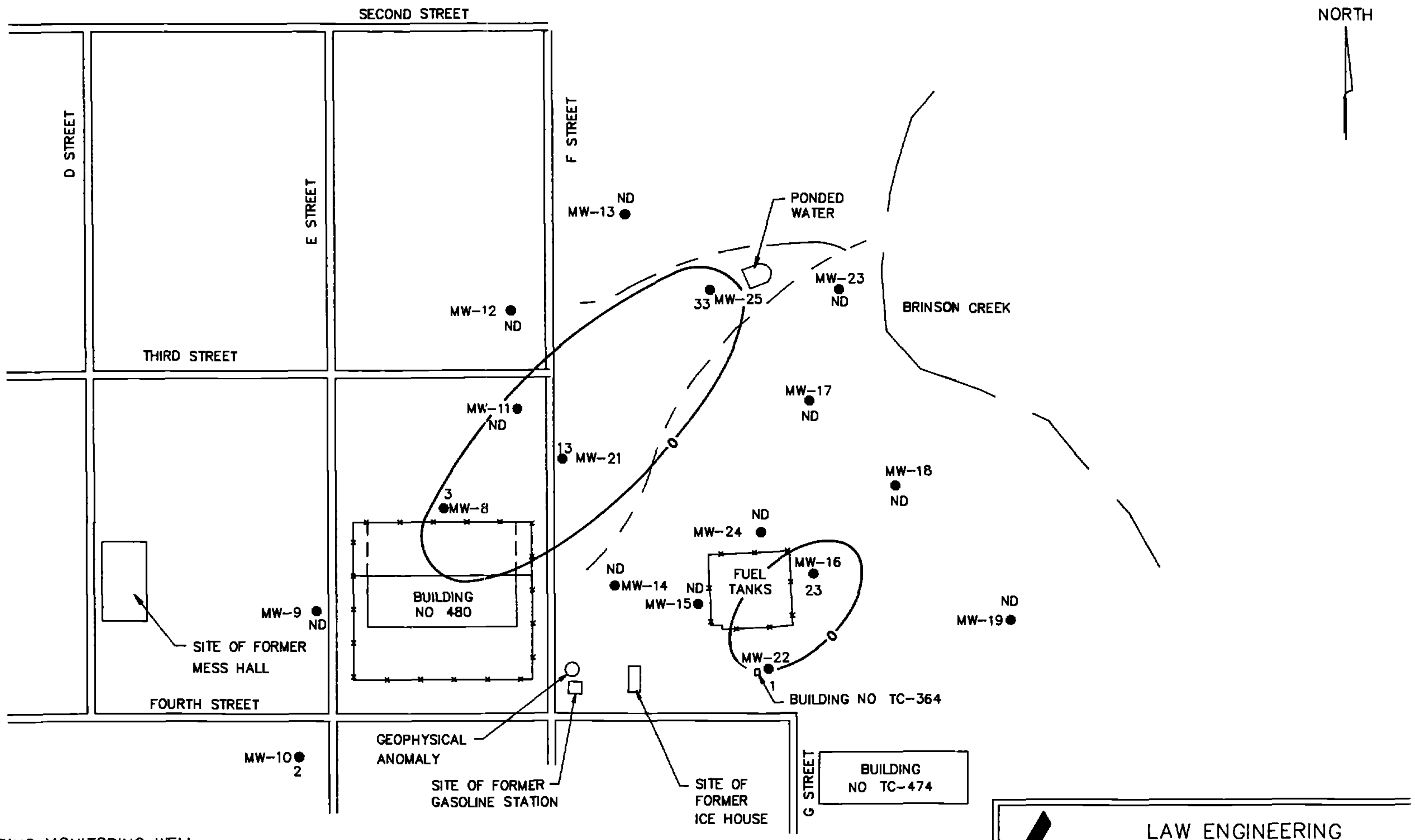

LEGEND

—×—×—	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
123	CONCENTRATION OF TOLUENE IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
— —	PERENNIAL STREAM

J8014M02

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – TOLUENE CONCENTRATIONS
WATER SAMPLES FROM DEEP SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN.	DATE· NOV. 1991
DFT CHECK ECC	SCALE 1"=150'
ENG CHECK RAK	JOB: J47590-6014
APPROVAL WDDixon	DWG 482

REFERENCE JAMES E STEWART AND ASSOC, SHT 1&2 OF 2, 9/13/91. USGS JACKSONVILLE SOUTH, N C

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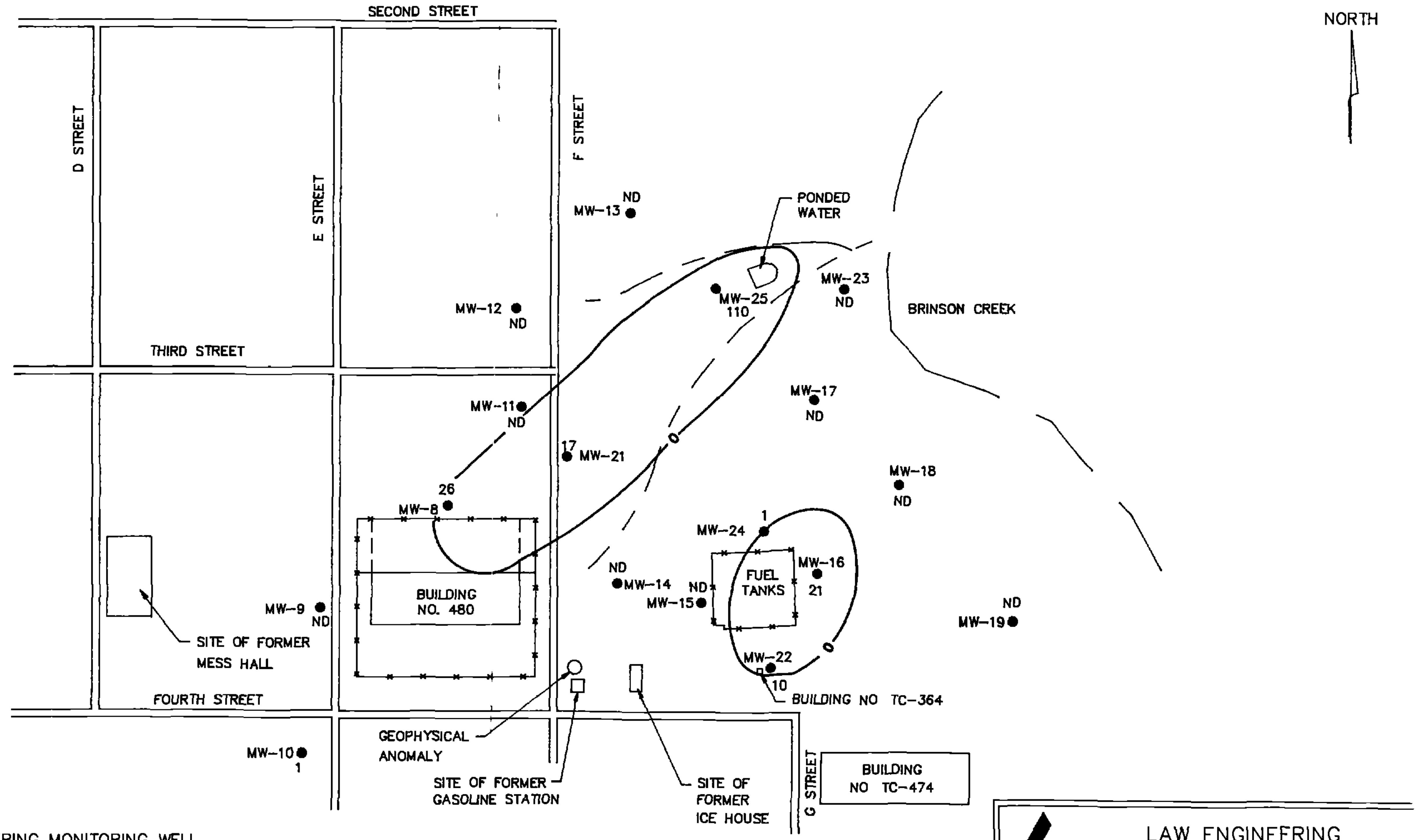

LEGEND

—×—×—	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
123	CONCENTRATION OF ETHYLBENZENE IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – ETHYLBENZENE CONCENTRATIONS
WATER SAMPLES FROM DEEP SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN DCC	DATE: FEB 1992
DFT CHECK:	SCALE: 1"=150'
ENG CHECK:	JOB: J47590-6014
APPROVAL:	DWG 4 8.3

REFERENCE: JAMES E STEWART AND ASSOC., SHT 1&2 OF 2; 9/13/91 USGS JACKSONVILLE SOUTH, N C

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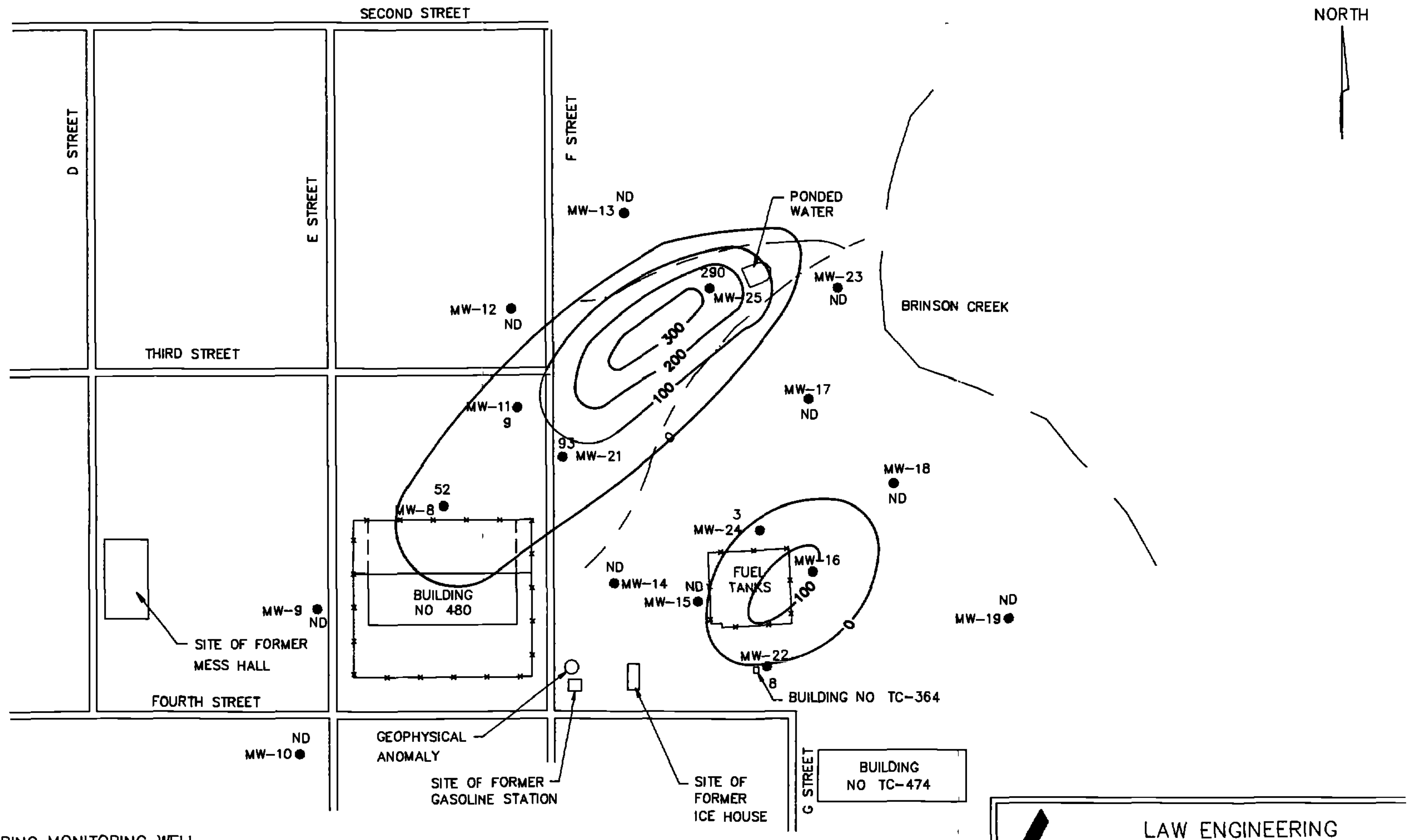

LEGEND

—×—×—	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
123	CONCENTRATION OF TOTAL XYLENES IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

CONTOUR INTERVAL 100 ug/L

J6014M04

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – TOTAL XYLENES CONCENTRATIONS
WATER SAMPLES FROM DEEP SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN:	DATE NOV 1991
DFT CHECK CCC	SCALE. 1"=150'
ENG CHECK: RAK	JOB J47590-6014
APPROVAL. WADixon	DWG 484

REFERENCE JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91 USGS JACKSONVILLE SOUTH, N C

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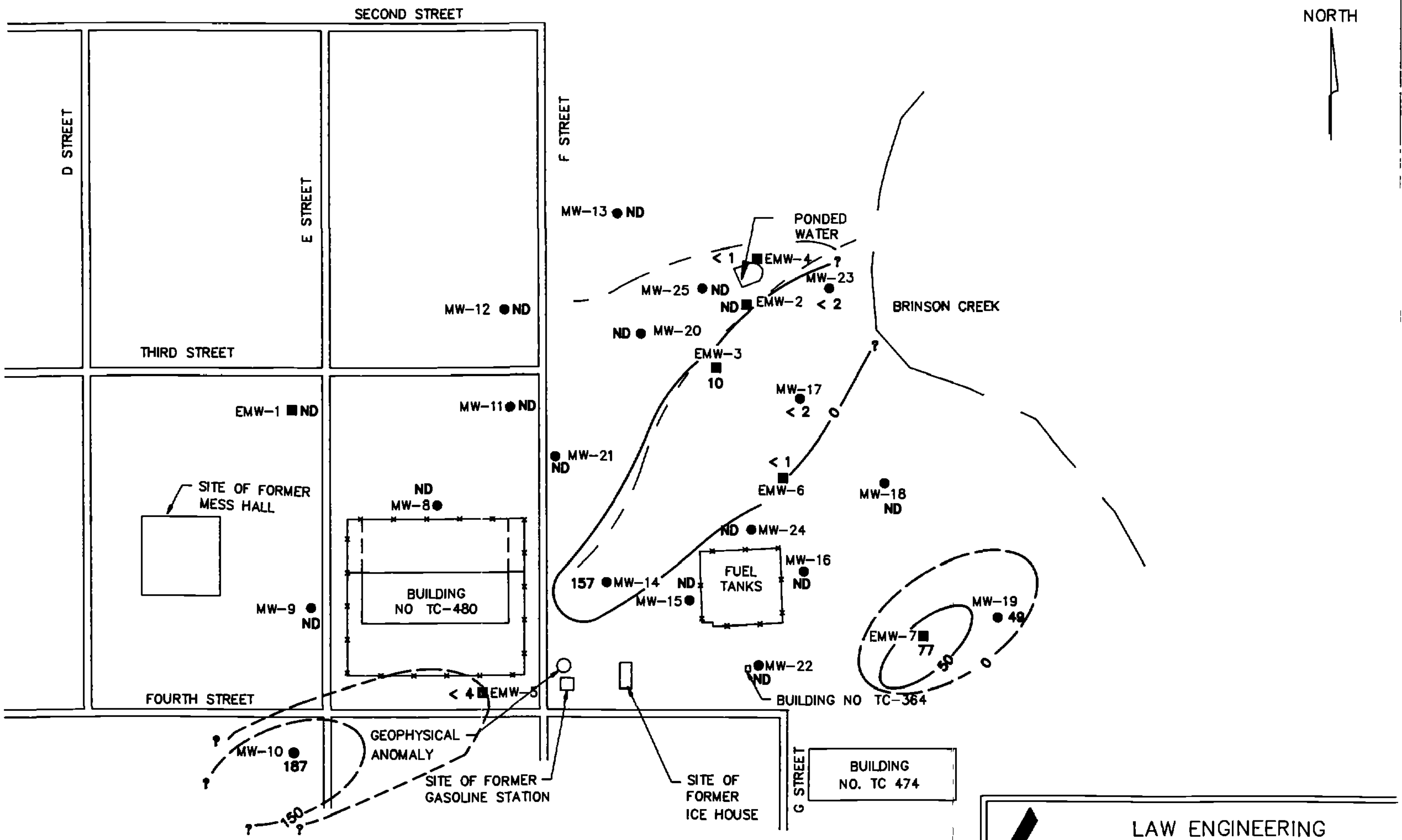


LEGEND

- ─×─×─ FENCE
- ■EMW-1 LOCATION OF PRE-EXISTING MONITORING WELL
- ●MW-1 LOCATION OF LAW ENGINEERING MONITORING WELL
- 49 CONCENTRATION OF CHLORINATED COMPOUNDS IN ug/L
- ND NONE DETECTED
- – – – TRANSITORY STREAM
- —— —— PERENNIAL STREAM

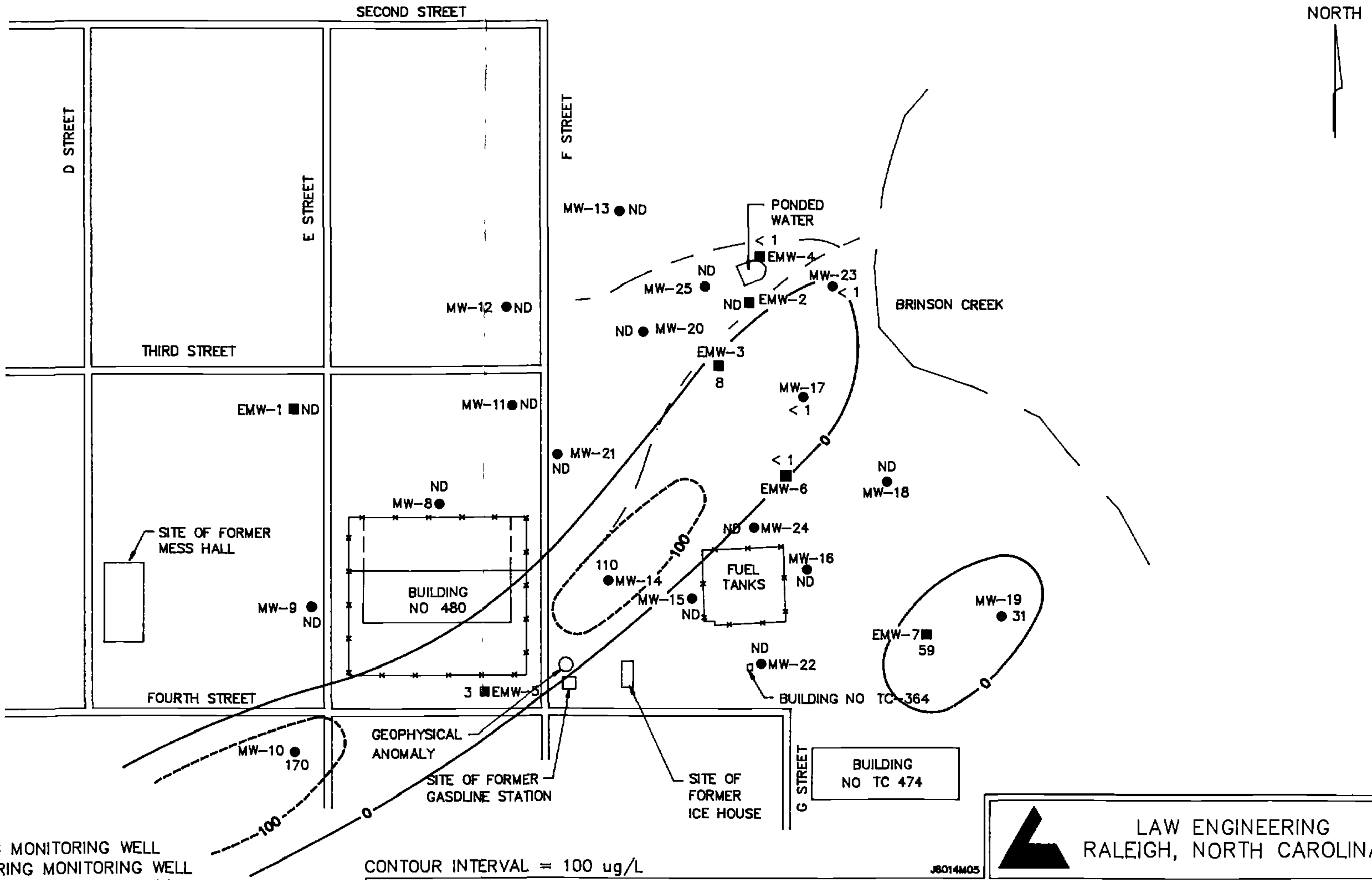
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP
COMBINED CONCENTRATIONS OF CHLORINATED COMPOUNDS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE NOV 1991
DFT CHECK:	SCALE. 1"=150'
ENG CHECK WDD	JOB: J47590-6014
APPROVAL. WDD	DWG· 4.9

REFERENCE JAMES E STEWART AND ASSOC, SHT 1&2 OF 2; 9/13/91

01985F 332



CONTOUR INTERVAL = 100 ug/L

J6014M05

LEGEND

—x—x—	FENCE
■EMW-1	LOCATION OF PRE-EXISTING MONITORING WELL
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
49	CONCENTRATION OF TRICHLOROETHENE IN ug/L\
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – TRICHLOROETHENE CONCENTRATIONS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE: FEB 1992
DFT CHECK:	SCALE 1"=150'
ENG CHECK:	JOB. J47590-6014
APPROVAL: WDDixon	DWG 4 9.1

REFERENCE JAMES E STEWART AND ASSOC, SHT 1 & 2 OF 2, 9/13/91

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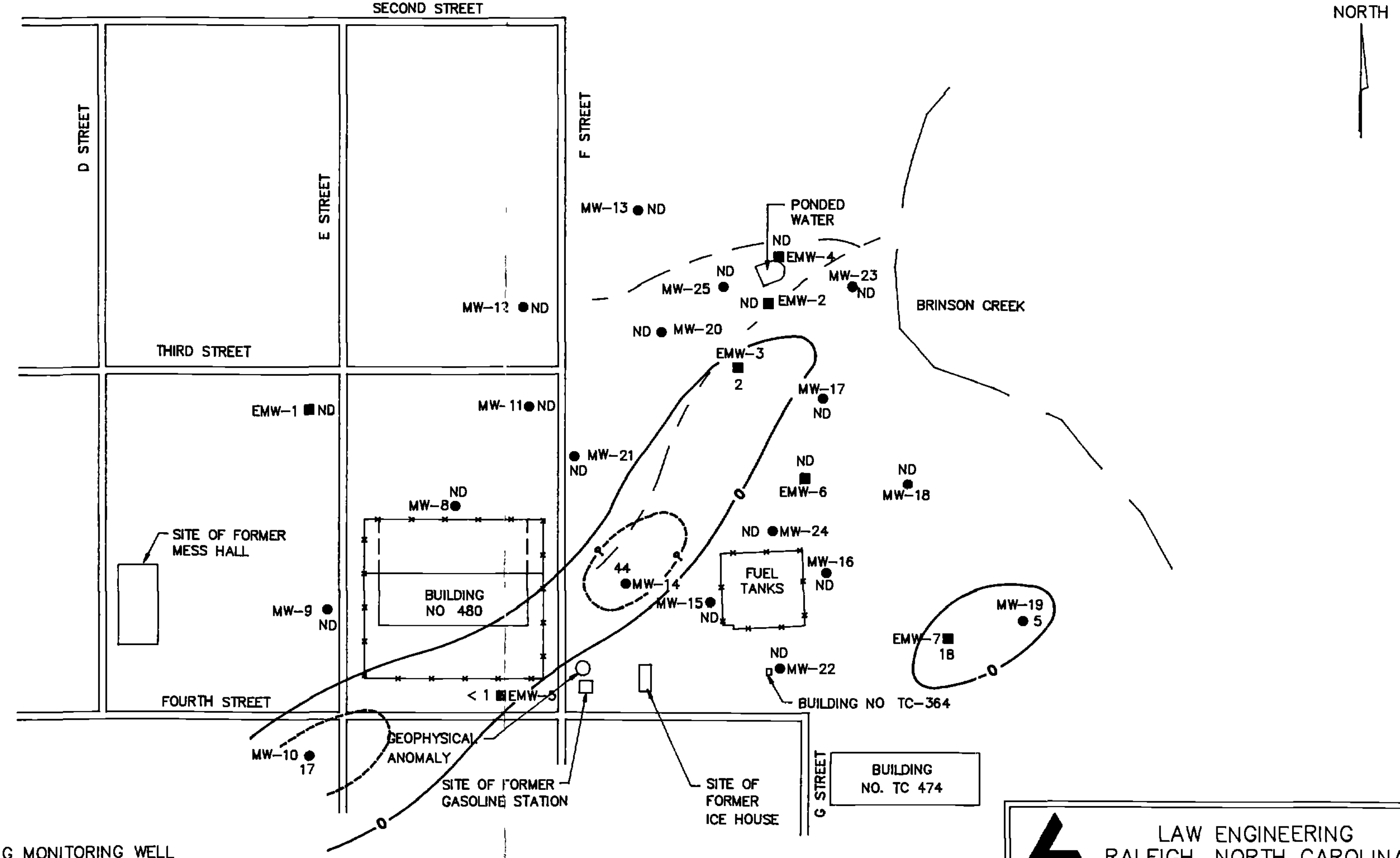


LEGEND

—×—×—	FENCE
■EMW-1	LOCATION OF PRE-EXISTING MONITORING WELL
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
49	CONCENTRATION OF TRANS-1,2-DICHLOROETHENE IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

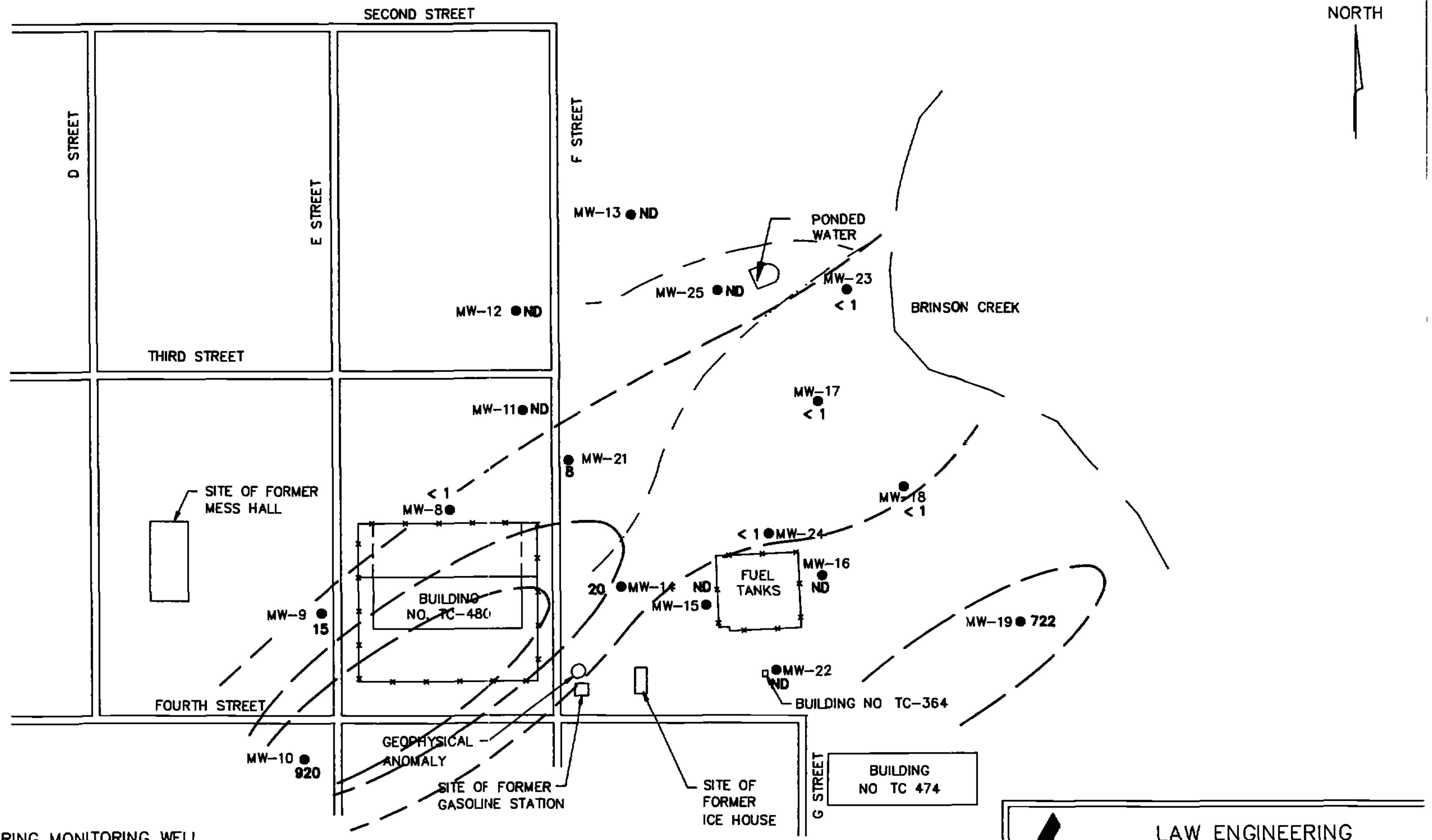
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – TRANS-1,2-DICHLOROETHENE
CONCENTRATIONS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE: FEB. 1992
DFT CHECK:	SCALE 1"=150'
ENG CHECK.	JOB: J47590-6014
APPROVAL:	DWG 4.9 2

REFERENCE. JAMES E STEWART AND ASSOC., SHT 1&2 OF 2; 9/13/91

01985F352



LEGEND

—×—×— FENCE
●MW-1 LOCATION OF LAW ENGINEERING MONITORING WELL
920 CONCENTRATION OF CHLORINATED COMPOUNDS IN ug/L
ND NONE DETECTED
— — — TRANSITORY STREAM
—— —— PERENNIAL STREAM

J6014Z18

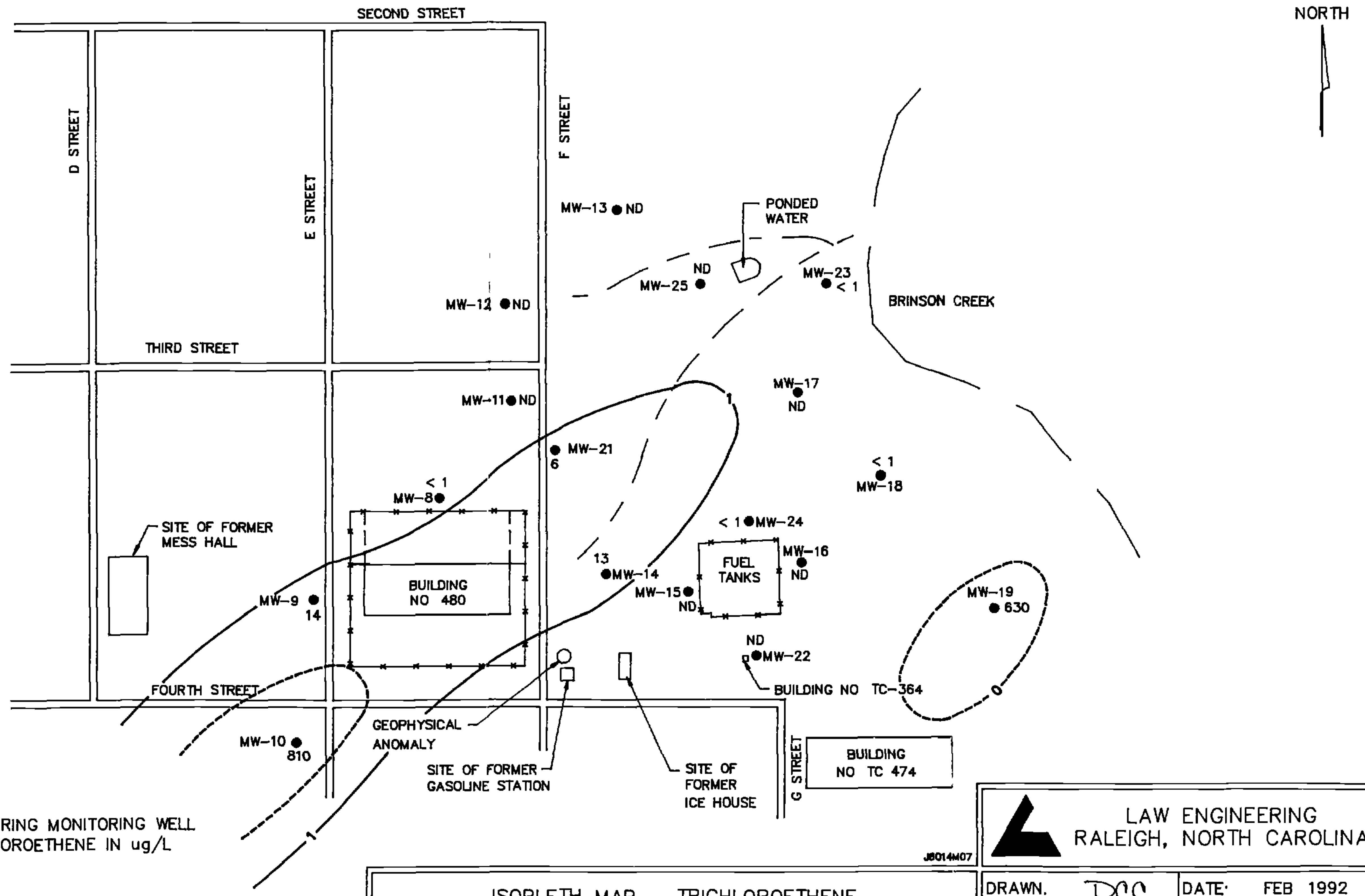
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP
COMBINED CONCENTRATIONS OF CHLORINATED COMPOUNDS
WATER SAMPLES FROM DEEP SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE. NOV 1991
DFT CHECK:	SCALE 1"=150'
ENG CHECK: WD Dixon	JOB. J47590-6014
APPROVAL. WD Dixon	DWG. 4 10

REFERENCE. JAMES E STEWART AND ASSOC, SHT 1&2 OF 2; 9/13/91

01985 F 362



LEGEND

—×—×—	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
49	CONCENTRATION OF TRICHLOROETHENE IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

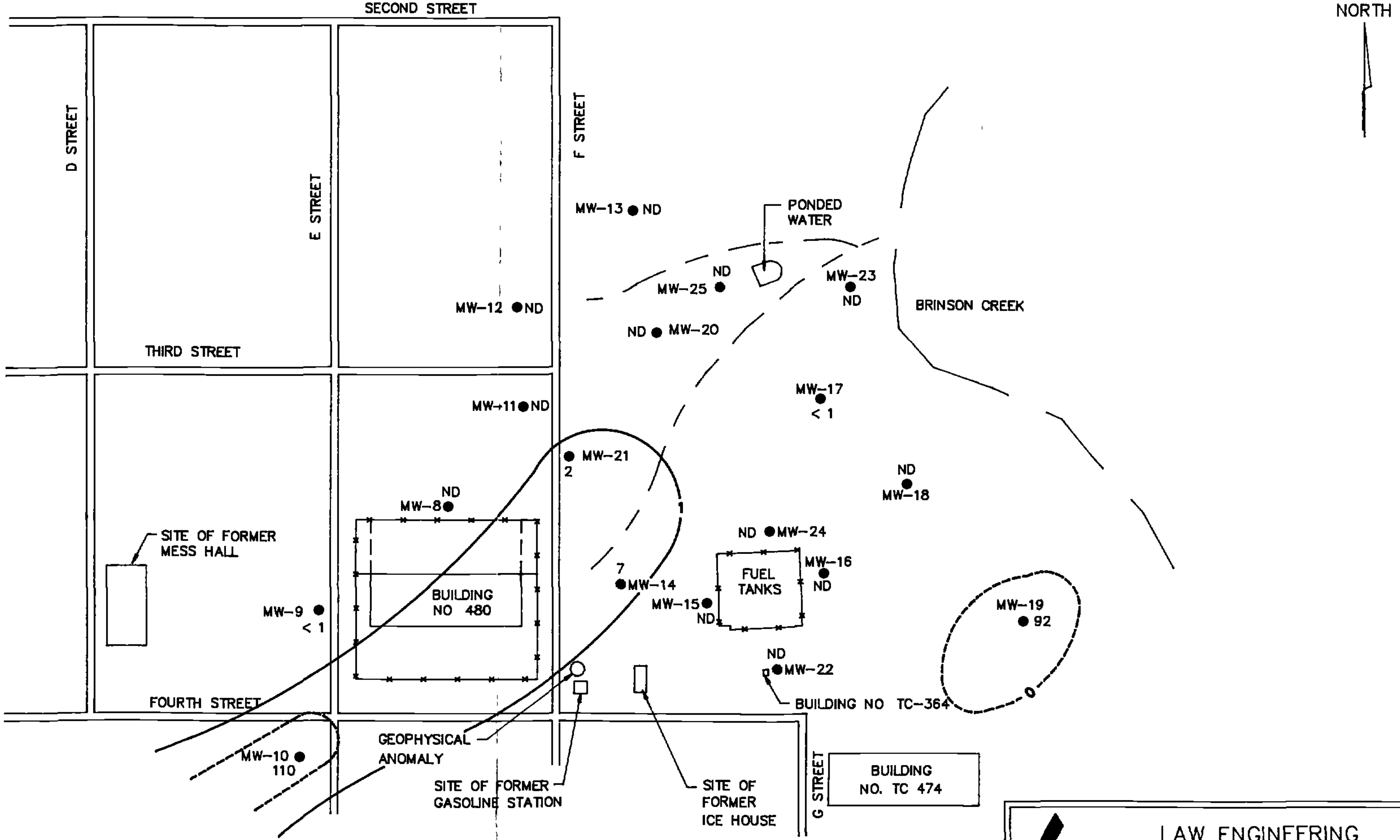
LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP – TRICHLOROETHENE
CONCENTRATIONS
WATER SAMPLES FROM DEEP SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN. DCC	DATE: FEB 1992
DFT CHECK:	SCALE. 1"=150'
ENG CHECK:	JOB: J47590-6014
APPROVAL:	DWG: 4101

REFERENCE JAMES E. STEWART AND ASSOC.; SHT 1&2 OF 2, 9/13/91

01985F372



LEGEND

—×—×—	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
49	CONCENTRATION OF TRANS-1,2-DICHLOROETHENE IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

ISOPLETH MAP - TRANS-1,2-DICHLOROETHENE CONCENTRATIONS
WATER SAMPLES FROM DEEP SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE FEB. 1992
DFT CHECK:	SCALE. 1"=150'
ENG CHECK.	JOB: J47590-6014
APPROVAL.	DWG: 4 10.2

REFERENCE: JAMES E STEWART AND ASSOC, SHT 1&2 OF 2; 9/13/91

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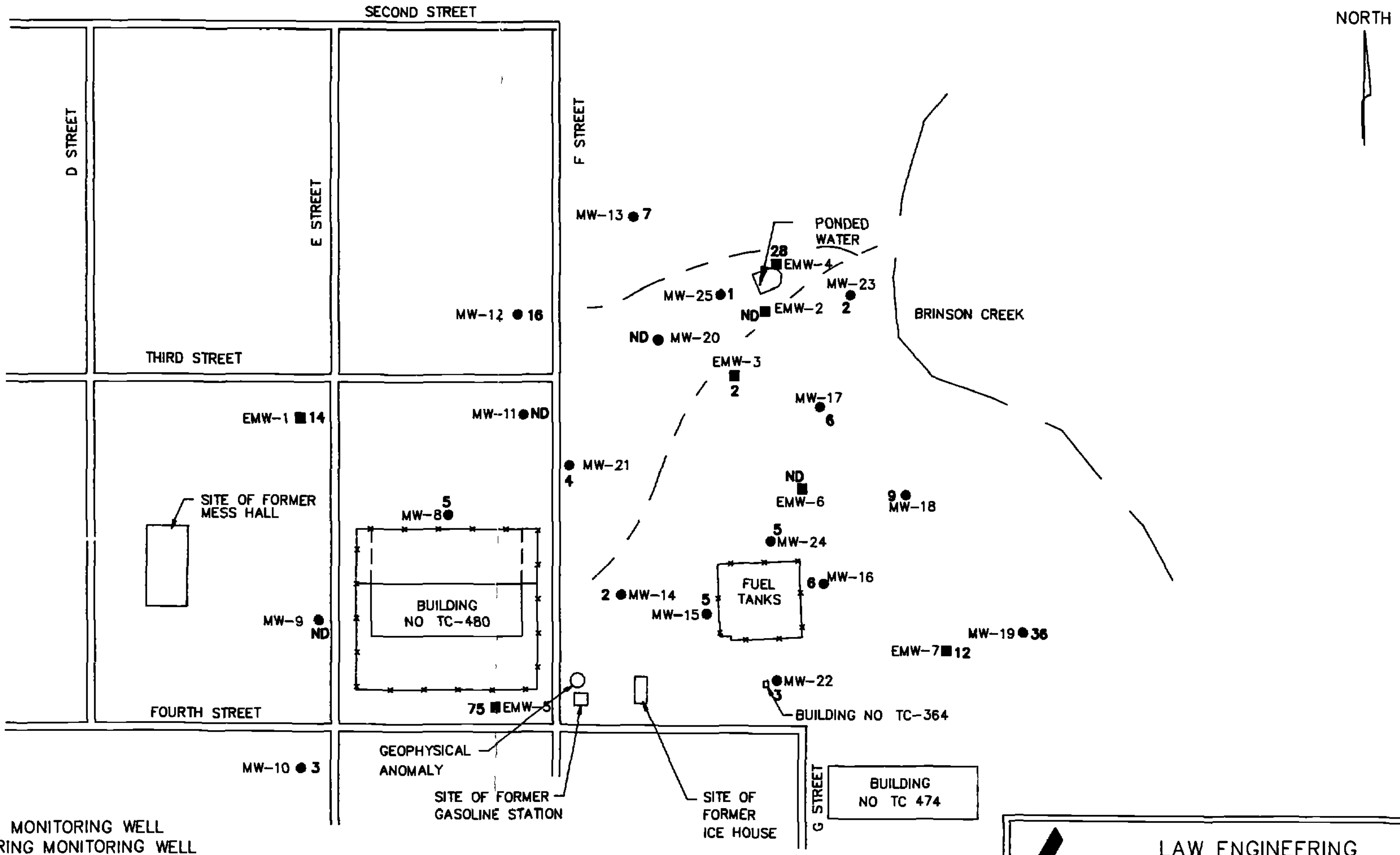

LEGEND

—×—×—	FENCE
■EMW-1	LOCATION OF PRE-EXISTING MONITORING WELL
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
8	CONCENTRATION OF TOTAL LEAD IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

TOTAL LEAD CONCENTRATIONS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN DCC	DATE. NOV 1991
DFT CHECK DCC	SCALE. 1"=150'
ENG CHECK WDDixon	JOB J47590-6014
APPROVAL WDDixon	DWG 4 11

REFERENCE: JAMES E STEWART AND ASSOC, SHT 1&2 OF 2, 9/13/91

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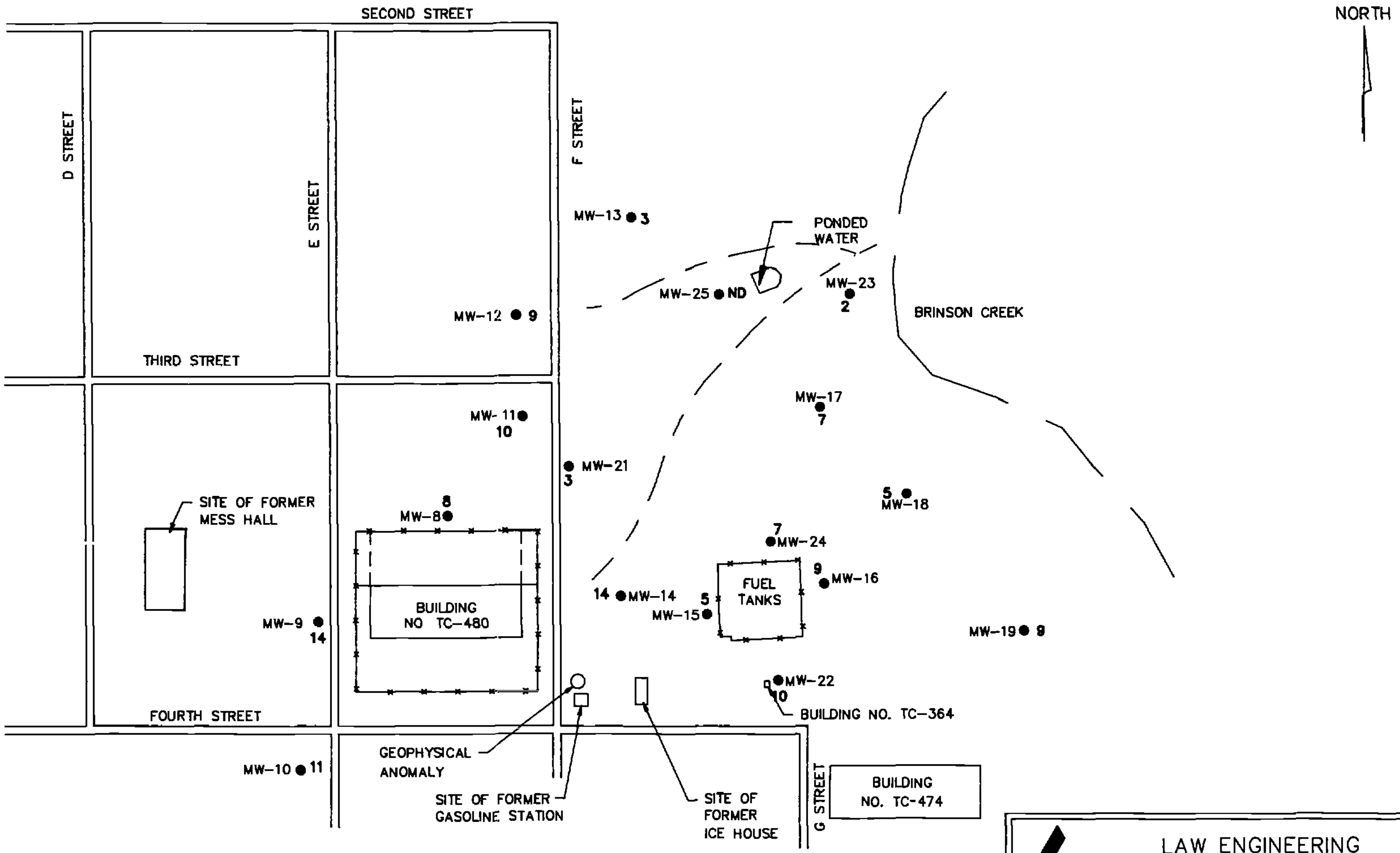

J6014Z13

LEGEND

——×——×——	FENCE
●MW-1	LOCATION OF LAW ENGINEERING MONITORING WELL
14	CONCENTRATION OF TOTAL LEAD IN ug/L
ND	NONE DETECTED
— — —	TRANSITORY STREAM
—— ——	PERENNIAL STREAM

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

TOTAL LEAD CONCENTRATIONS
WATER SAMPLES FROM DEEP SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN. DCC	DATE NOV. 1991
DFT CHECK. DCC	SCALE· 1"=150'
ENG CHECK WDDixon	JOB J47590-6014
APPROVAL: WDDixon	DWG 4 12

REFERENCE JAMES E STEWART AND ASSOC., SHT 1&2 OF 2, 9/13/91

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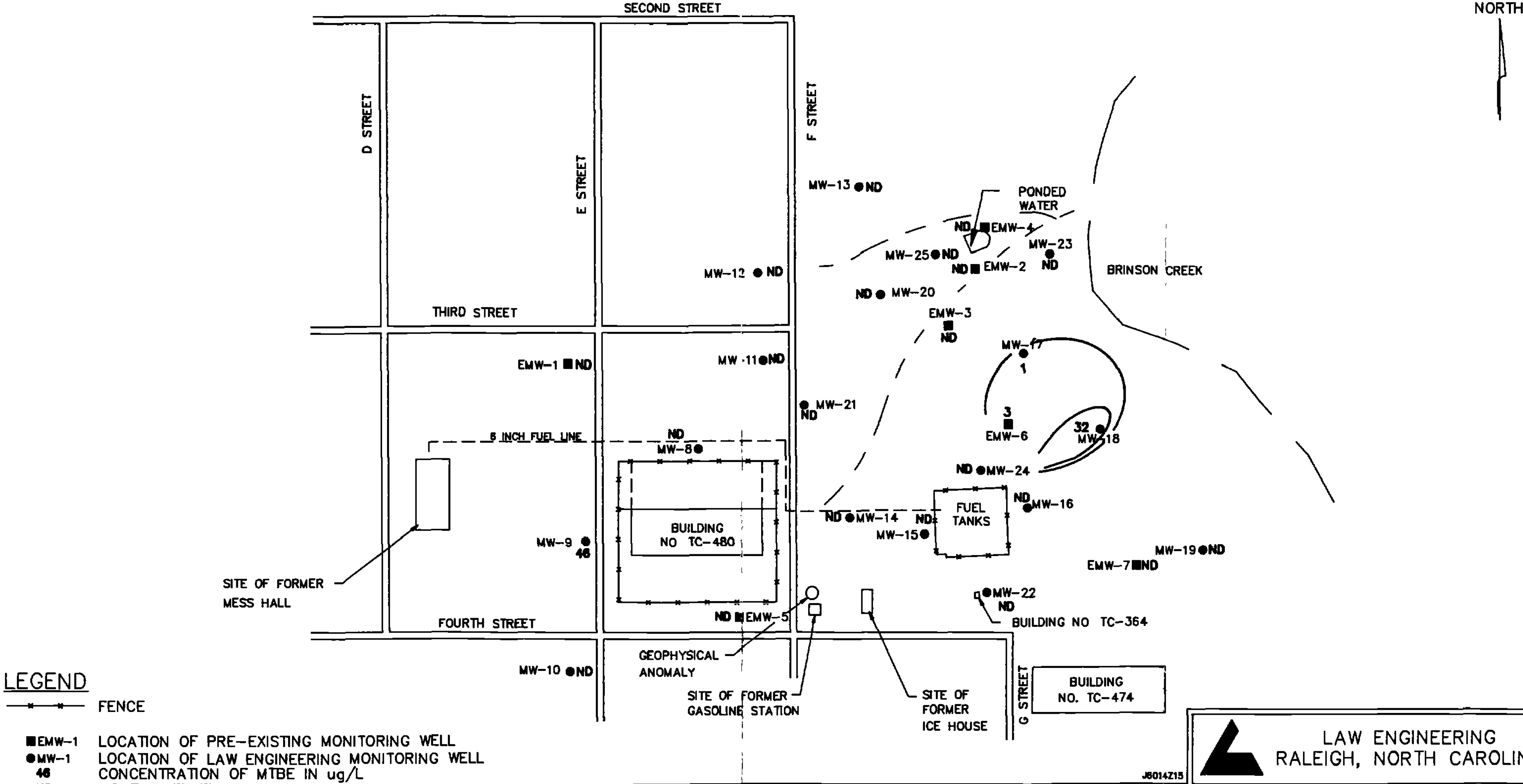

LAW ENGINEERING
RALEIGH, NORTH CAROLINA

MTBE CONCENTRATIONS
WATER SAMPLES FROM SHALLOW SCREENED INTERVAL
CAMP GEIGER FUEL FARM
CAMP LEJEUNE, NORTH CAROLINA

DRAWN: DCC	DATE. NOV. 1991
DFT CHECK:	SCALE: 1"=150'
ENG CHECK:	JOB: J47590-6014
APPROVAL:	DWG: 4 13

REFERENCE: JAMES E. STEWART AND ASSOC; SHT 1&2 OF 2; 9/13/91