APPENDIX A

PREVIOUS REPORTS

ENVIRONMENTAL INVESTIGATIONS
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2327 Englert Drive, Suite 1
Durham, NC 27713

R
APR 11 1994
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
GEOTECHNICAL UNIT

March 30, 1994

Mr. C. Edward Hales, III
North Carolina Department of Transportation
Geotechnical Unit
P.O. Box 25201
Raleigh, North Carolina 27611-5201

EI PROJECT NO. 14-402-688

Incident # 12706

Re: Preliminary Site Assessment Report
State Project: 8.T020401 (R-2414)
County: Camden
Description: Site 1: Camden Shell; Widening of US 158 from Elizabeth City to Belcross

Quality Oil

Dear Mr. Hales:

On February 23, 1994, Environmental Investigations, P.A. performed a Preliminary Site Assessment at the Camden Shell property located on US 158 approximately 200 feet southwest from the intersection of US 158 and SR 1139 in Camden County, North Carolina. A Location Map is included in this report as Figure 1. The scope-of-work for this project included the verification of existence and location of underground storage tanks (UST) located on the site by means of a limited electromagnetic survey. UST assessments were subsequently performed by advancing soil borings in the area of the USTs to determine the absence/presence of soil contamination in association with the USTs located on-site.

SITE DESCRIPTION

The subject property consists of one building which is currently utilized by the Camden Shell for retail and vehicle maintenance purposes. The UST fill pipes and vent pipes along with one kerosene above-ground storage tank (AST) and kerosene fuel dispenser are located on the northeastern portion of the property. A propane AST is also located on the northeastern portion of the property. Six gasoline fuel dispensers are located on two separate pump islands approximately 12 and 17 feet northwest of the building. A storage shed is attached to the northeastern portion of the building. A Site Map of the property is included as Figure 2.

Three gasoline USTs (6,000, 10,000, and 10,000 gallons) are currently registered (Facility ID# 0-011167) with the Division of Environmental Management (DEM). The USTs are of steel construction with no cathodic protection. All three USTs have been in place since May 5, 1970 and are located approximately 20 feet northwest of the building. The kerosene AST, fuel dispenser, and piping are situated on concrete. The kerosene fuel dispenser is elevated 1.5 feet on a concrete and steel platform which does not come in contact with the soil. No staining was noted in the vicinity of the kerosene AST and fuel dispenser. Therefore, no soil sample was taken at the kerosene fuel dispenser.

Farmland abuts the southern and eastern boundaries of the property. SR 1139 is located on the northern boundary of the property, and US 158 abuts the western boundary of the property.

Topographically, the northern portion of the site slopes slightly to the northwest. Standing water was observed in a drainage ditch located on the northwestern portion of the property. Soil type in the area of the UST pit and gasoline fuel dispensers varied from well-graded sand to clayey sand. Site photographs can be found in Appendix A of this report.

UST ASSESSMENT

On February 9, 1994, a limited electromagnetic survey was performed in order to locate and define the dimensions of the USTs located on-site. Subsequently, on February 23, 1994, soil borings were advanced in the area of the magnetic anomaly around the USTs and directly beneath the six gasoline fuel dispensers in order to determine the absence/presence of soil contamination in association with the USTs present.

Due to suspected shallow groundwater conditions in this part of the state, hand-augers were utilized to advance the borings and perform soil sampling activities. Since asphalt covered the area of the USTs, an electric jackhammer was first used to penetrate the asphalt. A total of fourteen soil borings were attempted. The USTs were oriented in a northeast/southwest direction.

Soil borings SB-1 through SB-8 were advanced in the area of the three USTs. Hand-augers were decontaminated between each boring location and auger-heads were decontaminated prior to each sampling event. Each soil boring was sampled at two foot intervals from a depth of two feet and continued to groundwater. Groundwater was encountered at a depth of 3.0 to 3.5 feet.

Soil borings SB-9 through SB-14 were advanced directly beneath the gasoline fuel dispensers. The dispensers were opened, and hand-augers were utilized to advance the borings to a depth of 2.0 feet. A Sample Location Map is included as Figure 3. Field soil boring logs containing soil classifications are included in Appendix B of this report.

All soil samples were collected using clean vinyl gloves and placed in two zip-lock plastic bags. One bag was placed on ice while the other bag was allowed to equilibrate for 15 minutes. An HNu photoionization detector was then used to screen the head space in the equilibrated samples. HNu screening and laboratory analytical results are summarized in Table 1. The soil sample from each soil boring exhibiting the highest HNu reading was then placed in a clean laboratory supplied jar, placed on ice, and delivered under chain-of-custody protocol to CompuChem Laboratories, Inc., located at 3308 Chapel Hill/Nelson Highway, Research Triangle Park, North Carolina.

Fourteen soil samples were submitted to the laboratory for analysis of Total Petroleum Hydrocarbons (TPH) by California Gas Chromatograph Method with SW-846 Method 5030 (purge and trap) and Method 3550 (sonification extraction). Method 5030 identifies volatile fuels such as gasoline, and Method 3550 identifies less volatile fuels such as diesel, fuel oil, and kerosene. The laboratory analytical report is located in Appendix C of this report.

RESULTS AND CONCLUSIONS

Of the fourteen borings performed, HNu screening results for samples collected from borings SB-1 through SB-8, SB-10, SB-11, and SB-14 indicated hydrocarbon concentrations ranging from 3 to 350 parts per million (ppm). Laboratory analysis of these samples indicated that petroleum hydrocarbon contamination was present in the samples submitted from all of the borings. Petroleum hydrocarbon concentrations ranged from 0.031 to 1,400 ppm. Soil sample SB-11 (collected from 1.5-2.0 feet) contained 1,400 ppm gasoline and 1,000 ppm diesel fuel. Soil sample SB-11 concentration exceeds the NC Division of Environmental Management (NCDEM) standard of 10 ppm for gasoline contaminated soil and 40 ppm for diesel contaminated soil. No other samples contained TPH concentrations which exceeded NCDEM standards when analyzed in the laboratory.

Table 1 contains a summary of HNu soil screening results and laboratory analytical results for these samples.

Information gathered during field activities and from the laboratory analytical report indicates that there has been a release of petroleum hydrocarbons from the USTs and fuel dispensers located on the Camden Shell property that exceed NCDEM standards. Also, since the USTs are potentially located at a depth below the groundwater table, the probability of groundwater impact from petroleum hydrocarbon contamination is high.

It is recommended that the USTs located on the Camden Shell property be removed and properly disposed and that contaminated soil encountered during removal activities also be excavated and properly disposed.

If you have any questions, please do not hesitate to contact Gary D. Babb or myself at (919) 544-7500.

Sincerely,

Scott M.E

Scott M. Eden
Project Geologist

Gary D. Babb

Gary D. Babb, P.G.
Vice President

Attachments

TABLE 1

HNu Screening Results and TPH Laboratory Results
Site 1: Camden Shell
US 158
Camden County, North Carolina

Sample ID	Depth (ft)	HNu (ppm)	TPH 5030 (mg/kg)	TPH 3550 (mg/kg)
SB-1	1.5-2.0	30		
	3.0-3.5	40	2.3[2]	BDL[1]
SB-2	1.5-2.0	180	1.5[2]	9.2J[4]
	3.0-3.5	165		
SB-3	1.5-2.0	40		
	3.0-3.5	55	1.9[2]	BDL
SB-4	1.5-2.0	8		
	3.0-3.5	60	0.70[2]	BDL
SB-5	1.5-2.0	60		
	3.0-3.5	100	0.50[2]	BDL
SB-6	1.5-2.0	5		
	3.0-3.5	7	1.8[2]	BDL
SB-7	1.5-2.0	5		
	3.0-3.5	7	0.14[2]	BDL
SB-8	1.5-2.0	0		
	3.0-3.5	3	0.74[2]	BDL
SB-9	1.5-2.0	0	0.031J[4]	BDL
SB-10	1.5-2.0	6	0.14[2]	BDL
SB-11	1.5-2.0	350	1,400[2]	1,000[3]
SB-12	1.5-2.0	0	0.18[2]	BDL
SB-13	1.5-2.0	0	0.50[2]	BDL
SB-14	1.5-2.0	110	0.48[2]	BDL

Notes:
1 - BDL: Below detection limit
2 - Sample contains a petroleum hydrocarbon blend with a distillation range similar to gasoline.
3 - Sample contains a petroleum hydrocarbon blend with a distillation range similar to diesel fuel.
4 - "J" indicates an estimated level.
mg/kg: milligrams per kilogram
ppm: parts per million
ppm = mg/kg

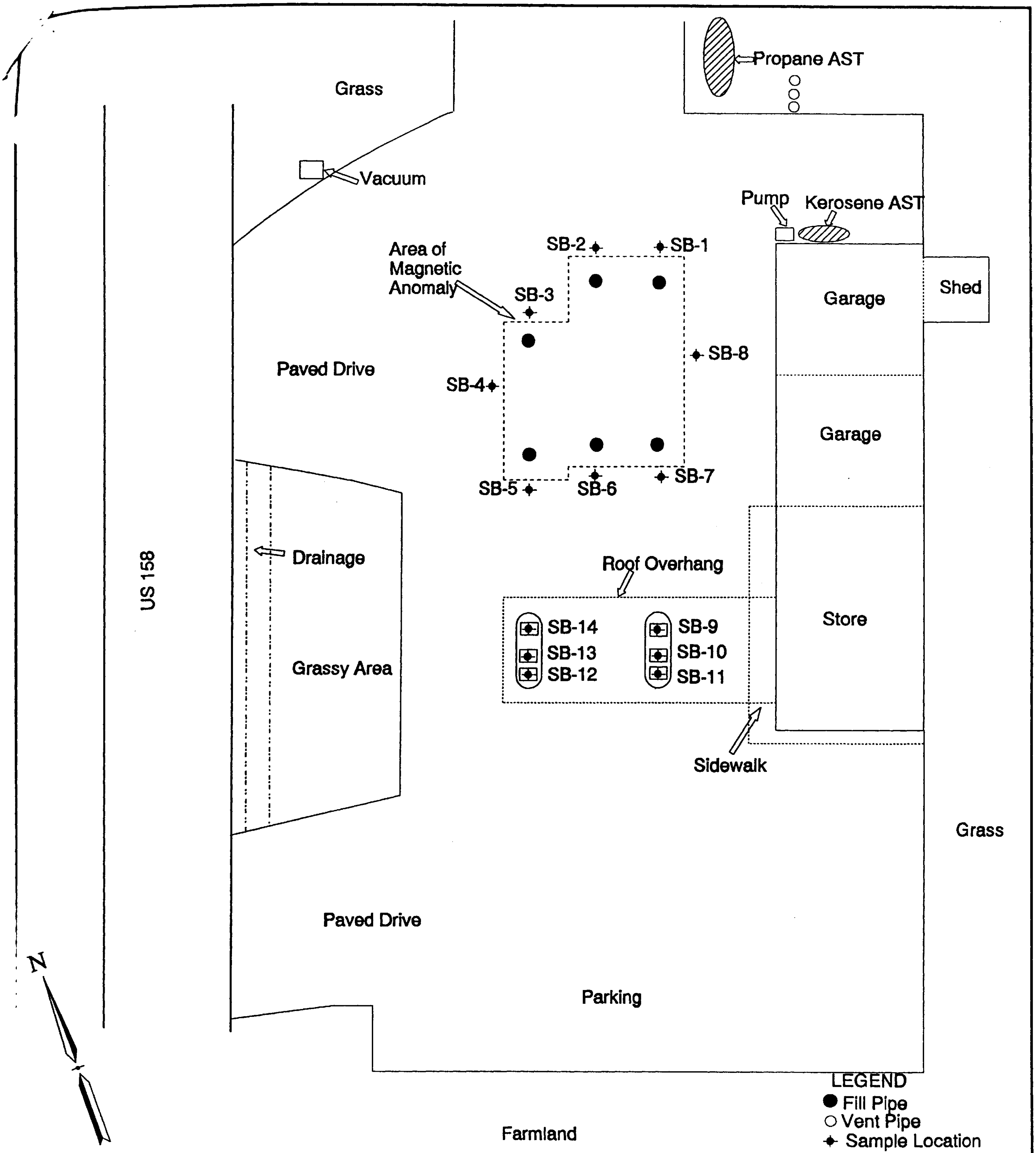
ENVIRONMENTAL INVESTIGATIONS PA

PROJECT TITLE:

LOCATION MAP

Camden Shell
East US 158
Camden County, North Carolina

PROJECT NO.: 14-402-688	*FIGURE NO.:* Figure 1
CHECKED BY:	*SCALE:* 1"=2000'
DRAWN BY: SME	*DATE:* 3-7-94



ENVIRONMENTAL INVESTIGATIONS PA

PROJECT TITLE: SAMPLE LOCATION MAP Camden Shell East US 158 Camden County, North Carolina	*PROJECT NO.:* 14-402-688	*FIGURE NO.:* Figure 3
	CHECKED BY:	*SCALE:* 1"=20'
	DRAWN BY: SME	*DATE:* 3-8-94

APPENDIX A: SITE PHOTOGRAPHS

PROJECT TITLE: DOT-Camden: Camden Shell
LOCATION: US 158, Camden County, NC

JOB NUMBER: 14-402-688
DATE: 2/23/94

Photograph 1: A view of the Camden Shell from the northern portion of the property.

/UT

COMPREHENSIVE SITE ASSESSMENT REPORT

CAMDEN SHELL
US HWY 158 AT SR 1139
CAMDEN, NORTH CAROLINA

RECEIVED
WASHINGTON OFFICE

JAN 16 1995

D. E. M.

Prepared For:

Mr. Danny Stroud, Vice President of Operations
Quality Oil Company, Ltd.
P.O. Box 2736
Winston-Salem, North Carolina 27102-2736

January 1995
TEC Project No. 02694

TURNER ENVIRONMENTAL CONSULTANTS, P.C.
110 WEST MAIN STREET • SUITE 2-M • CARRBORO, NC 27510 • PHONE 919·932·1590 • FAX 919·932·1594

CERTIFICATION FOR THE SUBMITTAL
OF AN ENVIRONMENTAL / GEOLOGICAL ASSESSMENT

Attached is the Comprehensive Site Assessment Report for:

Responsible Party: Quality Oil Company, Ltd.
Address: P.O. Box 2736
City: Winston-Salem State: NC Zip Code:27102-2736

Site Name: Camden Shell
Address: US HWY 158 at SR 1139
City: Camden State: NC Zip Code:27921

I, Michael J. Brown, a Licensed Geologist in the State of North Carolina for TURNER ENVIRONMENTAL CONSULTANTS, P.C. do hereby certify that I am familiar with and have reviewed all material including figures within this report and that to the best of my knowledge the data, site assessments, figures, and other associated materials are correct and accurate. My seal and signature is affixed below. Additional seals and/or signatures are also affixed below.

TURNER ENVIRONMENTAL CONSULTANTS, P.C.

1185
MICHAEL J. BROWN

James M. Gamble

James M. Gamble, P.G.
Project Manager

Michael J. Brown, P.G., REP
Project Geologist

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APPENDICES

EXECUTIVE SUMMARY

Turner Environmental Consultants, P.C. (TEC) has completed comprehensive site assessment activities at the Camden Shell facility in Camden, North Carolina. Quality Oil Company, Ltd. (QUALITY) has operated gasoline underground storage tanks (USTs) at the facility since 1970. The USTs are currently in operation.

Site characterization work to date has documented the presence of soil and groundwater contamination at the site. The vertical and horizontal extent of petroleum constituents has been delineated through the installation of soil borings and monitoring wells. All soil samples collected were analyzed for gasoline constituents. Select soil samples were analyzed for diesel fuel constituents in addition to gasoline.

Laboratory analyses of samples collected by Environmental Investigations (EI) revealed total petroleum hydrocarbon (TPH) concentrations in soil ranging up to 1,400 parts per million (ppm) as gasoline and 1,000 ppm as diesel. Although diesel compounds were detected in soil during initial work by EI, no diesel compounds were detected during the work by TEC. Vadose zone soil impact exists as one small area beneath one product dispenser.

Gasoline constituents have been found in groundwater beneath the site at concentrations which exceed the limits set forth in 15A NCAC 2L. Monitoring well MW2 contained benzene and MTBE at concentrations of 350 parts per billion (ppb) and 3,750 ppb respectively. The type III well (MW4) contained 1,2,4, Trimethylbenzene at a concentration of 3.0 ppb. No free product has been detected in wells or borings at the site. The site and surrounding community receive their water from potable wells.

In conclusion, the release of gasoline from the UST system at the Camden Shell facility has resulted in petroleum concentrations in soil and groundwater in excess of present regulatory levels. The impacted soil remaining in situ at the site may continue to contribute to groundwater impact. Because soil and groundwater have been impacted at levels in excess of regulatory standards, a Corrective Action Plan (CAP) is required for the site. The completed CAP should at a minimum identify available treatment options, perform a cost benefit analysis, and recommend an appropriate remediation option.

1.0 INTRODUCTION

Under current regulations, responsible parties with facilities that have soil and/or groundwater impact at concentrations above permissible levels, must complete a Comprehensive Site Assessment (CSA). The purpose of the CSA is to define the extent of environmental impact, define specific aquifer characteristics which influence the movement of compounds, and identify any potential hazards created by the release such as dangerous or explosive vapor accumulations, free product, and/or impacted potable wells.

Previous studies have documented the presence of petroleum constituents in soil and groundwater at the Camden Shell facility (Figure 1). In March 1994, Environmental Investigations (EI) of Durham, NC conducted soil sampling at the subject facility. EI was contracted by the North Carolina Department of Transportation (NCDOT) to conduct the sampling as part of a planned widening of US HWY 158. EI submitted one soil sample from each of fourteen soil borings advanced at the site. Each sample was analyzed for total petroleum hydrocarbon concentration (TPH) per EPA methods 5030 and 3550. Laboratory results showed sample SB-11 collected from beneath one dispenser to contain TPH concentrations of 1,400 parts per million (ppm) as gasoline and 1,000 ppm as diesel fuel. Findings of the assessment were forwarded to the NCDOT and the North Carolina Department of Environment Health and Natural Resources - Division of Environmental Management (NCDEM). Upon receiving the results, the NCDEM issued a Notice of Regulatory Requirements to QUALITY instructing them to conduct additional investigations.

Subsequent to the EI investigation, TEC conducted additional field work and completed an Initial Abatement Measures and Initial Site Characterization Report for the facility. That report documented the existence of groundwater impact from a release of petroleum at the site. Analysis of a groundwater sample from one of three monitoring wells revealed benzene and MTBE at concentrations of 350 ppb and 3,750 ppb respectively. That report also indicated that the extent of soil impact was limited to the area immediately surrounding the dispenser associated with SB-11. All previous reports are on file at the Washington Regional Office of the NCDEM. TEC has completed comprehensive site assessment activities since that time. Findings of that investigation are presented herein.

Standard technical procedures were utilized in completing the environmental assessment work at the Camden Shell. Appendix A describes the technical procedures and standard practices used during this investigation.

2.0 SITE HISTORY AND SOURCE CHARACTERIZATION

2.1 History of Ownership and UST Operations

The Camden Shell facility is a retail gasoline station. Courthouse records indicate that QUALITY is the owner of the property. Prior to QUALITY's ownership of the site, the property was undeveloped.

QUALITY has operated petroleum USTs at the site since 1970. The North Carolina Petroleum UST Database shows that two (2) 10,000 gallon, one (1) 6,000 gallon, and one (1) 550 gallon gasoline USTs were installed at the site on May 5, 1970. Representatives of QUALITY report that the 550 gallon UST was not used for gasoline storage. That tank is believed to have been a waste oil tank. The database further indicates that the 550 gallon UST was permanently closed on September 1, 1988. The remaining USTs are currently in operation. Current USTs and the estimated location of the former waste oil UST are depicted in Figure 2.

2.2 Initial Assessment Summary

Assessment tasks conducted prior to the current study include the soil sampling conducted by EI, and an Initial Abatement Measures and Initial Site characterization Report completed by TEC. These activities revealed that both soil and groundwater at the facility had been impacted by petroleum at levels in excess of current NCDEM standards. Conclusions of those reports indicated that the extent of soil impact was limited to the area immediately surrounding one product dispenser. They also revealed the presence of groundwater impact in the vicinity of the UST bed. A copy of each report is on file with the Washington Regional Office of the NCDEM.

2.3 Release Scenario

No discrete release event has been documented for the site. Neither inventory monitoring nor tank tightness testing indicate a release from the UST system. Inventory fluctuations have remained within allowable ranges and the UST system has passed all routine tightness testing.

TPH concentrations as gasoline and diesel were detected in soil beneath the product dispenser. No source for the diesel compounds has been identified at the site.

2.4 Potential On-Site Petroleum Hydrocarbon Sources

Potential on-site hydrocarbon sources include USTs and ASTs currently and formerly operated at the facility. QUALITY currently operates three gasoline USTs on the property. In addition, one waste oil UST was formerly used at the site. Aboveground waste oil and heating oil tanks are also currently in operation.

Pertinent information regarding the USTs and ASTs is given in Table 1 attached. Figure 2 illustrates the locations of all known on-site petroleum hydrocarbon sources.

2.5 Potential Off-Site Petroleum Hydrocarbon Sources

The area immediately surrounding the Camden Shell is mostly residential. Hydraulically upgradient from the site are agricultural fields. Although no heating oil tanks were observed, some of the area residents could possess them. No sources off-site sources of gasoline were identified. The site and surrounding vicinity are shown in Figure 2.

2.6 Preliminary Corrective Actions

The UST system in question meets all current leak detection requirements. The location and extent of environmental impact delineated at the site indicates that the release was from a dispenser which is not currently leaking. No release point for the groundwater impact detected adjacent to the UST bed has been identified. Since no ongoing release is suspected, no corrective actions have been taken to date. Remedial activities have not been implemented at the site.

3.0 POTENTIAL RECEPTORS AND MIGRATION PATHWAYS

3.1 Site Setting and Land Use

The Camden Shell facility occupies a lot approximately 1 acre in size. The property is located along US HWY 158 at its intersection with SR 1139 southwest of Camden in Camden County, NC. The site contains one building which provides retail space, storage, and two auto repair bays. The UST system with two dispenser island is located on the northwest side of the site building (Figure 2).

Land usage surrounding the site is agricultural / rural residential. The nearest residence lies about 220 ft northwest. Land immediately surrounding the southwest and southeast is open field. HWY 158 abuts the site on the northwest. The nearest surface water body is a man made bay off the Pasquotank River and is located about 300 ft. northwest of the UST system. Figure 2 depicts land usage for the vicinity. Figure 4 depicts the names of surrounding property owners and their adjacent property locations. Table 2 lists the names and addresses of owners of surrounding properties.

3.2 Water Supply

Water is supplied to the site from a potable well located behind the facility. Area residents also receive their water from potable wells. Although no well was observed at the residential property located immediately downgradient, one likely exists there. The well for the downgradient residence would lie two to three hundred feet from the UST system at the Camden Shell.

3.3 Structures Potentially at Risk

The Camden Shell building is the only structure identified which could be at risk due to vapor accumulation. Petroleum vapors could potentially collect in areas beneath these features and migrate along conduits entering the floor or otherwise enter the buildings. However, visual inspection of both structures and surrounding ground cover indicates that the likelihood of any vapor accumulation is minimal. In addition, neither soil nor groundwater contamination is suspected beneath the buildings.

3.4 Underground Utilities

Underground utility lines in the immediate vicinity were located by North Carolina

One-Call and by field observation. Subsurface utilities are depicted in Figure 3.

4.0 SITE TOPOGRAPHY AND SURFACE WATER FEATURES

4.1 Regional Topography/Hydrography

Regionally, the area is characterized by flat marshy land with numerous natural and manmade drainages. Topographic elevations in the vicinity range from approximately 10 feet above sea level (ASL) at the site to 0 feet ASL immediately north of the site.

The dominant surface water feature in the area is the Pasquotank River. The meandering estuary passes 1000 feet northwest of the subject property. A narrow man-made bay extends from the Pasquotank River southeast and abuts the residential lots across US HWY 158 from the subject site. Numerous other drainages, both man-made and natural, traverse the region. Figure 1 illustrates topographic features for the area.

4.2 Local Topography

The site is located about 1000 feet southeast of the Pasquotank River. The land surface at the site is flat with no discernable slope. To the south and west the land extends to the banks of the aforementioned river after it has widened to join the intracoastal waterway.

4.3 Land Cover / Surface Drainage

Land cover at the site consists of asphalt, concrete, and grass. The area immediately surrounding the dispensers is a paved driveway and parking area. Paved driveways provide access to the property on the northwest and northeast.

The areas surrounding the pavement are primarily grass. Various land cover types across the site are indicated in Figure 2.

Precipitation which falls on the unpaved portions of the site will likely infiltrate to the water table surface. If precipitation falls quickly enough to overcome the infiltration rate then surface runoff will occur. The subject property is completely surrounded by ditches. Surface runoff across the unpaved portions of the site will likely occur toward the nearest surface drainage where it is directed to the nearby river or infiltrates to the water table. Grading of the land surface prior to construction sloped the parking area to the northwest and northeast. Surface runoff on the paved surfaces proceeds in the direction of slope to the edge of US HWY 158 or SR 1139 where it is directed to an open ditch.

4.4 Surface Water Features

As mentioned previously, the nearest surface water feature is a man-made bay to the Pasquotank River. The "T" shaped bay lies some 300 feet northwest from the UST system. One leg of the "T" is parallel to US HWY 158. The other is perpendicular to the first and extends to the river. The water level in both the bay and the Pasquotank River is influenced by the rise and fall of the tide.

5.0 SOIL INVESTIGATION

5.1 Geologic Setting

The site lies in the Coastal Plain physiographic province of North Carolina. The region is underlain by unconsolidated sediments laid down during the Quaternary period. The region has experienced numerous transgressions and regressions of the ocean over its entire history. The changing depositional environment over time has resulted in a complex interfingering of beds and lenses of sand, silt, and clay.

According to the North Carolina Geologic Map (Brown, et al., 1985), the site lies in an area mapped as sand, clay, gravel, and peat deposits.

5.2 Site Geology

The subsurface geology of the site and immediate vicinity was determined by split-spoon soil sampling and examination of drill cuttings during monitoring well installation, and by grab sampling during the hand augered soil boring investigation (see Section 5.3). Soil lithology was highly variable across the property. From the surface to about 6 feet to 12 feet was intermingle lenses of sands, silts, and clays. From about 6 feet on the southeast side of the property and about 12 feet on the northwest side of the property several of the wells encountered layer of Poorly Graded Sand. This layer, where encountered, graded into a silty clay at about 30 feet.

Figure 5 presents geologic cross-sections based on soil boring logs constructed during monitoring well installation. Figure 6 depicts the surface traces of the cross-sections. Soil boring logs are presented in Appendix C.

5.3 Soil Boring Survey

Soil samples collected from beneath one dispenser during the EI investigation documented the existence of soil impact. In order to define the horizontal and vertical extent of the remaining vadose zone soil contamination, TEC installed four additional soil borings (B15 - B17). Soil borings were concentrated around the dispenser in question. One sample from each boring was selected for submittal to a laboratory for TPH analysis by EPA Method 5030, which targets low boiling point fuels such as gasoline and Method 3550 which targets high boiling point fuels such as diesel fuel. Boring locations are depicted in Figure 7.

5.4 Soil Sampling Protocol and Results

Soil borings were advanced with either a hand auger or a hollow stem auger drill rig. Grab or split spoon soil samples were collected at periodic depths. Each sample was inspected and its lithologic characteristics were recorded.

A portion of each soil sample was placed in a sealable "ziplock" bag for field testing. Bagged samples were allowed to sit for a few moments so that any vapors emanating from the soil could accumulate in the bags headspace. The samples were then tested using a GASTECH organic vapor monitor (OVM). The OVM is a qualitative tool employed to detect the presence of organic vapors. A thin probe from the OVM is inserted through a small break in the bags seal. An air sample from the headspace of the bag is drawn through the probe into the instrument. The instrument utilizes a platinum catalyst to measure the concentration of organic vapors. The concentration is registered on a needle scale in ppm. Soil Boring logs containing soil descriptions and vapor readings are provided in Appendix C. Analytical results for soil samples are summarized in Table 3.

5.5 Extent of Vadose Zone Soil Contamination

The detection of TPH concentrations beneath one dispenser during the EI investigation established the presence of vadose zone soil impact at the site. Analytical results of samples from borings B15 - B17, SB-10 (advanced by EI) and monitoring well MW1 define the lateral extent of impact. The circular plume is limited laterally to within six feet of the dispenser. The soil impact may extend vertically to the water table surface. Samples from borings MW1 and B16 displayed organic vapor concentrations near the water table surface at about 7.5 feet below grade. The lateral extent of vadose zone impact is depicted in figure 7. The estimated vertical extent is shown on the geologic cross-sections (Figure 5).

5.6 Extent of Capillary Zone Impact

Due to the presence of groundwater impact, see section 6.0, a narrow zone of soil contamination may exist at the soil/water interface. This contamination is the result of petroleum compounds in or on the groundwater being retained on the surface of soil in the capillary zone. This zone is usually found in the areas with higher concentrations of groundwater contamination. It may not be a continuous zone due to variations in soil lithologies and petroleum concentrations in the groundwater. In addition, fluctuations in the water table elevation affect the thickness of this zone.

6.0 GROUNDWATER INVESTIGATION

6.1 Local Hydrogeology

The thick accumulation of sediments in the Coastal Plain make porous media a significant repository of precipitation. A large portion of water is also present in surface water bodies such as rivers and sounds. The importance of surface water processes is evident because of the many streams and tidal features in the region.

The mingling of marine and surface processes in the deposition of area sediments has resulted in a complex layering of sands, silts, and clays. In locations where the unconsolidated sediments are underlain by an impermeable or significantly less permeable layer, water may accumulate in the overlying sediment and form a water table or unconfined aquifer. This aquifer is open to the atmosphere and is thus affected by changes in precipitation. The water table aquifer is composed of interfingered sands, silts and clays near the surface grading to a poorly graded sand. The sand layer which was fairly consistent across the property has a gradational contact with an underlying fossiliferous clay bed. The lowest bed likely has sufficient clay to constitute a confining layer by about 40 feet below ground surface.

6.2 Monitoring Well Network

The horizontal and vertical extent of groundwater impact at the site was delineated through analytical data from six groundwater monitoring wells. Five of these wells (MW1 - MW3, MW5 - MW6) are Type II shallow groundwater monitoring wells. The Type II wells were constructed of 2" diameter PVC with the well screens bracketing the water table so that the water levels would be representative of the water table surface. Additionally, this allows for the entry of free product, if present, and for the highest levels of dissolved contaminants to enter the well. MW4 is a Type III deep groundwater monitoring well. It was installed with a 6" diameter outer casing from the land surface to a depth of 25 feet. Following the installation of the outer casing, a 2" diameter PVC monitoring well was installed inside the casing to a total depth of 33 feet. The 2" well was equipped with a 5' length of well screen which allowed for discrete sampling of the lowest portion of the aquifer. Well construction records and monitoring well installation details are included in Appendix C.

6.3 Site Hydrogeology

Information gathered during the monitoring well and soil boring assessment was used to construct two geologic cross-sections (Figure 5). The trace of the potentiometric surface was projected onto the cross-sections in order to illustrate the site hydrogeology.

Observation of the cross-sections reveal that the water table aquifer lies within two soil lithologies. The upper of these two units consists of interfingered lenses of sands, silts, and clays. This layer extends to about six to twelve feet below grade.

The lower unit consists of a poorly graded sand from six to twelve feet down to about thirty feet. A soil sample of the aquifer material from 9 feet below grade was collected and analyzed for grain size distribution. Based on the reported distribution, the soil is a silty sand (Unified Soil Classification System). In addition, an undisturbed soil sample was collected from B16 at 1.5 to 2 feet in depth. A constant head permeameter test was performed on the undisturbed sample. Results of the tests showed a vertical permeability in the unsaturated zone of 3.8 $X 10^{-7}$ cm/sec. Detailed soil boring logs are contained in Appendix C.

6.4 Groundwater Flow Data

Depth-to-groundwater measurements were collected on several dates to identify the location of shallow groundwater and determine the direction of groundwater flow. Groundwater elevation measurements were reduced to a common datum by surveying the relative elevation of the top of the casing for each monitoring well. The water table elevation data was then used to create potentiometric surface maps which illustrate the direction and gradient of groundwater flow (see Figures 8 and 9). Not surprisingly, the maps indicate that groundwater in the water table aquifer is flowing north-northwest toward the Pasquotank River. Table 4 gives the relative elevation and depth-to-groundwater measurements for all monitoring wells installed at the facility.

Hydraulic gradients at the site were consistent over the course of this study. The average hydraulic gradient across the property ranges from .0019 ft/ft to .002 ft/ft.

In order to provide preliminary estimates for hydraulic conductivity (K) and transmissivity (T) for the water table aquifer, slug tests were performed on wells MW5 and MW6. Results of the tests were used to estimate values for the above parameters for the development of the CSA and in preparation for a pumping test which may be required during the development of a corrective action plan. A complete explanation of the slug test procedures, data obtained, and data reduction is included in Appendix D. The preliminary estimates of hydraulic conductivity range from 6.5 ft/day at MW5 to 10.7 ft/day at MW6. These values for hydraulic conductivity fall within the range expected from a silty sand. They are consistent with the grain size analysis performed on an aquifer sample and with the lithologies observed in the field. The preliminary estimates for transmissivity based on an estimated aquifer thickness of 40 feet range from 260 ft^2/day to 428 ft^2 /day.

6.5 Monitoring Well Sampling and Results

After installation, each well was purged and developed to remove fine sediment. This process effectively purged the wells so that a representative sample of groundwater could be obtained. Groundwater samples were collected and stored on ice in appropriate glass containers pending transportation to a qualified environmental laboratory for analysis. Each monitoring well sample was analyzed per EPA Methods 502.2 + MTBE + IPE and 3030c (lead). Analytical results from the groundwater sampling are summarized in Table 5. Complete laboratory reports are contained in Appendix B.

6.6 Extent of Free-Phase Petroleum Product

No free product was encountered in monitoring wells or soil borings at the site during this investigation.

6.7 Horizontal Extent of Groundwater Impact

Monitoring well MW2 was the only Type II well to contain a petroleum constituent in excess of the current standards. Benzene and MTBE were detected in the well at a concentration of 350 ppb and 3,750 ppb respectively. The well is located immediately downgradient from the UST bed. The remaining wells which are located in upgradient, lateral, and downgradient directions showed no detectable petroleum hydrocarbons in excess of allowable concentrations. MTBE is the only compound to have been detected in more than one well. An MTBE isopleth map was prepared, Figure 10. The oval plume of dissolved MTBE extends from the tank bed north-northwest about thirty feet. Complete groundwater analytical results are presented in figure 10.

6.8 Vertical Extent of Groundwater Impact

Analytical results of the groundwater sample collected from the Type III well (MW4) showed one petroleum compound. 1,2,4 Trimethylbenzene was detected in the sample at a concentration of 3.0 ppb. That compound was not detected in any of the remaining wells. The appearance of this constituent at such a low concentration is probably the result of poor drilling decontamination practices and may not represent true groundwater quality. The vertical extent of groundwater impact is estimated to be less than 33 feet below ground level.

6.9 Qualitative Fate and Transport

The dissolved petroleum constituents present in groundwater at the Camden Shell facility will migrate in the direction of groundwater flow by advective transport and dispersion. These processes will tend to extend the plume to the north-northwest toward US HWY 158. Biodegradation, volatilization, and dilution will reduce the concentrations of petroleum constituents in groundwater over time. Advancement of the dissolved plume will continue until either equilibrium conditions are reached, a discharge point is intercepted, or biodegradation processes overtake transport processes.

Equilibrium between the advancing dissolved petroleum plume and retardation factors such as biodegradation, volatilization, and dilution may be reached. If groundwater flow propagates the contaminants at the same rate that retardation forces degrade it, then the plume will cease to advance. If equilibrium is maintained over time, the plume may degrade to below regulatory levels.

If a point of groundwater discharge is intercepted by the dissolved petroleum plume, contaminants may come into contact with surface water. Upon discharge to a surface water body, petroleum constituents in the groundwater would likely be diluted to below detection limits.

Biodegradation may act on the dissolved plume more quickly than groundwater forces advance the plume. In such a scenario, the limits of the plume would be reduced over time.

Impacted soils in the vadose and capillary zones may leach petroleum hydrocarbons into the groundwater. If site conditions remain as they are, petroleum compounds sorbed onto soil particles in the vadose zone will volatilize, biodegrade, or be leached into the groundwater. Volatilization and biodegradation of vadose zone contaminants can greatly reduce petroleum concentrations. Given sufficient time the entire vadose zone and dissolved plumes will dissipate to below detection limits.

7.0 CONCLUSIONS/RECOMMENDATIONS

Based on the findings of the Comprehensive Site Assessment activities conducted at the Camden Shell facility, the following conclusions can be drawn.

- Gasoline has been released into the environment at the subject site resulting in impact to the soil and groundwater. Vadose zone impact remaining in situ is limited to one small area beneath a product dispenser. Petroleum constituents dissolved in the groundwater are present adjacent to the UST bed. Petroleum impact to soil and groundwater delineated during this study does not extend onto adjacent properties.

- Groundwater flows north-northwest across the property and likely discharges into a man-made bay to the Pasquotank River some 250 feet northwest.

- No free product was observed during this investigation. Monitoring wells and borings have been installed and gauged at many locations over the assessment phase of this project. None have revealed any free product.

- At the present time, the soil and groundwater impact does not appear to pose a significant threat to the surrounding human population. Although the site receives its water from a potable well, employees of Camden Shell did not report any suspected contamination of the well. The well is located upgradient from the UST system. The limited vertical and horizontal extent of the dissolved plume will likely preclude it impacting the on-site potable well during the foreseeable future.

In conclusion, petroleum contamination delineated and the Camden Shell is of limited extent and does not appear to pose a significant threat to either the employees at the site or area residents. TEC does, however, recommend that MW4 be resampled to confirm that the petroleum constituent detected there is not representative of groundwater quality.

8.0 LIMITATIONS

This report is limited to the investigation of only petroleum hydrocarbons as gasoline and diesel fuel and does not imply that other unforeseen adverse impacts to the environment are not present at the facility. In addition, subsurface heterogeneities not identified during the current study may influence the migration of groundwater or contaminants in unpredicted ways. The limited amount of sampling and testing conducted during this study can not practically reveal all subsurface heterogeneities. Furthermore, the subsurface conditions, particularly groundwater flow, elevations, and water quality may vary through time. The opinions and conclusions arrived at in this report are in accordance with industry-accepted geologic and hydrogeologic practices at this time and location. No warranty is implied or intended.

TABLE 1
POTENTIAL ON-SITE PETROLEUM HYDROCARBON SOURCES

TANK	SIZE (Gal.)	TYPE	CONTENTS
T1	6000	UST	Gasoline
T2	10000	UST	Gasoline
T3	10000	UST	Gasoline
AT1	500	AST	Waste Oil
AT2	280	AST	Heating Oil

Information obtained from UST database and site inspection.

TABLE 3
SOIL SAMPLE ANALYTICAL SUMMARY

SAMPLE	DEPTH (Ft.)	OVM (ppm)	TPH 3550 (Diesel)	TPH 5030 (Gasoline)
SB-10	1.5-2	--	BRL	BRL
SB-11	1.5-2	--	1,000	1,400
B15	3	0	NA	BDL
B16	3	120	BDL	0.19
B17	3	40	BDL	NA
B18	3	0	BDL	NA
MW1	1-3	0	NA	BDL
MW2	2	680	NA	BDL
MW3	2	0	NA	BDL

NA - Not analyzed by this method.
BDL - below detection limit.
BRL - below regulatory level. As reported by Environmental Investigations.
All concentrations are shown in parts per million (ppm).
Shading denotes a TPH concentration above current regulatory level (10 ppm for gasoline and 40 ppm for diesel).
Samples SB-10 and SB-11 collected by Environmental Investigations.

TABLE 4
GROUNDWATER ELEVATION DATA

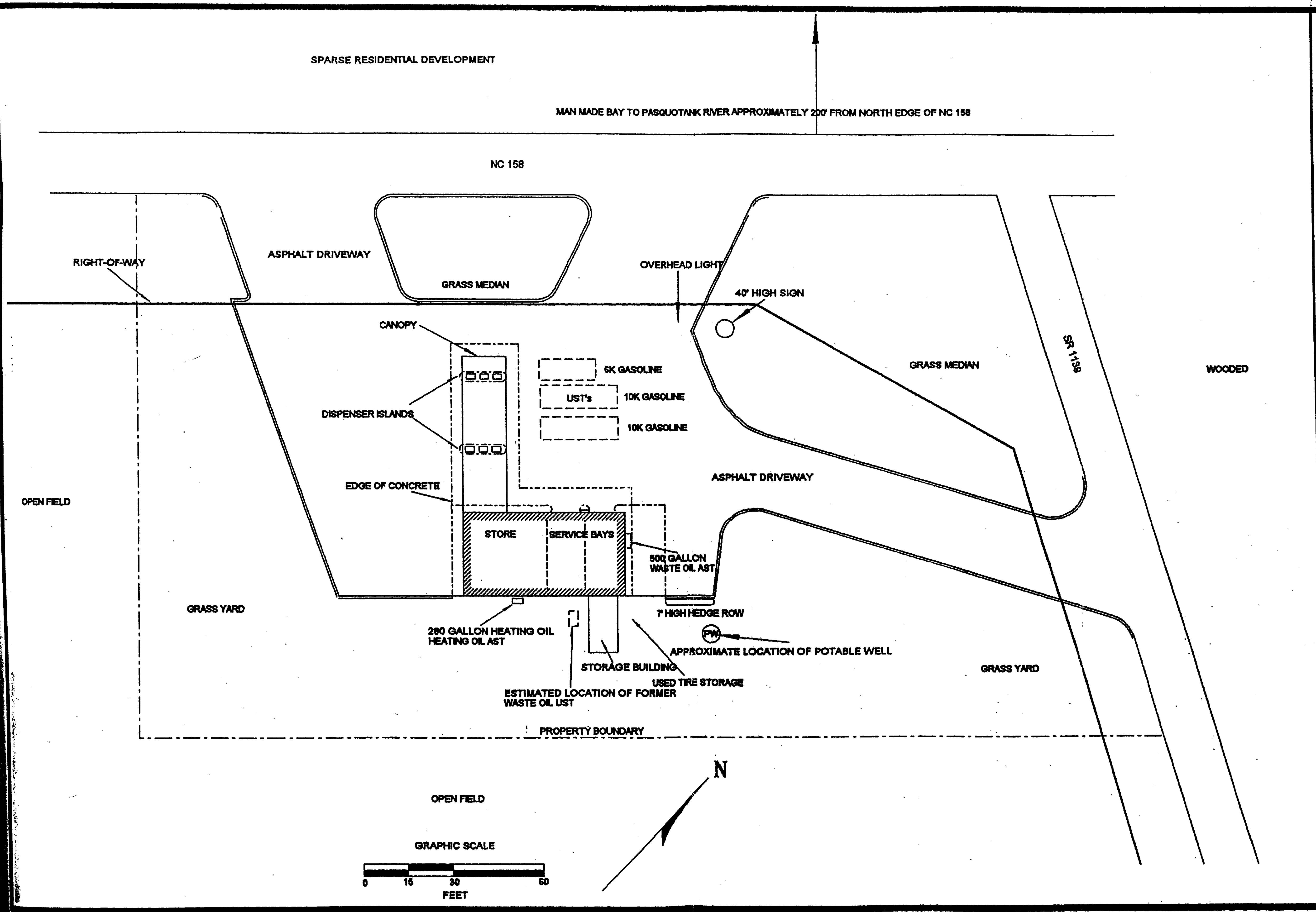
WELL	CASING ELEVATION	DEPTH TO WATER (9-1-94)	DEPTH TO WATER (9-14-94)	WATER ELEV. (9-1-94)	WATER ELEV. (9-14-94)
MW1	100.00	7.34	7.78	92.66	92.22
MW2	99.62	7.07	7.45	92.55	92.17
MW3	100.26	7.55	7.87	92.71	92.39

All measurements are in feet.
All elevations are in feet relative to an arbitrary datum plane of 100'.
Casing elevation = well elevation as measured from top of casing.
Inclimate weather during the site visit after the installation of MW4 - MW6 precluded the measurement of water levels.

TABLE 5
GROUNDWATER ANALYTICAL SUMMARY

ANALYTE	MW1	MW2	MW3	MW4	MW5	MW6	2L LIMIT
Benzene	BDL	350	BDL	BDL	BDL	BDL	1
MTBE	BDL	3,750	BDL	BDL	87	BDL	200
1,2,4, Trimethylbenzene	BDL	BDL	BDL	3.0	BDL	BDL	--
Lead	BDL	BDL	11	BDL	BDL	BDL	15

-- Denotes compound not allowed in any concentration.
BDL = Below detection limit
Shading denotes concentration above T15A NCAC 2L limits.
MW1-MW3 sampled on 8/31/94, MW4-MW6 sampled on 11/7/94
All concentrations are shown in parts per billion.



SITE LAYOUT MAP

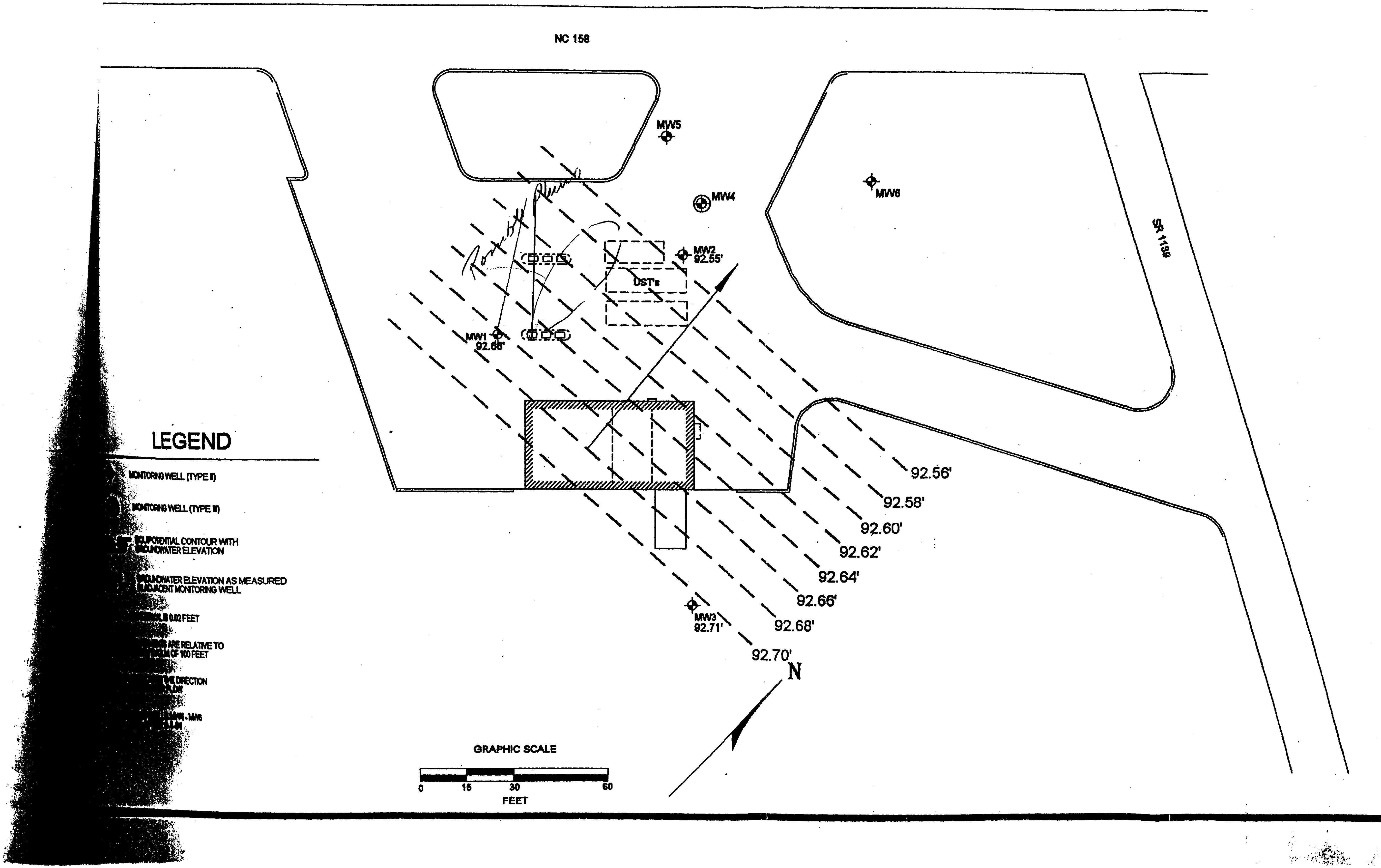
CAMDEN SHELL

QUALITY OIL COMPANY
CAMDEN, NORTH CAROLINA

PROJECT NO:	02694	CHECKED BY:	MJB	FIGURE NO.	2
SCALE:	1"=30'	DRAWN BY:	JMG	DATE:	1-6-95

TURNER ENVIRONMENTAL
CONSULTANTS, P.C.

CARRBORO, NC



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CARRBORO, NC

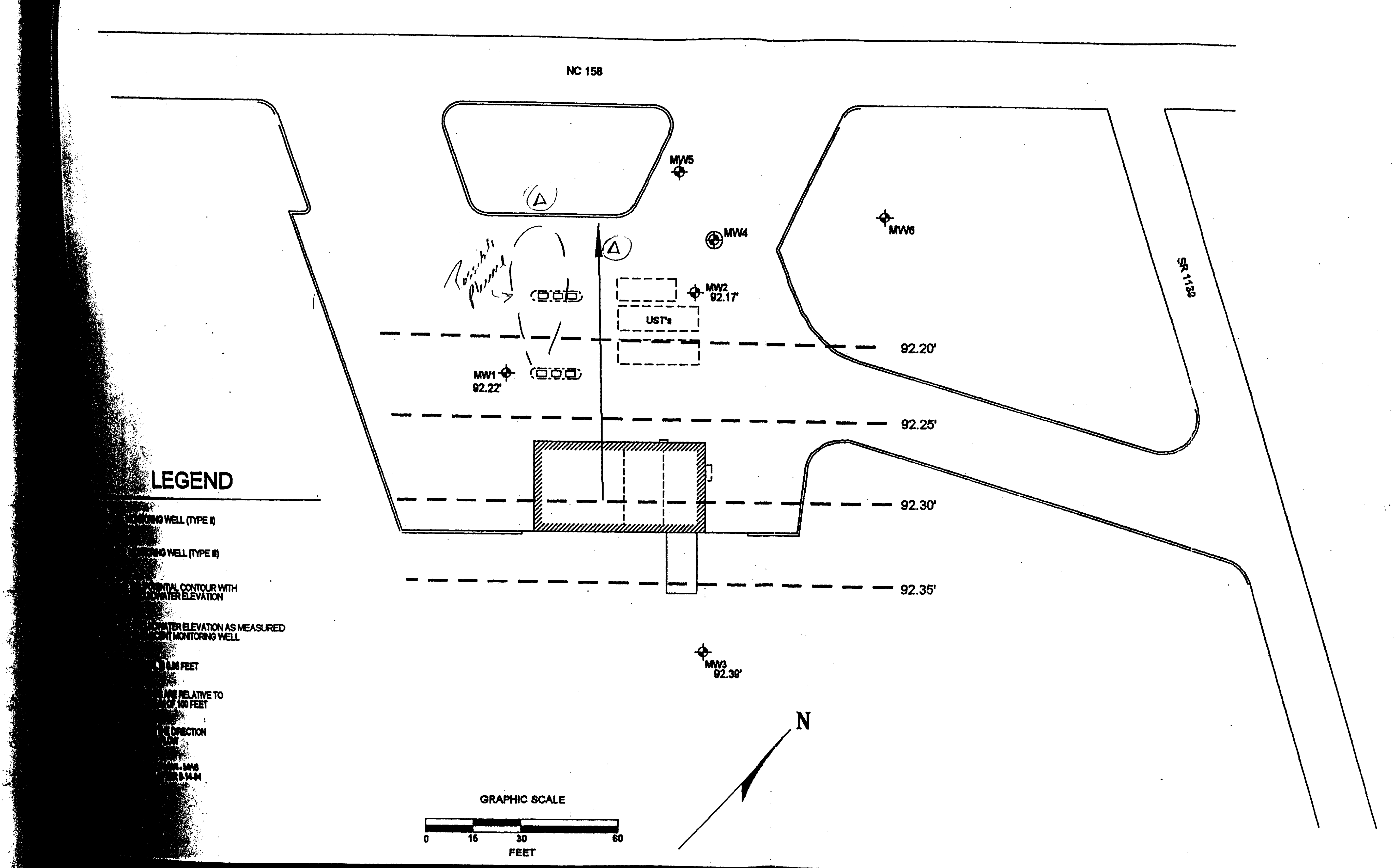
POTENTIOMETRIC SURFACE MAP (9-1-94)

CAMDEN SHELL

QUALITY OIL COMPANY

CAMDEN, NORTH CAROLINA

PROJECT NO:	02694	CHECKED BY:	MJB	FIGURE NO.	8
SCALE:	1"=30'	DRAWN BY:	JMG	DATE:	1-6-95



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CARRBORO, NC

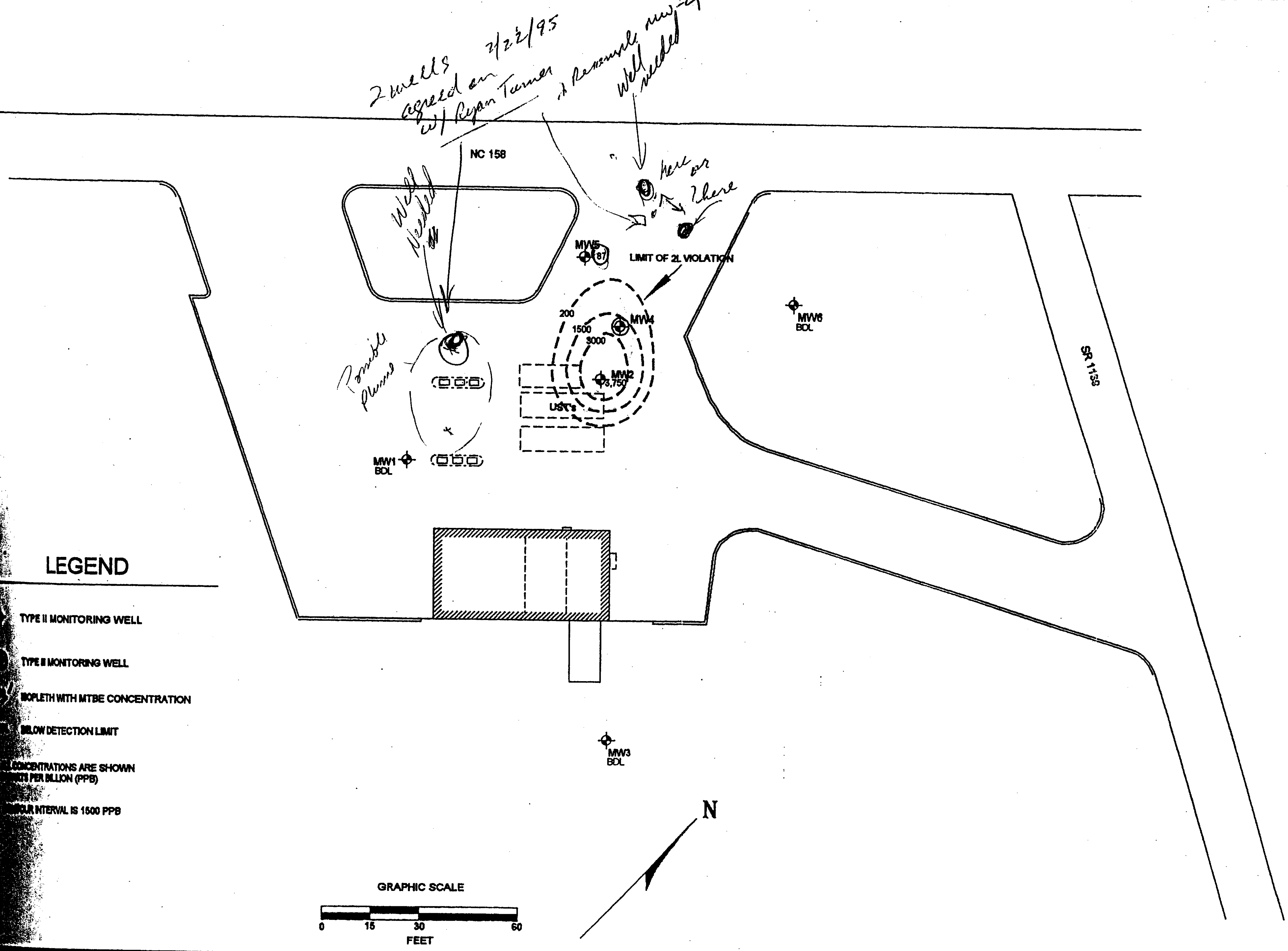
POTENTIOMETRIC SURFACE MAP (9-14-94)

CAMDEN SHELL

QUALITY OIL COMPANY

CAMDEN, NORTH CAROLINA

PROJECT NO:	02694	CHECKED BY:	MJB	FIGURE NO.	9
SCALE:	1"=30'	DRAWN BY:	JMG	DATE:	1-6-95



2 wells agreed on 2/22/95 w/ Ryan Turner

A Reasonable mw-4 well needed

here or there

Well Needed

Possible plume

LEGEND

TYPE II MONITORING WELL

TYPE III MONITORING WELL

ISOPLETH WITH MTBE CONCENTRATION

BELOW DETECTION LIMIT

CONCENTRATIONS ARE SHOWN
PER BILLION (PPB)

INTERVAL IS 1500 PPB

MTBE ISOPLETH MAP

CAMDEN SHELL

QUALITY OIL COMPANY

CAMDEN, NORTH CAROLINA

PROJECT NO:	02694	CHECKED BY:	MJB	FIGURE NO.	10
SCALE:	1"=30'	DRAWN BY:	JMG	DATE:	1-6-95

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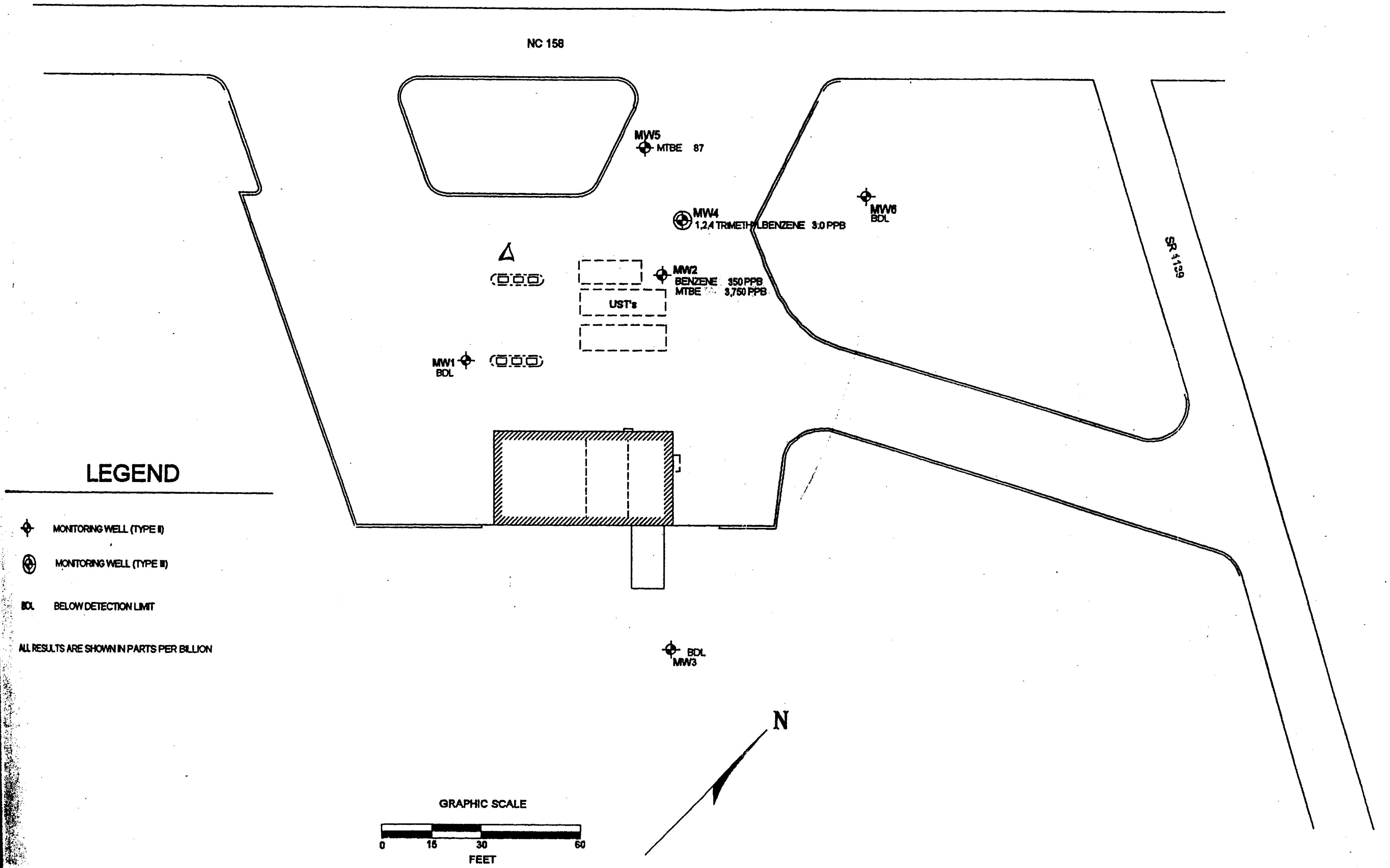

SITE MAP WITH GROUNDWATER ANALYTICAL RESULTS

CAMDEN SHELL

QUALITY OIL COMPANY

CAMDEN, NORTH CAROLINA

PROJECT NO:	02694	CHECKED BY:	MJB	FIGURE NO.	11
SCALE:	1"=30'	DRAWN BY:	JMG	DATE:	1-6-95

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CARRBORO, NC

38

1327
JSB

CORRECTIVE ACTION PLAN

CAMDEN SHELL
US HIGHWAY 158 AT SR 1139
CAMDEN, NORTH CAROLINA

NCDEM GROUNDWATER INCIDENT No. 12706

Prepared For:

Danny Stroud, Vice President of Operations
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RECEIVED
WASHINGTON OFFICE
DEC 20 1995
D. E. M.

October 1995
TEC Project No. 02694

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TABLE OF CONTENTS

1.0 INTRODUCTION

This Corrective Action Plan (CAP) proposes a strategy for reduction of gasoline constituents in soil and/or groundwater at the Camden Shell station in Camden, North Carolina (Figure 1). Underground storage tanks (USTs) which were operated at the facility by Quality Oil Company, Ltd. from 1970 to 1995 released gasoline into soil and groundwater resulting in violation of 15A NCAC 2N regulations. Groundwaters at the site are classified as GA waters and are subject to standards mandated under 15A NCAC 2L .0202(g). Benzene and methyl tert-butyl ether (MTBE) occur in the aquifer beneath the site at concentrations exceeding these standards.

In a Notice of Regulatory Requirements dated 8-1-94 and an untitled correspondence dated 4-21-95, the Division of Environmental Management (DEM) in the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR) instructed Quality Oil Company, Ltd. of Winston-Salem (Quality) to prepare a CAP to alleviate contamination at the site.

Consideration is first given to determine if the site conditions are favorable for natural biodegradation and attenuation of petroleum contaminants in soil and/or groundwater and to determine the risk associated with a passive remediation strategy. Because passive remediation is herein deemed unsuitable, active approaches - including groundwater recovery/treatment, air and bio sparging, and enhanced in-situ bioremediation - are evaluated. For active approaches, the feasibility of a strategy to provide remediation of groundwater to concentrations other than those set by the Director of the DEM in 15A NCAC 2L .0202(g) are considered. (This approach is also referred to as "risk-based" remediation standards determination.) Because the site appears to meet the requirements set forth in 15A NCAC 2L .0106(k), alternate groundwater standards are proposed herein.

The Camden Shell facility is currently owned by Quality. A detailed site plan illustrating the current site layout is depicted in Figure 2. Surrounding property owner information is summarized in Figure 3. The site is currently a convenience store and retail petroleum fuel facility. Table 1 summarizes the USTs which are suspected to have caused the impacts to the site. Note that none of the former UST system is currently in place. It has been completely replaced with an updated system. Figure 4 shows the locations of the former USTs and associated dispensers.

TABLE 1
Former USTs Information

Tank	Size (Gal.)	Type	Status	Contents
T1*	550	UST	Permanently Closed 9-18-95	Kerosene
T2	10,000	UST	Permanently Closed 9-18-95	Gasoline
T3	6,000	UST	Permanently Closed 9-18-95	Diesel
T4	6,000	UST	Permanently Closed 9-1-88	Gasoline

All tanks were installed underground.
All tanks were constructed of fiberglass-lined steel.

According to the UST database maintained by the NCDEM, tank T4 was permanently closed in September 1, 1988. TEC removed and permanently closed the remaining USTs (T1-T3) on September 18, 1995.

Preliminary assessment and corrective actions completed to date include the following items, which are listed in chronological order of completion:

- Environmental Investigations, P.A. performed a preliminary site assessment in February 1994. One soil sample was found to contain elevated concentrations of gasoline and diesel.
- Turner Environmental Consultants, P.C. (TEC) initiated site characterization activities in August 1994. Groundwater from one monitoring well was found to contain

benzene and MTBE at concentrations in excess of standards set forth in 15A NCAC 2L .0202(g).

- TEC submitted a comprehensive site assessment (CSA) report to the Washington Regional Office of the DEM in January 1995. Soil and groundwater containing petroleum constituents were delineated in the CSA.
- TEC supplemented the original CSA with an addendum in April 1995. This addendum provided additional delineation of the groundwater plume.
- TEC supervised the permanent removal and closure of the former UST system in September 1995. All identified vadose zone soil which contained petroleum hydrocarbons was excavated and removed from the site for disposal at an off-site facility.
- TEC conducted an air sparging pilot test in August 1995.

Previous reports generated for the Camden Shell facility include the following:

- Preliminary Site Assessment Report prepared by Environmental Investigations, P.A., March 1994. Report was submitted to NCDEM Washington Regional Office (WaRO) on April 28, 1994.
- Initial Abatement Measures and Initial Site Characterization Report prepared by TEC in October 1994. Report was submitted to WaRO on October 11, 1994.
- Comprehensive Site Assessment Report prepared by TEC in January 1995. Report was submitted to WaRO on January 18, 1995.
- Comprehensive Site Assessment Addendum prepared by TEC in April 1995. Report was submitted to WaRO on April 17, 1995.
- Underground Storage Tank Closure Report prepared by TEC in November 1995. Report was submitted to WaRO on November 16, 1995.

No previous permits or certificates that relate to environmental assessment or remediation have been issued for the site.

2.0 SUMMARY OF SITE ASSESSMENT ACTIVITIES

This section provides a condensed description of the findings presented in the CSA Report prepared by TEC. For more detailed presentation of the following topics, the reader is referred to CSA Report.

2.1 Hydrogeology

Vertical and horizontal soil compositions are variable across the property. The upper 6 to 12 feet consists of intermingled lenses of sands, silts, and clays. The composition and structure of this upper unit depend on horizontal location.

Below the upper soil unit (from about 6 feet depth on the southeast side of the property and about 12 feet on the northwest side of the property) several of the wells encountered a well defined uniform sand. This layer, where encountered, graded into a third unit of silty clay at about 30 feet.

Figure 5 presents geologic cross-sections based on soil boring logs compiled during monitoring well installation. Figure 6 depicts the surface traces of the cross-sections. Monitoring well locations are shown on this drawing.

Cross-sections are constructed from available data and represent a reasonable interpretation of stratigraphy. The three basis units can be seen in the profiles. Note the horizontal variation in composition of the uppermost unit. In general, it consists of lenses of varying proportions of sand, silt, and clay. Encountered USCS soil types include SC, ML, and CL. Soil boring logs are presented in the CSA report.

An unconfined aquifer exists at the site. The aquifer exists within the upper two stratigraphic units with the water table occurring approximately 7 to 8 feet below ground surface (based on available measurements). Given the high clay content of the third (lowermost) unit, it may behave as an aquitard to vertical migration.

Groundwater flow direction in the water table aquifer is depicted on Figure 7. The gradient trends to the north-northwest toward the Pasquotank River. The measured gradient is approximately 0.002 ft/ft.

Two rising head slug tests were performed in wells MW5 and MW6. The results for hydraulic conductivity are 6.5 ft/day and 10.7 ft/day, respectively. Wells MW5 and MW6 are both screened within the clayey sands of the uppermost soil unit. Estimates of aquifer transmissivity, based on an aquifer thickness of 40 feet, range from 260 ft^2/day to 428 ft^2/day.

2.2 Extent of Free Product

To date, free product has not been encountered on the premises. Free product monitoring has consisted of gauging monitoring wells with an electronic interface probe (capable of detecting a product thickness of 0.01 ft or larger) and visual examination of groundwater in the UST bed during closure.

2.3 Soil Analyses and Impacts

Soil samples were collected during the CSA field activities and in conjunction with soil excavation for the UST closure. As identified in the CSA report, petroleum impacts to vadose zone soils were limited to an area around the former dispenser island. The impacted area is shown in Figure 8. During the UST system closure, **this area of contamination was excavated and disposed**. (See Section 3.0 Initial Abatement Measures for discussion of soil excavation activities). Confirmation samples collected from sidewall samples revealed the area of impact had been removed.

Consequently, there is currently no recognized vadose zone soil contamination which requires remediation.

2.4 Groundwater Analyses

Eight monitoring wells have been installed on site. Each well has been sampled and analyzed by EPA Method 502.2 + MTBE + IPE and 3030c for Lead. One monitoring well, MW2, contained concentrations of target analytes which exceed the groundwater standard established by 15A NCAC 2L .0202(g). Benzene and MTBE were detected at 350 μg/l (ppb) and 3,750 μg/l, respectively. The well is located immediately downgradient from the UST bed.

The remaining wells, which are located in upgradient, lateral, and downgradient directions, showed no hydrocarbons in excess of allowable concentrations. MTBE is the only compound to have been detected in more than one well. Groundwater analytical results are depicted in Figure 9.

Analytical results of the groundwater sample collected from the Type III well (MW4) showed one petroleum compound. The volatile aromatic 1,2,4-Trimethylbenzene was detected in the sample at a concentration of 3.0 μg/l. That compound was not detected in any other well. A second sample collected from MW4 in March 1995 did not contain this compound. The appearance of this constituent at such a low concentration during only one sampling event is probably the result of poor drilling decontamination practices and may not represent true groundwater quality. The vertical extent of groundwater impact is estimated to be less than 33 feet below ground level.

2.5 Air Sparging Pilot Test

TEC conducted an air sparging pilot test at the site on August 24, 1995. Data listings and plots are provided in Appendix A. The test consisted of injection of compressed air into one sparging well and monitoring of water level, dissolved oxygen (DO), and temperature in observation wells.

Prior to initiation of the test, DO levels were measured in the existing monitoring wells (except for the Type III well, MW4). Table 2 summarizes the readings. Note that the DO levels in the outlying wells MW3 and MW6 are approximately an order of magnitude higher than wells MW1, MW2, MW5, and MW7 which are within or close to the plume. This apparent depletion of background DO near the plume is probable evidence that microbes are aerobically degrading dissolved hydrocarbons.

TABLE 2
Pre-Sparging Dissolved Oxygen Concentrations in Monitoring Wells
Camden Shell, Camden, NC

Well ID	Initial DO (μg/L)
MW1	0.2
MW2	0.2
MW3	5.0
MW5	0.6
MW6	4.3
MW7	0.3
MW8	2.2

Various air injection rates were applied to investigate aquifer responses. The injection rates ranged from 1.6 scfm to 3.5 scfm. The reader is referred to Appendix A for details on test results.

In general, increases in DO and water table elevation were observed in the monitoring wells closest to the injection well. Bubbles were observed in several of the monitoring wells.

Water table mounding in the nearby wells was substantial at the higher air flow rates. Additionally, the areal pattern of mounding around the injection well took an elliptical pattern (based on available observation points) with the major axis oriented approximately north-south. TEC suspects the reason for this bias is the heterogeneity in the upper unit of the aquifer.

The test was run for a relatively short period (less than 12 hours). It is possible that over longer periods of time the mounding observed would subside as the subsurface air flow and groundwater response settled into a state of equilibrium.

In summary, the results of the test indicate that air sparging in the range of flows implemented during the test caused substantial mounding in nearby wells such that, under the conditions of the pilot test, this method of remediation might not be suitable for the site. The presence of soils containing relatively high percentages of clay and silt in the vadose zone and upper portion of the aquifer is also a factor which may not favor air sparging. Overlying clay lenses interrupt the upward flow of air bubbles into the vadose zone. This vertical barrier could cause an unacceptable degree of vapor migration if flow rates are not carefully controlled.

Alternatively, the increase in DO due to air injection indicates that lower flow rates may be effective for a bio-sparging application. Lower flow will produce less mounding, and the increase in DO would benefit in-situ aerobic microbes which have adjusted to using hydrocarbons as a carbon source.

In conjunction with the pilot test, groundwater samples were collected and tested for dissolved iron content (ferrous iron, Fe^{2+}). The groundwater pH was also tested in several wells. Table 3 summarizes the results from these tests.

Table 3
Summary of Dissolved Iron and pH
in Monitoring Wells
Camden Shell, Camden, NC

Well ID	Dissolved Iron (mg/L)	pH
MW2	36	6.8
MW3	7.3	6.3
MW5	3.2	(not tested)
MW7	9.5	(not tested)

Note that samples collected for dissolved iron testing were placed in containers preserved with nitric acid. This preservative would have lowered the sample pH to approximately 2 units. At this lowered pH, both ferrous and ferric iron are much more soluble than at normal pH (6-8 units). Thus, it is reasonable that the dissolved iron concentrations present in the samples are higher than the actual concentrations in-situ. Nevertheless, only one of the four samples exceeds the recommended maximum concentration of 20 mg/L for sites where sparging is being considered.

3.0 INITIAL ABATEMENT MEASURES

As previously mentioned, initial abatement measures completed at the site include removal of the former UST system and removal of petroleum-impacted soils.

The UST system responsible for the release was permanently closed in September 1995. All identified vadose zone soil impact at the site was removed during the UST closure. At the outset of the UST removal operation, defined impact was limited to a small area beneath the southern most dispenser island. It extended no further than approximately six feet from one of the former dispensers and was expected to extend vertically to the water table. A volume of soil approximately 12' x 12' x 9' was removed from that area.

As the excavation of the USTs progressed, some of the tank bed backfill was also observed to posses a petroleum odor. This material was segregated from material that did not possess an odor. It was subsequently tested with an organic vapor monitor (OVM). All soil which possessed a vapor concentration exceeding 100 ppm was stockpiled.

A sheen of product was present on groundwater which infiltrated the excavation overnight. The product was not of retrievable volume but a portion was removed with impacted soils.

Once all of the impacted soil had been removed, samples were collected from the sidewalls of the excavation. The samples were tested for petroleum vapors with the OVM. Results of the testing showed moderate concentrations of vapors along the north wall of the excavation. An additional three feet of soil was removed from that area. Samples which displayed low or no concentration of vapors were immediately sealed into laboratory prepared containers and placed on ice for transport to an environmental laboratory for analysis.

A second set of samples was collected from the north sidewall and tested as before. The final limits of the excavation with sample locations and laboratory results are shown in Figure 10. Once all of the impacted soil had been removed from the tank bed, the soil that had been segregated as clean was returned to the tank bed. The soil was spread evenly across the bottom of the pit. The remainder of the pit (approximately 8 feet of depth) was backfilled with sand from a local quarry.

Each sample submitted to the laboratory was analyzed by EPA Method 5030. In addition, five samples - SW5, SW6, SW7, SW8, and SP1 - were analyzed for TPH by EPA Method 3550. The additional analyses were performed because a TPH concentration as diesel was detected beneath the dispenser during the initial site work conducted by Environmental Investigations. The sidewall samples (designated with SW) were collected from the limit of the excavation in that area.

Results of the analyses show no TPH concentrations above the established standards in any of the samples. Analytical results are summarized in Table 4. Complete laboratory reports were included with the UST Closure Report which is on file with the Washington Regional Office of the NCDEM.

A composite sample, SP1, of the contaminated soil stockpile was collected and analyzed for TPH. Results of the analyses showed the soil to contain a TPH concentration of 52.8 ppm as gasoline. No concentrations were found as diesel. On September 22, 1994, 289.5 tons of impacted soil were transported from the subject site to Environmental Soil Services, Inc.'s facility in Elizabeth City, NC for treatment by bio-remediation.

Table 4
Soil Sample Analytical Summary

Sample No.	Depth(ft)	OVM Reading	TPH by 5030	TPH by 3550
FP1	3	80	719	–
FP2	3	>1000	529	–
FP3	3	>1000	1,094	–
SW1	6	10	BDL	–
SW2	6	60	BDL	–
SW3	6	40	BDL	–
SW4	6	18	BDL	–
SW5	6	10	BDL	BDL
SW6	6	10	BDL	BDL
SW7	6	10	4.78	BDL
SW8	6	10	4.43	BDL
SW10	6	30	BDL	–
SW11	6	35	BDL	–
SW12	6	40	BDL	–
SB11	1.5-2	unknown	1,400	1,000
SP1	–	>1,000	52.8	BDL

All concentrations are shown in parts per million (ppm).
BDL = below detection limit
N/A = not applicable
– = sample not analyzed by method.
Sample SB11 was collected by Environmental Investigations on February 23, 1994.
Shading denotes a TPH concentration above the established limit (10 ppm by Method 5030 and 40 ppm by Method 3550).

4.0 EXPOSURE ASSESSMENT AND CAP OBJECTIVES

4.1 Physical and Chemical Characteristics of Contaminants

Selected physical and chemical properties of petroleum hydrocarbons identified by the CSA are summarized in Table 5.

4.2 Site Setting and Regional Land Use

The site is located in a predominantly rural-residential section of Camden County, NC. Ernie Swanner of the Camden County Planning Office indicated to TEC that the vicinity of the site is zoned highway-commercial. Currently, there are no plans for any particular development in the vicinity. Highway 158 has recently been expanded to 3 lanes at the site and is currently being expanded to 3 lanes north of the site.

4.3 Site and Regional Water Supply

The site and the surrounding properties are dependent on private water wells for water supply. Properties with identified potable water wells are the following (see Figure 3):

- Camden Shell facility;
- the lot of Mr. and Mrs. George Griffin (across Hwy. 158 from the site);
- the lot of William Metzger (southwest across Hwy. 158 from the site);
- the lot due south of William Metzger.

It is noted that, as of November 1995, the local area does not have a completed municipal water supply system. Thus, TEC expects that other private residences will be served by potable water wells not explicitly listed herein.

However, construction of a potable water supply network in the community is currently in progress. TEC contacted Phyllis Timmerman of the Town of Camden on September 28, However, construction of a potable water supply network in the community is currently in progress. TEC contacted Phyllis Timmerman of the Town of Camden on September 28, 1995 to discuss the water supply project. Ms. Timmerman indicated that the project was being conducted in phases and that all phases would be complete (and water available to all local establishments) by the end of May 1996. As of this conversation, water pipes were already in place along Highway 158 across from the site.

The well of Mr. and Mrs. George Griffin (see Figure 3) is the closest third party well to the site and the only well identified that is directly downgradient of the hydrocarbon plume. TEC spoke with Mrs. Griffin by phone on September 11, 1995. She indicated that she was using the potable well for all their water needs, but she intended to subscribe to the City water supply as soon as it became available. (The water in the aquifer they tap has a high sulfur content and, thus, objectionable taste and odor.) Thus, it is reasonably assumed that the Griffin well will not be a potential receptor after May 1996.

Camden has not developed any local water resource for public supply. For its new water distribution system, the Town will purchase water from Elizabeth City. Camden County Manager, John Smith, indicated to TEC that Camden has no future plans to develop any of its water resources for public supply.

Elizabeth City obtains its water from production wells. The well field is located west of Thunder Road, which is west of the town. The closest production well is approximately 5 miles from the Camden Shell station.

Appendix F contains phone logs of conversations with city officials regarding the local water supplies.

TABLE 5
SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF DETECTED COMPOUNDS

COMPOUND	SOL.	S.G.	V.P.	Henry's Constant (atm)	B.P. (°C)	Log K_{ow}	K_{oc}	HALF LIFE (Days)[1]	BIODEGRADABILITY
Benzene	1780 (20)	0.879	76 (20)	230	80	2.11	97	68	>0.1
MTBE	48,000 (20)	0.73	245	196	55	NA	NA	NA	NA

Density in g/mL
SOL - Solubility in mg/L (@°C)
V.P. - Vapor Pressure in mm of Hg (@°C) and 1 atm.
K_{ow} - Octanol/water partition coefficient
S.G. - Specific Gravity (dimensionless value)
B.P. - Boiling point
NA - Not available
K_{oc} - Adsorption coefficient

[1] Environmental Condition Half Life: Naturally occurring soil-groundwater system

Biodegradability: <0.01 Relatively undegradable, 0.01-0.1 Moderately degradable, >0.1 Relatively degradable

Sources: Nyer (1993), Lewis (1993), Walton (1988), Fetter(1988), Nyer (1992)

4.4 Potential Human Exposure Pathways

Table 6 summarizes potential exposure pathways and the qualitative risk of exposure associated with each pathway. The risks are specific to the site and are assigned on a subjective basis with consideration to site conditions.

TABLE 6
SUMMARY OF EXPOSURE PATHWAYS
AND QUALITATIVE RISK

MEDIUM	INGESTION (EATING)	INGESTION (DRINKING)	INHALATION	ADSORPTION
Free Product	None	None	-	None
Soil	None	-	-	-
Groundwater	-	Low	-	Low
Vapor	-	-	Low	-

(-) indicates method of exposure is not applicable.
SCALE: None / Low / Moderate / High / Very High

4.5 Potential Effects of Residual Contamination

4.5.1 Soil

As mentioned in Section 2.3. There is currently no recognized soil contamination at the site. Contaminated soils identified during the CSA were removed via excavation during the UST closure phase.

4.5.2 Groundwater

Petroleum hydrocarbons dissolved in groundwater will continue to migrate by advective transport and dispersion until equilibrium conditions are achieved. These processes will extend the plume in all directions. To a lesser degree, the plume will be extended in the upgradient and lateral directions. Based on review of available site data, no potential receptors are in immediate danger of being impacted. If private water wells continue to operate in the vicinity and no further actions are taken to alleviate or control groundwater contamination, one or more wells could become impacted at some point in the future. The Griffin well and the Camden Shell well are the closest and the most likely to be impacted.

Discharge of contaminated groundwater could also occur to the Pasquotank River if the plume remains intact long enough to reach the river. Discharge to the river would occur via seepage through the sediments in the river bed. However, given the slow groundwater velocity and the dilution which would occur in the plume as it approaches the river, the rate of mass transfer of petroleum hydrocarbons into the river would be expected to be so low that violations to surface water quality standards resulting from this discharge would be unlikely.

4.6 Corrective Action Goals and Target Cleanup Levels

The primary goal of corrective action is to restore the site groundwaters to protect the integrity of nearby groundwater and surface water resources. A risk-based approach has been taken in establishing standards to which the site groundwaters should be restored. Cleanup goals other than those provided in 15A NCAC 2L .0202(g) are proposed based on computer modeling of contaminant fate and transport. A nearby potable water well and the Pasquotank River have been designated as the critical receptors based on proximity, and the modeling effort investigates the potential of impacting these receptors.

4.6.1 Contaminant Transport Modeling

The fate and transport of dissolved contaminants in groundwater are controlled by the processes of advection, dispersion, sorption, degradation, and volatilization. These mechanisms are briefly discussed in the following paragraphs.

Advection

In a groundwater system, advection is the movement of groundwater from a location of higher hydraulic energy to a point of lower hydraulic energy. The rate of movement is dominated by the viscosity of the liquid, the hydraulic gradient, and the permeability of the aquifer medium. Dissolved contaminants are transported through the aquifer with the movement of groundwater.

Dispersion

Dispersion is a process of spreading or diluting substances within the aquifer. Dispersion results from two principal mechanisms: molecular diffusion and advection through porous media. It is dependent on the chemical properties of the compound, the physical structure of the aquifer, and the hydraulic gradient. Dispersion does not cause a mass reduction of hydrocarbons. Rather it acts to dilute the plume by spreading. Increased dispersion can enlarge the size of a dissolved plume while decreasing the concentration of the plume at a given point.

Sorption

Sorption is the process by which hydrocarbon molecules adhere to solid particles in the soil matrix. It is highly dependent on the chemical characteristics of the compound and the organic fraction of the soil matrix. Sorption does not contribute to mass reduction of hydrocarbons in the aquifer, but serves to immobilize a fraction of the contaminants. Consequently, increasing sorption can increase the total residence time of the release while decreasing the dissolved fraction and, thus, the groundwater concentrations.

Degradation

Degradation results in a chemical change in the dissolved compound to a different compound or to its component elements. It can occur through abiotic and biotic processes, depending on the chemical. In groundwater remediation of petroleum fuels, focus is often placed on degradation caused by biological processes, and of these, catabolism through aerobic pathways is often more significant than anaerobic. (Catabolism is the metabolic process of breaking substances down to less complex substances.) Degradation is highly complex and varied, but in general, it results in the actual removal of a compound from the aquifer. Thus, it reduces contaminant concentrations and can play a significant role in attenuation.

Volatilization

Volatilization is a mass transfer process of dissolved-phase compounds into the vapor phase. In the subsurface, it occurs principally in the capillary fringe. The occurrence of volatilization depends on the chemical properties of the compound, the physical conditions of the environment, and the composition and structure of the soil matrix. Like degradation, volatilization results in a mass reduction of dissolved hydrocarbons and the subsequent reduction in dissolved concentrations.

Mathematical formulations have been developed by researchers to predict the impact that these processes will have on the rate and direction of contaminant travel in the groundwater environment (e.g., Anderson, 1984; Cherry, Gillham & Barker, 1984; Gillham & Cherry, 1982; Mackay, Roberts & Cherry, 1985). When site specific parameters such as the average groundwater flow velocity, dispersion coefficients, contaminant decay, retardation and others are incorporated into the mathematical models the future distribution of contaminants at a given time can be estimated. Plots of the predicted plume movement can then be generated and used as a tool to evaluate the spread of contaminants in the groundwater environment.

Two dimensional versions of the advection-dispersion equation have been incorporated into analytical computer models (Cleary, R.W. & Ungs, M.J., 1978) so that more realistic predictions of the plume migration can be achieved. Analytical models are best used as primary tools of analysis where costs or lack of a multi-dimensional data base preclude the use of sophisticated numerical models. Analytical models are much easier to apply than numerical models. They do not require knowledge of numerical methods and parametric data can be input quickly and inexpensively. Practical applications of analytical models include:

- Design of pump and treat systems;
- Cost apportionment for cleanup when several plumes from different sources merge into one plume;
- Predicting the impact of a potential source of contamination;
- Generation of concentration vs. time predictions at sensitive receptors.

The one dimensional form of the advection-dispersion equation for nonreactive dissolved constituents in saturated, homogeneous, isotropic, materials under steady-state, uniform flow is given below:

$$\frac{\partial C}{\partial t} = D_I \frac{\partial^2 C}{\partial t^2} - v_I \frac{\partial C}{\partial I} \qquad \textbf{[5.1]}$$

Where: D_l = *(dispersion coefficient)* = $\propto_l v_l + D^*$
$\propto_l$ = *(dispersivity) = (0.1)l* [1]
v_l = *(groundwater flow velocity)*
C = *represents the concentration of the contaminant*
l = *is the distance from the source in the downgradient direction*
D^* = *is the effective molecular diffusion coefficient*

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[1] one-tenth rule used to estimate dispersivity value as recommended by EPA (1985) and Lallemand-Barres & Peaudecerf (1978)

A solution to the partial differential equation is obtained when certain boundary conditions are applied. Specifically it is assumed that the background concentration is zero, the source concentration does not decay with time, and the aquifer extends far beyond the area of inquiry. The solution as given by Ogata (1970) is:

$$\frac{C}{C_0}=\frac{1}{2}\left[erfc\left(\frac{l-vt}{2\sqrt{D_I t}}\right)+\exp\left(\frac{vl}{D_I}\right)erfc\left(\frac{I+vt}{2\sqrt{D_I t}}\right)\right] \qquad \textbf{[5.2]}$$

Where: erfc = *complimentary error function (values in Appendix V, Freeze & Cherry, 1979)*
t = *time in days*
(other parameters as previously defined)

When site specific parameters are incorporated into equation 5.2, a concentration profile can be obtained for any point downgradient of the source at any given time. The concentration profile is expressed as a fraction of the initial concentration (C/C_O) and may be plotted as a function of time or distance.

In order to estimate the future migration of the contaminant plume beneath Camden Shell, TEC has applied site specific parameters to the analytical advection-dispersion models developed by Cleary and Ungs, 1978. Known values for the groundwater flow velocity and estimated values for the dispersivity, contaminant decay and retardation were used to predict concentration profiles for the nearby Griffin residential well and the waters of the Pasquotank River.

Measured values from site assessment and published values and ranges were used for the necessary input parameters. Where actual field data were not available, conservative values from published ranges were used. Table 7 summarizes the input parameters, the typical ranges, and the values chosen for the simulations.

4.6.2 Model Sensitivity Analysis

Analytical flow and transport models are sensitive to parametric input including:

- Contaminant decay rate (K)
- Source decay rate (Gamma)
- Contaminant retardation (RD)
- Groundwater seepage velocity (v)

A model sensitivity analysis was performed to determine which parameters had the greatest affect on model output. A base model was constructed using the lowest and most conservative estimates of model parameters. Values for contaminant decay and retardation were then varied across the range of reported values to determine model sensitivity.

Note that the contaminant decay and retardation parameters used herein were assumed to represent the bulk decay and retardation characteristics of the entire hydrocarbon plume rather than specific compounds comprising the plume. In reality, these parameters are compound-specific. Thus, individual compounds will decay and migrate at different rates. However, the use of very conservative values for decay and retardation makes this bulk "averaging" assumption reasonable. The plume is assumed to decay and migrate at one bulk rate.

The sensitivity analysis was not performed with respect to the source decay rate (gamma) or the groundwater seepage velocity (v) because the final model was constructed assuming that the source did not decay at all (the most conservative case for decay). Groundwater seepage velocity is calculated using existing information for the site.

Results of the analysis indicate that model output was most heavily affected by contaminant decay (K) and is less affected by contaminant retardation (RD). Results of the sensitivity analysis are included in Appendix B.

TABLE 7
RANGE AND ASSUMED VALUES FOR MODEL PARAMETRIC INPUTS

Parameter	Symbol	Range of Values	Assumed Value	Reference
Groundwater Seepage Velocity	v	Very Wide	0.03 ft/day	Site specific - based on average hydraulic conductivity values from slug tests and known hydraulic gradient at site
Hydraulic Conductivity	k	6.5 ft/day - 10.7 ft/day	10 ft/day	Site specific - falling head slug tests conducted on wells MW5 & MW6
Contaminant Decay	K	0.0002/day - 0.025/day	0.0002/day	• Prince Model Documentation • Cleary & Ungs, 1978
Source Decay	Gamma	0.000/day - 0.05/day	0.000/day	Not applicable - source was not assumed to decay
Contaminant Retardation	RD	1.00/day - 1.96/day	1.05/day	Thomas, et al, 1988
Longitudinal Dispersion	Dx	0.29ft^2/day- 2.95ft^2/day	0.72 ft^2/day	• Prince Model Documentation • 1/10 rule used to calculate dispersivity (α) as recommended by EPA (1986) and Lallemand-Barres and Peaudecerf (1978)
Lateral Dispersion	Dy	0.077ft^2/day- 0.77ft^2/day	0.07 ft^2/day	Prince Model Documentation

4.6.3 Modeling Results

Two-dimensional concentration profiles were generated for the Griffin well and the Pasquotank River to predict the time of arrival and the concentration of the contaminant plume as it migrates under the natural processes of advection and dispersion. The Griffin well is approximately 150 feet downgradient of the leading edge of the plume, while the Pasquotank River is approximately 250 feet from the plume.

The primary purposes of generating the concentration profiles are:

- to determine if the plume, under the condition of no remediation effort, will reach the Griffin well before or after that residence has subscribed to the City water supply in May 1996;

- to determine appropriate risk-based cleanup standards for the contaminant plume.

The model was used to generate a time versus concentration profile for the Griffin well assuming no remediation occurs on site. The plot is depicted in Figure 11. This plot represents the predicted concentration of the hydrocarbon plume (or individual compounds) at the Griffin well as a function of time. Results of this analysis indicate the following:

- the leading edge of the plume will reach the well on or after May 1995. (Note that the actual plume had not reached the downgradient edge of the site, much less the well, as of that date. Thus, the model predictions are artificially conservative.)
- the maximum concentration at the well will occur on or after September 2005, which is 5,300 days after the release;
- the maximum concentration at the well is predicted to be 5.4% of the concentration at the release.

Although the model predicts the plume will reach the Griffin well on or after May 1995, we know from field observations that this occurrence has not happened and will not happen in the immediate future. To date, the plume has not moved beyond the property boundary of the site. Thus, the model predicts faster migration than is actually occurring.

Based on field observations, it is reasonable to conclude that the Griffin well will not be impacted prior to its abandonment, which is assumed to occur in May 1996.

4.6.4 Risk-based Cleanup Standards

Using the model refinements indicated from sensitivity analysis, an exposure assessment of the Pasquotank River was conducted. Instead of the Griffin well, the river was chosen as the sensitive receptor because the indications from field observations were that the Griffin well would be abandoned by the time the plume actually reached it.

The model was used to generate a time versus concentration profile for the river. The plot is depicted in Figure 12. This plot represents the predicted concentration of the hydrocarbon plume (or individual compounds) at the river as a function of time. The results of this analysis indicate the following:

- the leading edge of the plume will reach the river on or after September 1997 (2,734 days after the release);
- the maximum concentration at the river will occur on or after March 2013 (8,000 days after the release);
- the maximum concentration is predicted to be approximately 2% of the release concentration;
- the maximum concentrations for various compounds will be less than current groundwater standards for Class GA waters if the site is cleaned up to the concentrations provided in Table 8.

TABLE 8
Risk-Based Cleanup Concentrations
Camden Shell, Camden, NC

Compound	Concentration (µg/L)
Benzene	48
Toluene	47,620
Ethylbenzene	1,381
Xylenes	19,048
MTBE	9,524

This risk-based analysis shall be adopted in the establishment of alternate cleanup standards. The methodology is very conservative, since even if groundwater were to intercept the river at current groundwater standards, the likelihood of surface water standards being violated by infiltration of contaminated groundwater is low. Dilution of groundwater into the surface water would likely reduce the concentrations to acceptable levels.

It is important to note that the use of the river as the eventual receptor assumes that all the downgradient potable water wells will be abandoned in lieu of the new City water supply, which is scheduled to be available May 1996. (See Section 4.3 Site and Regional Water Supply.)

To date, only one compound has been detected on site at a concentration exceeding the risk-based levels determined above. That compound is benzene. **Consequently, benzene shall be considered the critical contaminant in evaluation of potential groundwater remediation methods.** The concentrations shown in Table 8 are proposed as the alternate cleanup standards, as permitted under 15A NCAC 2L .0106(k). Thus, evaluation of possible groundwater remediation options shall consider the potential for reduction of the on site concentrations to the alternate levels listed in Table 8.

5.0 GROUNDWATER REMEDIATION ALTERNATIVES

5.1 Available Remediation Options

In general, remediation activities address three primary objectives for petroleum-contaminated sites: source removal, soil remediation, and groundwater remediation. At the Camden Shell, source removal and soil remediation have already been completed. The leaking UST system has been removed and permanently closed, and contaminated soils were excavated and removed. A new UST system has been installed and is currently in operation in another area of the site beyond the current area of petroleum hydrocarbon contamination.

Consequently, this section will evaluate potential methods for groundwater remediation. Selection of the most appropriate option depends on site specific conditions including soil type, aquifer characteristics, and type of petroleum compound(s) present at the site. Options which have been considered for remediation of groundwater at the facility include:

- Groundwater recovery and treatment ("pump and treat");
- Air sparging and Bio-sparging;
- Enhanced in-situ bioremediation;
- Natural Attenuation with groundwater monitoring.

Table 9 summarizes the relative advantages and disadvantages of the various groundwater remediation options.

TABLE 9
EVALUATION OF REMEDIAL ALTERNATIVES FOR GROUNDWATER

Item	Pump & Treat	Enhanced In-Situ Bioremediation	Air Sparging	No Action
Feasibility	Yes	Yes	Yes	No
Advantages	Retards plume migration Reduces contaminant levels Established technology Promotes the protection of public health	Contaminants remain in-situ during treatment Low system maintenance costs	Contaminants remain in-situ during treatment Enhances natural biodegradation	Low yearly cost for continued sampling and reporting requirements Natural biodegradation and attenuation of contaminants is the most cost effective method of remediation for suitable sites
Disadvantages	Usually results in air emissions Long duration Continued yearly overhead expense	Difficult to achieve hydrodynamic control of plume Difficult to ensure even distribution of nutrients and microbes	Difficult to achieve hydrodynamic control of plume Difficult to ensure even distribution of air into aquifer	Relies on sorption and biodegradation at natural rates Provides no means of plume control, so downgradient receptors may be exposed to concentrations in excess of standards
Initial Capital Outlay	Moderate to High	Moderate to High	Low to Moderate	None to Low
Monitoring and Operating Expenses	Moderate to High	Moderate to High	Low to Moderate	Low
Alternative Water Supply	Not applicable	Not applicable	Not applicable	Not applicable

5.2 Initial Evaluation of Groundwater Alternatives

Several of the above-listed options can be eliminated initially. First, natural attenuation is not recommended due principally to the occurrence of multiple receptors downgradient of the site. As the modeling efforts presented in Section 4.6.1.3 conclude, 48 µg/L of benzene is the recommended target cleanup level. From the most recent analytical data on groundwater samples, the highest benzene concentration on site was 350 µg/L. Although degradation and/or retardation of benzene might be sufficient enough to reduce concentrations in the benzene plume before it migrated off-site, there is no certainty this occurrence would be the case. Given the number and distance to potential receptors, therefore, natural attenuation is eliminated on a strategic basis from further consideration.

Enhanced in-situ bioremediation is also ruled out. The stratigraphic profile of the site is comprised of three basic units (see Section 2.1) with the uppermost unit being comprised of varying clays, silts, and sands. Additionally, the water table resides in this uppermost unit. Since, enhanced in-situ bioremediation schemes for shallow water table contamination sites rely on delivering enriched water via percolation across the water table, percolation at this site would have to occur within this mixed upper unit. Because of its heterogeneity and the lack of detail on the structure of the heterogeneity, designing an infiltration system which would evenly distribute enriched water would be tenuous. Since there are other more suitable options available, this option is ruled out on a technical basis.

An air sparging (AS) pilot test was conducted for the site, as discussed previously in Section 2.5. As discussed in the pilot test results, the test revealed that the subsurface is unsuitable to an aggressive air sparging remediation scheme, due to the high mounding caused by air sparging injection rates and the occurrence of clayey soils in the vadose zone. Therefore, AS is eliminated from consideration on a technical basis. It should be

5.3 Secondary Evaluation of Groundwater Alternatives

Two groundwater remediation options have been identified as potentially suitable. These are bio-sparging and groundwater recovery and treatment. This section will provide a closer look at each of these options to provide a basis on which to choose between them.

5.3.1 Evaluation of Bio-Sparging

As indicated previously, the intent of bio-sparging is to enhance natural in-situ biodegradation by providing an oxygen source to allow for aerobic pathways of microbial catabolism of hydrocarbons. The method of oxygen delivery is direct injection of compressed air using a bubbler installed below the water table.

5.3.1.1 Biodegradability of Contaminants

Several studies have shown that petroleum constituents degrade in the groundwater environment due to the activities of naturally occurring microorganisms. For instance, Barker, et al. (1987) injected BTEX and chloride into a natural unconfined aquifer and measured the attenuation of the contaminants with time. Their results showed that the BTEX compounds migrated slightly slower than the groundwater due to sorptive retardation and that all of the injected mass of BTEX was lost within 434 days due to biodegradation.

In addition, Tabak, et al. (1981) showed that naturally occurring microorganisms have significant capacity to degrade naphthalene and BTEX compounds and that the microorganisms adapt rapidly to using the organic constituents as a food source. Barker, et. al. (1987) reported that dissolved BTEX was readily biodegraded even in aquifers that have a low organic content.

The results of these studies conclude that dissolved petroleum constituents such as those found in the groundwater beneath Camden Shell have a significant capacity to degrade under the influence of naturally occurring microorganisms. Additionally, the pre-sparging dissolved oxygen concentrations discussed in Section 2.5 indicate there is aerobic microbial activity in the aquifer.

5.3.1.2 Biosparge System

At this site approximately 4 sparge points would be used. The sparge points would consist of porous bubblers with air supplied by a remote air compressor or blower. A soil vapor extraction (SVE) system would be installed to capture vapor emerging from the water table. The SVE system would consist of trenches (three or four) interspersed among the sparge points. A regenerative blower would be connected to a vacuum piping system to provide vacuum pressure to the SVE trenches. Piezometers equipped with float switches would be installed at various critical locations in the sparge area to monitor for excessive groundwater mounding. A central controller would disengage air flow to the sparge point(s) in the event of a high water level. Flow would resume after a pre-programed period of time. An equipment shed would house the compressor, blower, central controller and ancillary equipment and protect them from the elements.

The total cost for such a system is comprised of capital, operating, and monitoring expenses. The estimated present value cost to purchase, install, and operate a system for a period of 4 years is $65,633. The estimated present value costs for monitoring over a 4-year period is $98,012. These cost estimates are detailed in Appendix C.

Thus, assuming an operating period of 4 years, the estimated total present value cost is $163,645.

The primary advantage of bio-sparging is the fact that no treated wastewater is generated. The primary disadvantage is that the method does not provide a means of containment of mobile hydrocarbon plumes.

5.3.2 Evaluation of Groundwater Recovery and Treatment

The method of pump and treat relies on the solubility of hydrocarbons. Groundwater is physically removed from the subsurface through extraction wells, brought to the surface, and treated to remove dissolved hydrocarbons. Treatment of gasoline-contaminated waters typically involves physical treatment with air stripping and sometimes filtering through granular activated carbon. The treated water is disposed in some manner which depends on the available options at the site.

At this site, 2 or 3 groundwater recovery wells would likely be used. Submersible, bottom-loading pneumatic pumps would be installed in the wells to collect groundwater. Compressed air would be supplied to the pumps from a remote air compressor, and the pumps would discharge to a piping system which would deliver the water to the treatment equipment. Hoses and pipes would be laid in underground trenches.

The degree of required treatment is determined in some part by the mode of wastewater discharge. At this site, the likely mode would be direct discharge to a surface water drainage feature under a permit from the NPDES. In this case, the minimum required treatment stages are oil/water separation, aeration, and carbon adsorption. Thus, the treatment system would consist of an oil/water separator, a low profile air stripper or diffused aerator, and a bank of activated carbon vessels equipped with an automatically back washing prefilter. A booster pump would be provided after the aeration unit to force water through the carbon vessels and on to the eventual discharge point. Primary safety functions would consist of monitoring and responding to overflow conditions in the various tanks in the system by shutting off the air supply to the groundwater pumps. A central controller would perform these functions as well as the automatic timed back wash procedure. An equipment shed would house the compressor, aeration unit, carbon vessels, central controller, and ancillary equipment and protect them from the elements. The oil/water separator would be placed outside of the shed to prevent potentially flammable vapors (emanating from free product) from accumulating and coming into contact with non-explosion-proof electrical equipment in the shed.

The total cost for such a system is comprised of capital, operating, and monitoring expenses. The estimated present value cost to purchase, install, and operate a system for a period of 4 years is $75,095. The estimated present value costs for monitoring over a 4-year period is $111,391. These cost estimates are detailed in Appendix C.

Thus, assuming an operating period of 4 years, the estimated total present value cost is $186,486.

The primary advantage of pump and treat is that it can provide containment or retardation of migration of a hydrocarbon plume through alteration of the natural hydraulic gradient. The primary disadvantages are that the wastewater must be disposed and that equipment costs are generally higher (than sparging and natural attenuation, for example).

5.4 Selected Alternative For Groundwater Remediation

Based on the above discussions, bio-sparging is the recommended method for groundwater remediation at the site. This recommendation is based principally on two factors: cost and practicality.

First, the bio-sparging cost estimate is significantly less than the pump and treat estimate: $163,645 versus $186,486 to purchase equipment, install the system, and operate and monitor the site for 4 years. It is important to note that although the cost estimate for sparging assumes 4 years of operation, it is reasonably possible the site will be remediated sooner. In this case, monitoring costs would be lower, and since monitoring costs account for approximately 60% of the 4-year total, the total cost would be substantially less. However, based on experience at other sites, it is not as likely that pump and treat will remediate the aquifer much sooner than 4 years.

Second, given the relatively low concentrations at the site, there is not necessarily a decided advantage to direct removal of groundwater. Thus, its higher cost would not necessarily yield better results. The low concentrations would result in a low rate of hydrocarbon mass removed per volume of water treated. If concentrations were much higher (e.g. in the thousands of µg/L), this would not be the case. Additionally, as a result of the modeling efforts to assign some understanding of risk to receptors, plume containment is not deemed a necessary function of site remediation, provided a competent monitoring plan is put into effect.

6.0 PROPOSED CORRECTIVE ACTION PLAN

6.1 Corrective Action Overview

The proposed method of groundwater remediation is bio-sparging with SVE to provide collection of soil vapors. Source removal and contaminated soil removal have already been completed at the site. A schematic of the sparging system is presented in Figure 13. The schematic depicts the basic system components and their connections to other components.

6.2 Remediation System Description

6.2.1 Sparging System

The bio-sparging system will consist of 4 sparge points distributed across the site as shown in Figure 14. The locations of the sparge points were determined based on the known distribution of contaminants in the aquifer and the data collected during the pilot test. An attempt was made to position the wells close enough to provide adequate coverage in the plume yet far enough apart to minimize the effect of combined mounding from multiple sparge points. (It is noted that the pilot test could not produce an exact "radius of aeration", since preferential flow paths were observed during the test and the air flow rates used during the test were higher than those which will be used for remediation.) The wells were also oriented keeping in mind the anisotropy in radial mounding.

Each sparge point will consist of an augered borehole in which a porous bubbler has been installed to the total depth. Figure 15 is a detail of the proposed sparge point design. The annulus above the bubbler will be filled with bentonite and cement-bentonite grout. The upper 6 feet of borehole will be converted into a piezometer with 2-inch-diameter screen and casing. The piezometer will be fitted with a float switch and used to monitor for excessive mounding in the water table.

Air shall be supplied to the sparge points by a rotary vane compressor. The anticipated flow and injection pressure for a bio-sparging application are 0.25-0.50 scfm per well at 9.0-11.0 psig. The system shall be capable of supplying a maximum of approximately 2.5 scfm per well at 15 psig (at the well head). These values are estimated from pilot test data and take into account submerged depth of the porous bubblers. The compressor shall be powered from the main controller with a manual "On-Off" switch.

A separate air line will be installed from the blower manifold to each sparge point. Each line shall have a dedicated solenoid air gate, a pressure regulating valve, and an instantaneous flow meter. The solenoid air gate will be ½-inch, two-way, normally-closed valve and will be operated by the main system controller.

6.2.2 Soil Vapor Extraction System

The soil venting system shall consist of three extraction trenches. Figure 14 depicts the system layout. The trench locations were chosen based on the objective to collect a large portion of the air which is injected into the ground surface. Ideally 100% recovery is desired. Realistically, this objective is not practical due to soil heterogeneity and space limitations. However, the SVE system is over designed such that the capacity to withdraw vapor exceeds the capacity to inject it (via sparging) by a factor of at least three.

A detail of the proposed trench design is provided in Figure 16. The vapor extraction screens in each trench shall be connected to a vacuum line at the midpoint of the screen. This "T" coupling will provide more even distribution of vacuum pressure along the trench. The vacuum lines to each trench shall be connected to a main vacuum line in a junction box. The junction boxes will contain vacuum pressure gages and air flow meters to monitor vacuum extraction from each trench.

Vacuum shall be generated in the main vacuum line by a regenerative blower. The blower shall driven by a 3.0 HP (nominal) explosion-proof motor operating at 230 V and single-phase. An EG&G Rotron EN606 blower is specified for reference.

Upstream of the vacuum blower, a manual ball valve, a 55-gallon (nominal) moisture knockout tank, and a 10 micron particulate filter will be provided. The moisture knockout tank will be equipped with a high water level float switch and an automatic drain valve. A vacuum relief valve shall be provided to prevent the blower from running with no inlet flow. Vacuum pressure gages will be installed at key points in the line to monitor for operating pressures and pressure losses. The blower will vent to the atmosphere.

Electrical power for the blower and the float switch will be provided by the main controller. The blower will be activated by a manual "On-Off" switch.

The mounding piezometers shall be installed adjacent to each SVE trench to monitor for high water table and protect the trenches from flooding. The piezometer locations are shown in Figure 14 and a typical detail is shown in Figure 17.

6.2.3 Equipment List and Performance Requirements

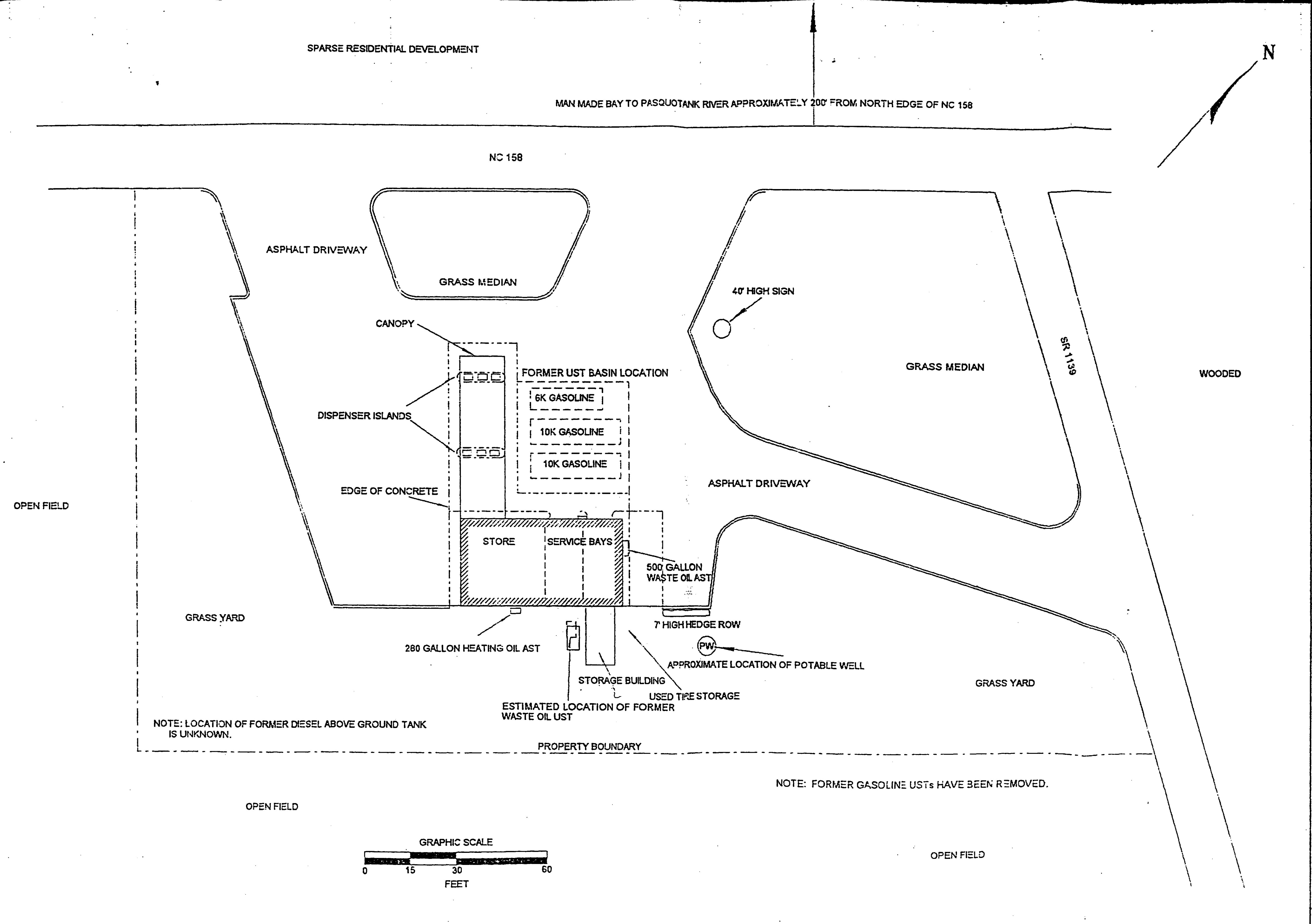
The following is a list of selected equipment components. Appendix D contains specification and performance sheets for major components.

- Rotary vane air compressor, quantity 1; GAST Model 2067 or similar; 18.0 scfm at 15.0 psig minimum capacity; 230 VAC; single phase; adjustable flow/pressure bleed valve

- Solenoid air valves, quantity 5; ½-inch (nominal); two-way; normally closed; 20 psig minimum rating
- Pressure Regulating Valves, quantity 4; 20.0 scfm and 25.0 psig minimum capacity
- Air flow meters, quantity 4; Dwyer RMC 102 or similar; 10-100 scfh (i.e. 0.167-1.667 scfm); 20.0 psig minimum rating
- Porous bubbler, quantity 4; 4 scfm at 15 psig minimum capacity
- Down-well float switches, quantity 10; intrinsically safe barrier; slosh guard
- Main Control with Programmable Logic Controller, quantity 1; NEMA 4 enclosure; 8 inputs minimum; 6 timing channels with independent output; 2 HOA switches
- Vacuum blower, quantity 1; Rotron EN606 or similar; 50.0 scfm at 60.0 inches H_2O minimum capacity; 230 VAC; single phase; explosion proof; flow/vacuum relief valve
- Vapor moisture tank, quantity 1; 55-gal (nominal); automatic drain valve
- Equipment shed, quantity 1; 8x10x7 ft (nominal); heater with thermostatic control; vent fan with thermostatic control; explosion proof division wall for SVE equipment; separate outside doors

6.2.4 Conduit Trenches and Hoses

Air hose conduits, vacuum lines, and electrical lines running from the equipment shed to the area of remediation shall be installed underground. Trench lines and piping segments are depicted in Figure 18. A typical trench detail is shown in Figure 19.



NOTE: LOCATION OF FORMER DIESEL ABOVE GROUND TANK IS UNKNOWN.

NOTE: FORMER GASOLINE USTs HAVE BEEN REMOVED.

TURNER ENVIRONMENTAL
CONSULTANTS, P.C.

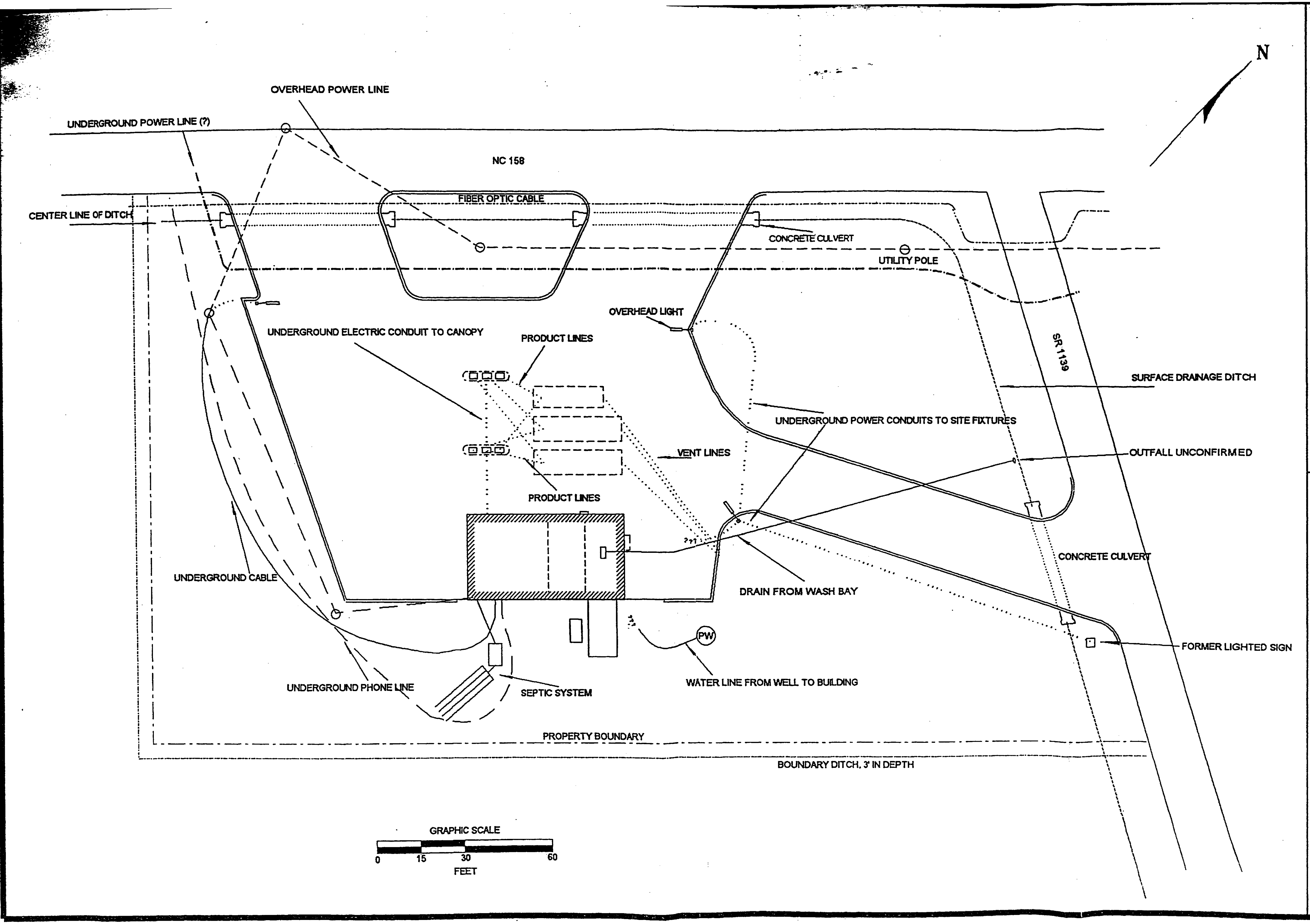
CARRBORO, NC

SITE LAYOUT MAP

CAMDEN SHELL

QUALITY OIL COMPANY
CAMDEN, NORTH CAROLINA

PROJECT NO:	02694	CHECKED BY:	GAT	FIGURE NO.	2
SCALE:	1"=30'	DRAWN BY:	SKP	DATE:	11/29/95



SITE UTILITIES MAP

CAMDEN SHELL

QUALITY OIL COMPANY

CAMDEN, NORTH CAROLINA

PROJECT NO:	02694	CHECKED BY:	GAT
SCALE:	1"=30'	DRAWN BY:	SKP
FIGURE NO.	4	DATE:	11/28/95

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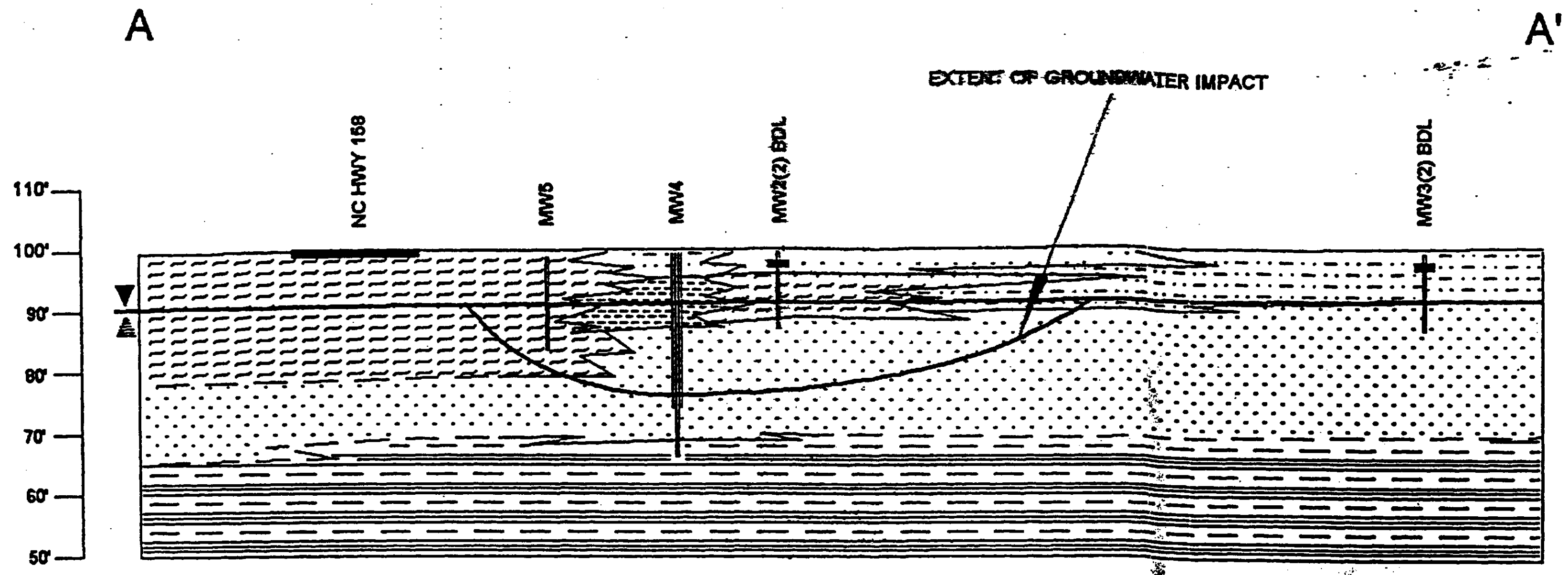
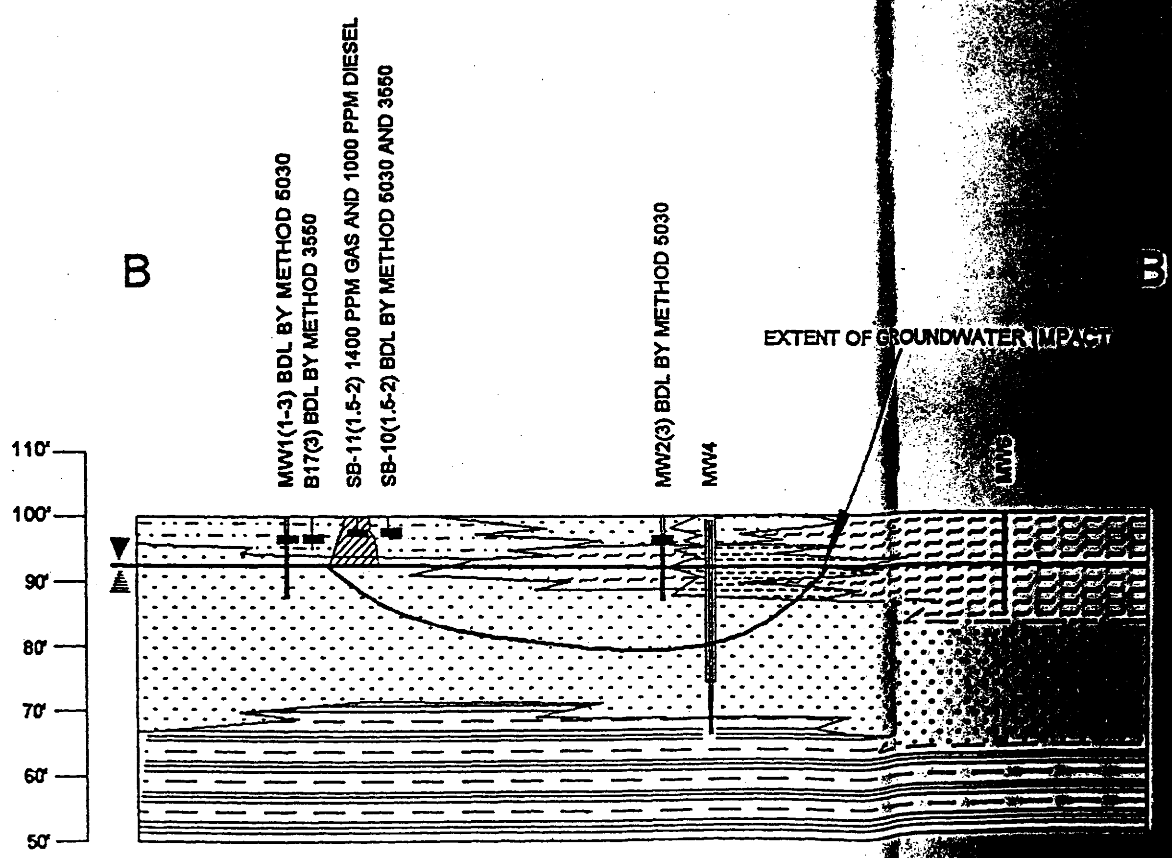
CARRBORO, NC





LEGEND

▼ WATER TABLE

▬ SOIL SAMPLE LOCATION

B16(3) BORING NUMBER (SAMPLE DEPTH IN FEET)

POORLY GRADED SAND (SP)
LIGHT GREY TO TAN ORANGE, DRY TO WET, MOSTLY FINE TO MEDIUM GRAINED SAND, 5% TO 30% CLAY, OCCASIONAL SHELL FRAGMENTS BELOW 25 FEET

CLAYEY SAND (SC)
GREEN, MOIST, MOSTLY FINE TO MEDIUM GRAINED SAND, 15% TO 25% CLAY, TRACE SHELL FRAGMENTS

CLAY (CL)
GREY TO TAN ORANGE MOTTLED, MOIST, MOSTLY CLAY, UP TO 30% SILT

SILT (ML)
TAN GREY, WET, MOSTLY SILT, 5% TO 10% CLAY

SILTY CLAY (CL)
GREY, WET, MOSTLY CLAY, UP TO 30% SILT, SHELL FRAGMENTS

▨ AREA OF SOIL IMPACTED ABOVE REGULATORY LEVEL (10 PPM FOR GAS AND 40 PPM FOR DIESEL)

BDL = BELOW DETECTION LIMIT

ALL RESULTS ARE SHOWN IN PARTS PER MILLION

ELEVATIONS ARE RELATIVE TO AN ARBITRARY DATUM OF 100 FEET.

SOIL IDENTIFIED ACCORDING TO THE UNIFIED SOIL CLASSIFICATION SYSTEM

GRAPHIC SCALE
0 15 30 60
FEET

NO VERTICAL EXAGGERATION

GEOLOGIC CROSS-SECTIONS

CAMDEN SHELL

QUALITY OIL COMPANY
CAMDEN, NORTH CAROLINA

PROJECT NO:	02894	CHECKED BY:	MJB	FIGURE NO.	5
SCALE:	1"=30'	DRAWN BY:	JMG	DATE:	1-6-95

TURNER ENVIRONMENTAL CONSULTANTS, P.C.
CARRBORO, NC

RECEIVED
WASHINGTON OFFICE

SEP 17 1996

D. E. M.

September 11, 1996

Scott Bullock
NC Division of Water Quality
Washington Regional Office
1424 Carolina Avenue
Washington, NC 27889

Transmittal: Groundwater Monitoring Report
Camden Shell Station, Camden, NC
NCDWQ Incident # 12706

Dear Scott:

Enclosed is one copy of a groundwater monitoring report for the referenced site. Our technicians sampled the site on July 29, 1996 after installing three downgradient wells across Highway 158 from the site. The wells were recommended in the CAP. Their purpose is to monitor for downgradient plume movement while the site undergoes remediation.

Because of nearby potable wells, this site has a "B" ranking (high priority) based on the NCDWQ's revised site priority ranking system. Consequently, remediation must continue there, while Senate Bill 1317 has suspended activities at low priority sites. Your office has approved the CAP for the site. The recommended treatment method is biosparging (or low flow air sparging). We are prepared to initiate bidding for equipment and installation on behalf of Quality Oil Company, Ltd.

However, the recent analytical results show a substantial drop in concentrations since the previous sampling over a year ago. The latest results show only a few minor violations of groundwater standards (15A NCAC 2L .0202(g)) and no violations of the alternate cleanup standards proposed in the CAP. If these results are consistent, no further action may be necessary.

We will wait until after the October 1996 sampling event to further pursue implementation of the existing CAP. If the next round of samples echo the last, then we will reevaluate the situation, including the status on the use of the local potable wells.

In the meantime, please call me if you have questions.

Sincerely,

TURNER ENVIRONMENTAL CONSULTANTS, P.C.

Glenn Thesing

Glenn Thesing
Project Engineer

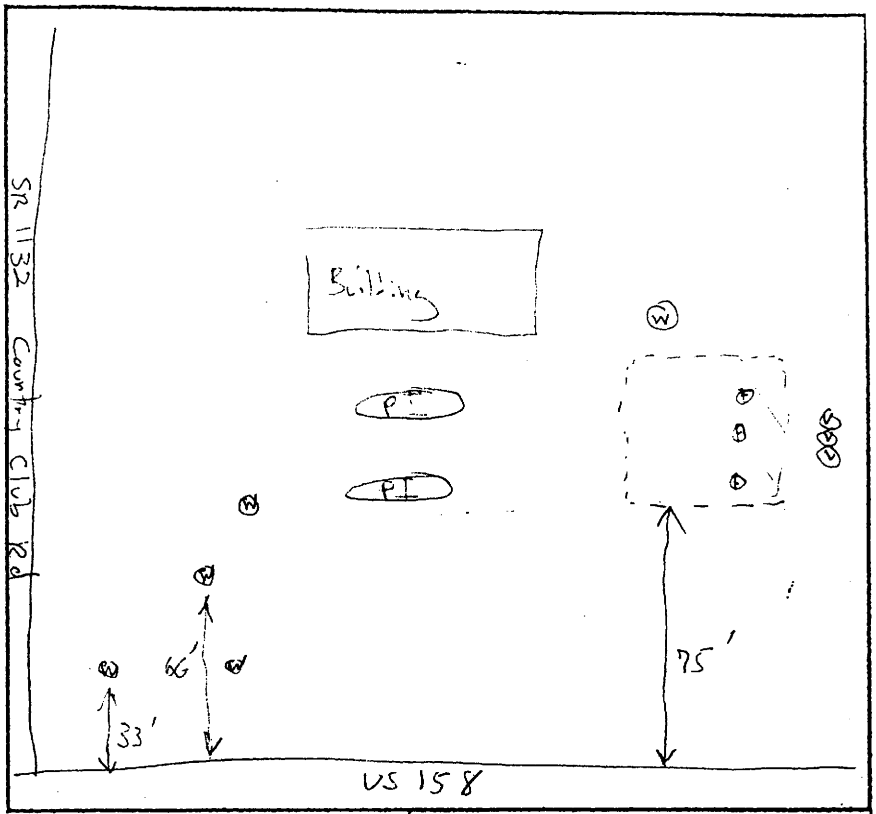
TURNER ENVIRONMENTAL CONSULTANTS, P.C.
110 WEST MAIN STREET • SUITE A • CARRBORO NC 27510 • PHONE 919-932-1590 • FAX 919-932-1594

UST Information Checklist-Site Recon

Sketch Site (Ref. to -C-Line & Intersection)

UST Site # ②
Project #
Tip# R-2414 B
County Camden
DEM Registry Yes No Pg#
UST ID#
Installation Date(s):
UST Type: steel FRP Steel w/FRP
Cathodic Protection: yes no

UST	size	contents
2	8,000	gas
1	10,000	gas



Legend: PI - Pump Island
O - monitor well

Site Information

Facility Name: Camden Shell
Address :
Phone:
Evidence of UST system (?): yes no
(ie. fill caps, vent pipes etc.)

UST Owner
Address:
Phone:
Approx # of USTs:
Approx. distance from -C-Line:
(closest point of UST system)

Intersection Quadrant (?):
Evidence of UST Removal (?): yes no
Is site under remediation (?): yes no
Are remediation wells in place (?): yes no
Additional Notes:

1.0 INTRODUCTION

Turner Environmental Consultants, P.C. (TEC) has completed the first groundwater sampling event at the Camden Shell located in Camden, North Carolina since the approval of the Corrective Action Plan (CAP). The purpose of this report is to document groundwater quality beneath the site.

The site location in reference to surrounding geographic and cultural features is depicted in Figure 1. The site layout and monitoring well network is depicted in Figure 2.

2.0 NEW MONITORING WELL CONSTRUCTION

Monitoring wells MW1, MW2, MW4, and MW7 were destroyed during the renovation of the gas station. TEC reinstalled the monitoring wells as near as possible to their original locations. Also, in accordance with the CAP, three additional Type II monitoring wells were installed to monitor groundwater downgradient of the plume. The locations of the replacement and the new monitoring wells are depicted in Figure 2. Soil boring logs for MW1, MW2, MW4, and MW7 were not included due to their proximity to the previous monitoring wells. Soil boring logs for monitoring wells MW9 - MW11 and the monitoring well construction records for monitoring wells MW1, MW2, MW4, MW7, and MW9 - MW11 are located in Appendix A.

3.0 GROUNDWATER MONITORING

3.1 Previous Groundwater Analytical Results

Groundwater at the site has been sampled on three occasions previous to the July 29, 1996 event: August 31, 1994 (monitoring wells MW1 - MW3), November 7, 1994 (monitoring wells MW5 and MW6), and March 23, 1995 (monitoring wells

TABLE 2
GROUNDWATER ANALYTICAL SUMMARY (7/29/96)
Camden Shell
(ppb)

ANALYTE	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	NCAC LIMI
Benzene	<1	<1	<1	<1	<1	<1	1.77	<1	<1	<1	<1	1
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1,000
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	29
Xylenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	530
MTBE	<5.0	**180**	<5.0	<5.0	**55.8**	<5.0	**99.9**	**77.6**	**34.4**	<5.0	<5.0	200
cis-1,2-Dichloroethene	<1	<1	1.48	<1	<1	<1	1.21	<1	<1	<1	<1	NE
sec-Butylbenzene	<1	<1	<1	<1	1.05	<1	<1	<1	<1	<1	<1	NE
1,1-Dichloroethane	<1	<1	<1	<1	<1	<1	1.28	<1	<1	<1	<1	NE
1,3,5-Trimethylbenzene	<1	<1	<1	<1	<1	<1	1.10	<1	<1	<1	<1	NE

ppb = parts per billion; < - indicates result is less than method detection limit
NE = NCAC 2L Limits Not Established
Shading denotes concentration exceeding NCAC 2L standard; **BOLD** - denotes a detected concentration

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ENVIRONMENTAL CONSULTANTS, P.C.

20

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NATURAL ATTENUATION GROUNDWATER MONITORING REPORT

(Subsequent Report)

FOR THE MONITORING PERIOD OF JANUARY 2001 - JULY 2001

CAMDEN SHELL
US HIGHWAY 158 AT SR 1139
CAMDEN, NORTH CAROLINA

NCDWM - UST Incident No.: 12706
Risk Classification: High
Land Use: Commercial/Residential

Release Information
Date Discovered: February 1994
Estimated Release Quantity: Unknown
Release Cause/Source: Gasoline Underground Storage Tank System
Capacity of USTs: two 10,000-gallon gasoline and one 6,000-gallon gasoline
Latitude: 36° 19' 00" N Longitude: 76° 10' 45" W

Responsible Party/Property Owner:

Quality Oil Company, LLC
Post Office Box 2736
Winston-Salem, NC 27102

August 2001
TerraQuest Project No. 02694

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401 W. Weaver Street · Carrboro, North Carolina 27510
Telephone (919) 932-1590 · Facsimile (919) 932-1594
www.terraquestpc.com

CERTIFICATION FOR THE SUBMITTAL OF AN ENVIRONMENTAL / GEOLOGICAL ASSESSMENT

Attached is the Natural Attenuation Groundwater Monitoring Report (Subsequent Report) for:

Responsible Party: Quality Oil Company, LLC.
Address: Post Office Box 2736
City: Winston-Salem State: NC Zip Code: 27102

Site Name: Camden Shell
Address: US Highway 158 at SR 1139
City: Camden State: NC Zip Code: 27921

I, Jonathan Reed Grubbs, a Licensed Geologists in the State of North Carolina for TERRAQUEST ENVIRONMENTAL CONSULTANTS, P.C., do hereby certify that I am familiar with and have reviewed all material including figures within this report and that to the best of my knowledge the data, site assessment, figures and other associated materials are correct and accurate. All work was performed under my direct supervision. My seal and signature are affixed below. Additional seals and/or signatures are also affixed below.

TERRAQUEST ENVIRONMENTAL CONSULTANTS, P.C.

SEAL 1691
JONATHAN REED GRUBBS

Ryan D. Kerins
Project Manager

Jonathan R. Grubbs, P.G.
Vice President

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FIGURES

APPENDICES

1.0 INTRODUCTION

TerraQuest Environmental Consultants, P.C. (TerraQuest) has completed the thirteenth groundwater sampling event at the Camden Shell facility located in Camden, North Carolina since the approval of the Corrective Action Plan (CAP) in May 1996. TerraQuest prepared the CAP in accordance with regulations under Title 15A of the North Carolina Administrative Code (NCAC), Subchapter 2L, Section .0106(k). The alternate standards proposed in the CAP have been met. The purpose of this report is to document groundwater quality beneath the site during the natural attenuation phase of the CAP. Presently, natural attenuation groundwater monitoring occurs on a semi-annual basis.

The site location is depicted in Figure 1. Figure 2 is a site vicinity map that identifies potential receptors, such as potable wells, within a 1,500-foot radius of the site. The site layout and monitoring well network are depicted in Figure 3.

2.0 GROUNDWATER MONITORING

2.1 Previous Groundwater Analytical Results (1/9/01)

On January 9, 2001, TerraQuest personnel sampled monitoring wells MW1, MW2, MW4-MW7, MW9, and MW11. In accordance with the North Carolina Division of Waste Management-Underground Storage Tank Section's (NCDWM-UST) sampling protocol, each monitoring well was purged a minimum of three well volumes of water with a new disposable bailer prior to sample collection. These same disposable bailers were then used to collect a water sample from each monitoring well. Upon collection, samples were placed in the appropriate laboratory-prepared containers and placed on ice pending transit to a North Carolina-certified laboratory for analysis. All groundwater samples were analyzed for volatile organic compounds by EPA Method 6210D + methyl tertiary-butyl ether (MTBE) + isopropyl ether (IPE). Refer to Appendix A for Technical Methods and Standard Procedures utilized by TerraQuest for monitoring well sampling.

Analytical results revealed one Title 15A NCAC 2L .0200(g) Groundwater Quality Standard (2L Standard) violation; MW7 had a 2,100 parts per billion (ppb) concentration of MTBE which exceeds the 2L Standard of 200 ppb for this compound. Additionally, concentrations of MTBE and/or IPE were detected in monitoring wells MW1, MW2, MW5, MW6, MW7, and MW9, although none of the detected concentrations exceeded the respective 2L Standard for either compound. Note that the Target Cleanup Concentrations (TCC's) approved in the CAP were not exceeded for any of the detected contaminants. Appendix B contains a complete analytical history of each monitoring well in the monitoring well network. The full analytical report is included in the January 2001 Natural Attenuation Groundwater Monitoring Report on file with the Washington Regional Office (WRO) of the NCDWM-UST.

2.2 Recent Groundwater Analytical Results (7/2/01)

On July 2, 2001, TerraQuest personnel sampled monitoring wells MW1 - MW11 using the same sampling protocol previously discussed. Groundwater samples were analyzed per EPA Method 6210D + MTBE+ IPE.

Analytical results revealed two 2L Standard violations; MW2 and MW7 had reported MTBE concentrations of 1,200 and 4,800 ppb, respectively. Additional concentrations of other petroleum-type compounds were detected in monitoring wells MW1, MW5, MW6, MW8, MW9, and MW11, however, none of the detected concentrations exceeded their respective 2L Standard. Note that this is the first sampling event that MTBE has been detected in monitoring well MW11. Also, note that the TCC's approved in the CAP were not exceeded for any of the detected contaminants. Analytical results are summarized in Table 1 and Figure 4. Appendix B contains a complete analytical history of each monitoring well in the monitoring well network. The full analytical report for the July 2, 2001 sampling event is included in Appendix C.

All of the monitoring wells were gauged for the presence of free product. None of the monitoring wells contained evidence of free product.

Isoconcentration maps for individual compounds were not generated due to the lack of enough data points for any individual compound to support such a map. An isoconcentration map delineating the vertical extent of hydrocarbon contaminant concentrations was not constructed since there are not enough monitoring points to support such a map.

Based upon a review of historical and recent groundwater analytical data, the geometry, location, and dimensions of the plume have changed slightly. The estimated extent of the dissolved phase contamination plume in excess of the 2L Standards is shown on Figure 4. As shown on Figure 4, the plume has been extended around monitoring well MW2. The reason for this change is the presence of MTBE in monitoring well MW2 at levels which exceed the 2L Standard limit for this compound. Note that MTBE was detected in monitoring well MW11 for the first time, suggesting that the leading edge of the plume has migrated in that direction. Future sampling events will confirm the size and location of the dissolved phase contamination plume.

MTBE concentration versus time graphs and hydrographs were constructed for monitoring wells MW2 and MW7 (Appendix D). Both the monitoring well MW2 and MW7 graphs depict a gradual fluctuation in concentrations over time and then a recent increase. The reason for these recent increases is unknown. Future sampling events of these monitoring wells and others in the network will assist in tracking future increases/decreases. Concentration versus time and hydrographs graphs for other compounds and other monitoring wells were not constructed due to the minor contaminant concentrations.

2.3 Natural Attenuation Processes

The CAP prepared for Camden Shell relies on natural attenuation processes to remediate groundwater at the site. Consequently, field tests have been conducted for dissolved oxygen (DO), pH, conductivity, and groundwater temperature during the various sampling events. The field tests were performed to provide information about the potential for biodegradation of the dissolved petroleum contaminants. Technical Methods and Standard Procedures utilized by TerraQuest personnel in the collection of these field measurements are described in Appendix A.

DO is an important groundwater parameter in that aerobic biodegradation of certain gasoline constituents can occur with its presence. DO concentrations measured on July 2, 2001 in all of the monitoring wells with detected contaminant concentrations were aerobic (> 2 mg/L DO) or upper hypoxic (> 1 mg/L). These measurements are conducive to aerobic biodegradation (McAllister and Chiang, 1994). Groundwater parameter data collected for each monitoring well during the July 2, 2001 sampling event is included in Table 2.

2.4 Groundwater Hydrogeology

Prior to sample collection, depth-to-water measurements were collected from the entire monitoring well network. Figure 5 depicts the potentiometric surface on July 2, 2001. A review of the water level data reveals an oscillating water table indicative of low-gradient surficial aquifers. In addition, the drainage ditches along both sides of Highway 158 as well as tidal influences of the nearby Pasquotank River could have an effect on the site's shallow phreatic water table. Figure 5 indicates that the groundwater head decreases to the north. The migration path of the groundwater contamination plume, discussed in Section 2.2, as well as historical flow directions also affirms the groundwater flow direction. A listing of the recent depth-to-water and groundwater elevation data can be found in Table

3.. A complete groundwater elevation history for the site is contained in Appendix B. Monitoring well construction data is listed in Table 4.

3.0 SUMMARY AND CONCLUSIONS

Analytical results from the July 2, 2001 sampling event reveal that groundwater beneath the site remains impacted with petroleum concentrations above the 2L Standards. However, the detected concentrations did not exceed the TCC's established in the CAP.

In comparison with the previous sampling event results, the concentrations of detected compounds have both increased and decreased. These vacillations are common and may be linked to water table fluctuations which are common in aquifers directly influenced by surficial infiltration. Note that MTBE is the primary contaminant detected at the site. MTBE, unlike other common gasoline constituents (i.e. benzene, toluene, etc.), does not readily biodegrade and is not affected by retardation since it does not typically adsorb to soil or organic carbon (Andrews, 1998 and Grady and Casey, 2001). These factors coupled with the compound's high solubility mandates the compound be monitored closely especially with a natural attenuation remedial method in place.

As of the June 2, 2001 sampling, the distance from the outermost extent of the plume to the closest surface water receptor, the Havenwood Inlet of the Pasquotank River, is approximately 50 feet. Currently, the distance to the closest potable well used as the primary source of drinking water (PW6) is approximately 400 feet downgradient of the core of the contaminant plume in monitoring well MW7. Though this well is within 500 feet of the site, it was not sampled since an inlet of the Pasquotank River lies between the well and the contaminant plume. The remaining wells are located laterally to the interpreted groundwater flow direction and do not appear to be threatened by the site contaminant plume (see Figure 2 for receptor locations). Table 5 lists all of the property owners of known potable wells within a 1,500 foot radius of the source.

For the implementation of a CAP under 15A NCAC 2L .0106(k), a period of natural attenuation monitoring is required once the alternate standards have been met. This groundwater monitoring is required until the concentrations meet the standards in 15A NCAC 2L .0202(g). The monitoring event documented by this report is the thirteenth consecutive report in which TCC's have not been exceeded. If future sampling events reveal that the contaminant concentrations are slowly approaching allowable 2L Standard limits, concentration vs. time graphs will be constructed to see if an asymptotic slope (1:40) is evolving. When levels begin to drift towards 2L Standards in this fashion, groundwater sampling will begin occurring on a quarterly basis in the hopes of site closure. Until then biannual sampling will continue. The next event is scheduled for January 2001. Upon receipt of those analytical results, a natural attenuation groundwater monitoring report will be prepared and submitted to the Washington Regional Office of the NCDWM - UST.

4.0 LIMITATIONS

This report is limited to the investigation of dissolved petroleum hydrocarbons, such as gasoline, in groundwater and does not imply that other unforeseen adverse impacts to the environment are not present at or around the Camden Shell Station in Camden, NC. In addition, subsurface heterogeneities not identified during the current study may influence the migration of groundwater or contaminants in unpredicted ways. The limited amount of sampling and testing conducted during this study cannot practically reveal all subsurface heterogeneities. Furthermore, the subsurface conditions, particularly groundwater flow, elevations, and water quality, may vary through time. The opinions and conclusions determined in this report are in accordance with industry-accepted geologic and hydrogeologic practices at this time and location. No warranty is implied or intended.

TABLE 1
GROUNDWATER ANALYTICAL SUMMARY (7/2/01)
Camden Shell
TerraQuest Project No. 02694

ANALYTE	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	NCAC 2L LIMIT	TCC
Benzene	<1.0	<50.	<1.0	<1.0	<2.0	<1.0	<100	<1.0	<1.0	<1.0	<1.0	1	48
Toluene	<5.0	<250	<5.0	<5.0	<2.0	<5.0	<500	<5.0	<5.0	<5.0	<5.0	1,000	47,620
Ethylbenzene	<1.0	<50.	<1.0	<1.0	<2.0	<1.0	<100	<1.0	<1.0	<1.0	<1.0	29	1,381
Total Xylenes	<3.0	<150	<3.0	<3.0	<6.0	<3.0	<300	<3.0	<3.0	<3.0	<3.0	530	19,048
MTBE	**37.**	**1,200**	<1.0	<1.0	**58.**	**13.**	**4,800**	**32.**	**41.**	<1.0	**1.7**	200	9,524
IPE	<1.0	<50	<1.0	<1.0	**47.**	<1.0	<100	<1.0	**3.3**	<1.0	<1.0	70	NE
tert-Butylbenzene	**1.1**	<50.	<1.0	<1.0	<2.0	<1.0	<100	<1.0	<1.0	<1.0	<1.0	70	NE
1,1-Dichloroethane	<1.0	<50.	<1.0	<1.0	<2.0	<1.0	<100	**1.3**	<1.0	<1.0	<1.0	700	NE

Notes:

1. All results in parts per billion
2. < - indicates result is less than sample detection limit
3. **BOLD** - denotes a detected concentration; Shading denotes concentration exceeding NCAC 2L standard
4. - sample not collected
5. NE - TCC not established
6. TCC - Approved target clean-up concentration
7. This table is a summary of the full analytical report contained in Appendix B.

TABLE 2
GROUNDWATER PARAMETER DATA (7/2/01)
Camden Shell
TerraQuest Project No. 02694

WELL	TEMPERATURE (°C)	CONDUCTIVITY (µS/cm)	pH	DISSOLVED OXYGEN (mg/l)
MW1	24.4	603	6.11	1.97
MW2	25.5	1,100	6.41	1.98
MW3	21.3	1,283	6.03	2.60
MW4	22.5	513	7.22	5.78
MW5	24.8	892	6.43	2.46
MW6	21.6	531	5.68	6.06
MW7	22.7	528	6.29	4.15
MW8	24.4	1,049	6.07	3.95
MW9	23.3	544	6.10	3.72
MW10	21.7	450	6.06	1.86
MW11	23.3	1,280	6.13	1.28

Notes:
1. °C - degrees Celsius
2. µS/cm - microsiemens per centimeter
3. mg/l - milligrams per liter

TABLE 3
GROUNDWATER ELEVATION DATA
Camden Shell
TerraQuest Project No. 02694

WELL	CASING ELEVATION	DEPTH TO WATER (1/9/01)	WATER ELEVATION (1/9/01)	DEPTH TO WATER (7/2/01)	WATER ELEVATION (7/2/01)
MW1	99.10	6.64	92.46	6.35	92.75
MW2	98.67	6.28	92.39	6.22	92.45
MW3	99.33	6.78	92.55	6.75	92.58
MW4	98.57	8.72	89.85	15.68	82.89
MW5	97.69	5.34	92.35	5.50	92.19
MW6	98.88	6.43	92.45	6.67	92.21
MW7	98.65	6.11	92.54	6.40	92.25
MW8	97.97	5.69	92.28	5.85	92.12
MW9	98.18	6.10	92.08	6.45	91.73
MW10	96.55	4.24	92.31	4.93	91.62
MW11	94.97	2.98	91.99	3.18	91.79

Notes:

1. All elevations are listed in feet.
2. Casing elevations are relative to an arbitrary datum point of 100 feet.
3. MW4 is a Type III monitoring well.

TABLE 4
MONITORING WELL CONSTRUCTION DATA
Camden Shell
TerraQuest Project No. 02694

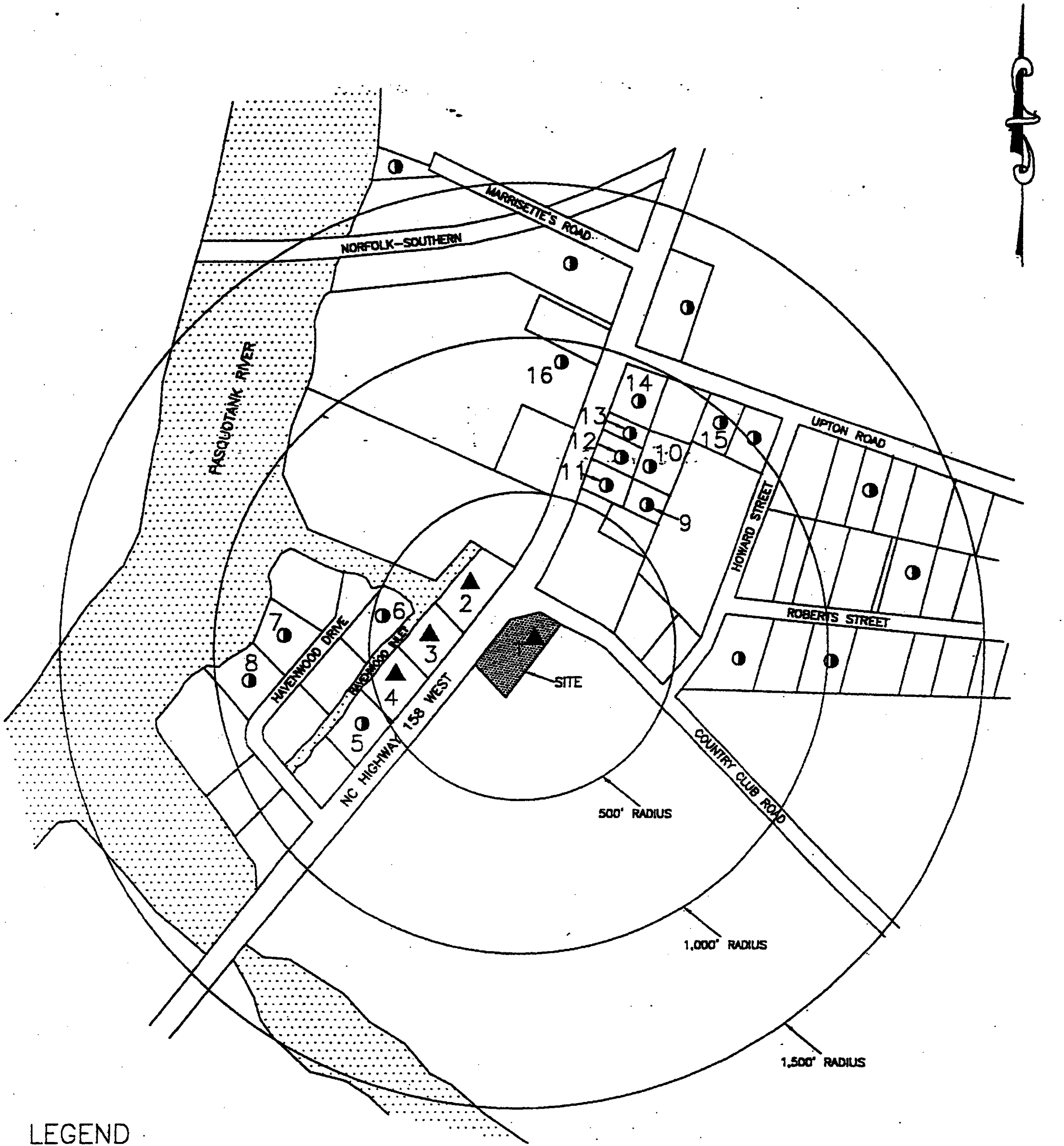
WELL	Date Constructed	Total Depth (ft.)	Screened Interval
MW1	8/31/94	12.5	3 - 12.5
MW2	8/31/94	12.5	3 - 12.5
MW3	8/31/94	12.5	2 - 12.5
MW4	11/4/94	33.0	28 - 53
MW5	11/4/94	15	3.5 - 15
MW6	11/3/94	15	3.5 - 15
MW7	7/15/96	13	3 - 13
MW8	7/15/96	13	3 - 13
MW9	7/15/96	13	3 - 13
MW10	7/15/96	13	3 - 13
MW11	7/15/96	12	2 - 12

Notes:
1. Complete well construction records, soil boring logs, and monitoring well installation details are in the site's CSA and September 1996 Groundwater Monitoring Report.

TABLE 5
POTABLE WELL PROPERTY OWNER INFORMATION
Camden Shell
TerraQuest Project No. 02694

Property ID	Tax Parcel Map Number	Name and Address of Property Owner
1	1945	Quality Oil Company, LLC P.O. Box 2736 Winston-Salem, NC 27102
2 (not in use)	9184	George T. Griffin 186 US 158 West Camden, NC 27921
3 (not in use)	8939	Jamie Wooten 192 US 158 West Camden, NC 27921
4 (not in use)	7805	Rossalyn Faircloth 196 US 158 West Camden, NC 27921
5	5770	Robert & Lynn Massiello 200 US 158 West Camden, NC 27921
6	6025	James A. Harold Jr. 118 Havenwood Dr. Camden, NC 27921
7	2091	Luciam Morrisette 115 Havenwood Dr. Camden, NC 27921
8	1878	Winfred Wood P.O. Box 159 Camden, NC 27921
9	6445	Russel J. East 117A US 158 West Camden, NC 27921
10	6587	Doris R. Rogers 175 US 158 West Camden, NC 27921
11 & 12	5501 & 5549	Lena Stallings 177 US 158 West Camden, NC 27921
13	5678	Dorthy Hurtle 175 US 158 West Camden, NC 27921

Notes:
1. Information obtained from the Camden County tax office.
2. PW1 - PW16 located on Tax Map 8934 (01).



LEGEND

◑ POTABLE WELL

▲ THE POTABLE WELLS ON PROPERTIES 2, 3, AND 4 ARE SERVICED BY CITY WATER, BUT THEIR WELLS HAVE NOT BEEN ABANDONED AND CAN STILL BE USED TO WASH CARS, WATER LAWNS, ETC.,

THE POTABLE WELL ON PROPERTY 1 IS NO LONGER IN USE, BUT IT HAS NOT BEEN ABANDONED.

GRAPHIC SCALE

0' 250' 500' 1000'

1" = 500'

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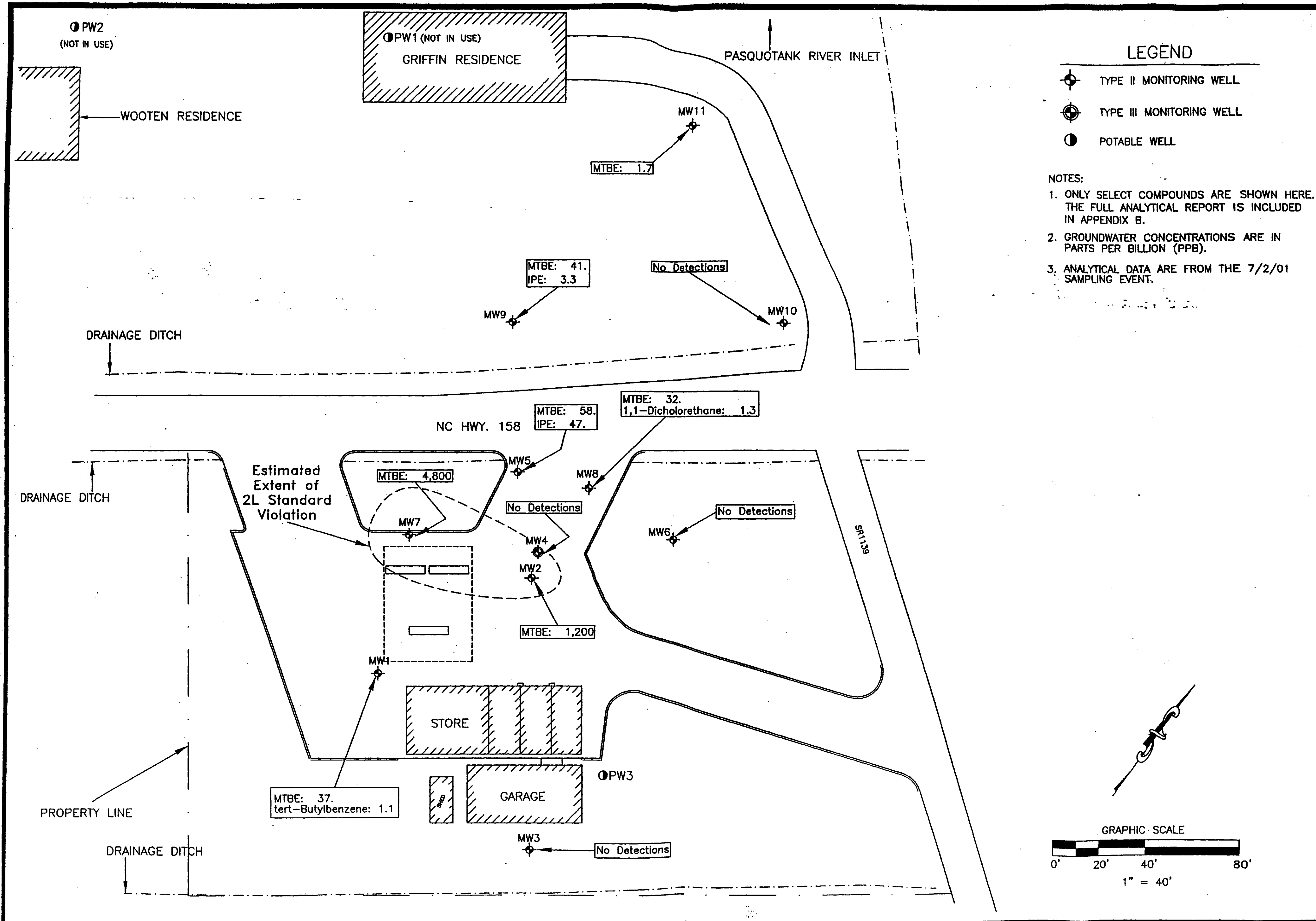
SITE VICINITY MAP

CAMDEN SHELL

QUALITY OIL COMPANY, LLC CAMDEN, NC

PROJECT NO.	02694	DRAWN BY:	JRG	DATE:	1/28/01
SCALE:	1" = 500'	CHECKED BY:	MB	FIGURE NO.	2



LEGEND

- ⌖ TYPE II MONITORING WELL
- ⊕ TYPE III MONITORING WELL
- ◑ POTABLE WELL

NOTES:

1. ONLY SELECT COMPOUNDS ARE SHOWN HERE. THE FULL ANALYTICAL REPORT IS INCLUDED IN APPENDIX B.
2. GROUNDWATER CONCENTRATIONS ARE IN PARTS PER BILLION (PPB).
3. ANALYTICAL DATA ARE FROM THE 7/2/01 SAMPLING EVENT.

GROUNDWATER ANALYTICAL RESULTS (7/2/01)
CAMDEN SHELL
US HIGHWAY 158 AT S.R. 1139
QUALITY OIL COMPANY, LLC.
CAMDEN, NC

PROJECT NO: 02694	CHECKED BY: MJB/JRG	FIGURE NO: 4
SCALE: 1" = 40'	DRAWN BY: JML/RDK	DATE: 8/7/01

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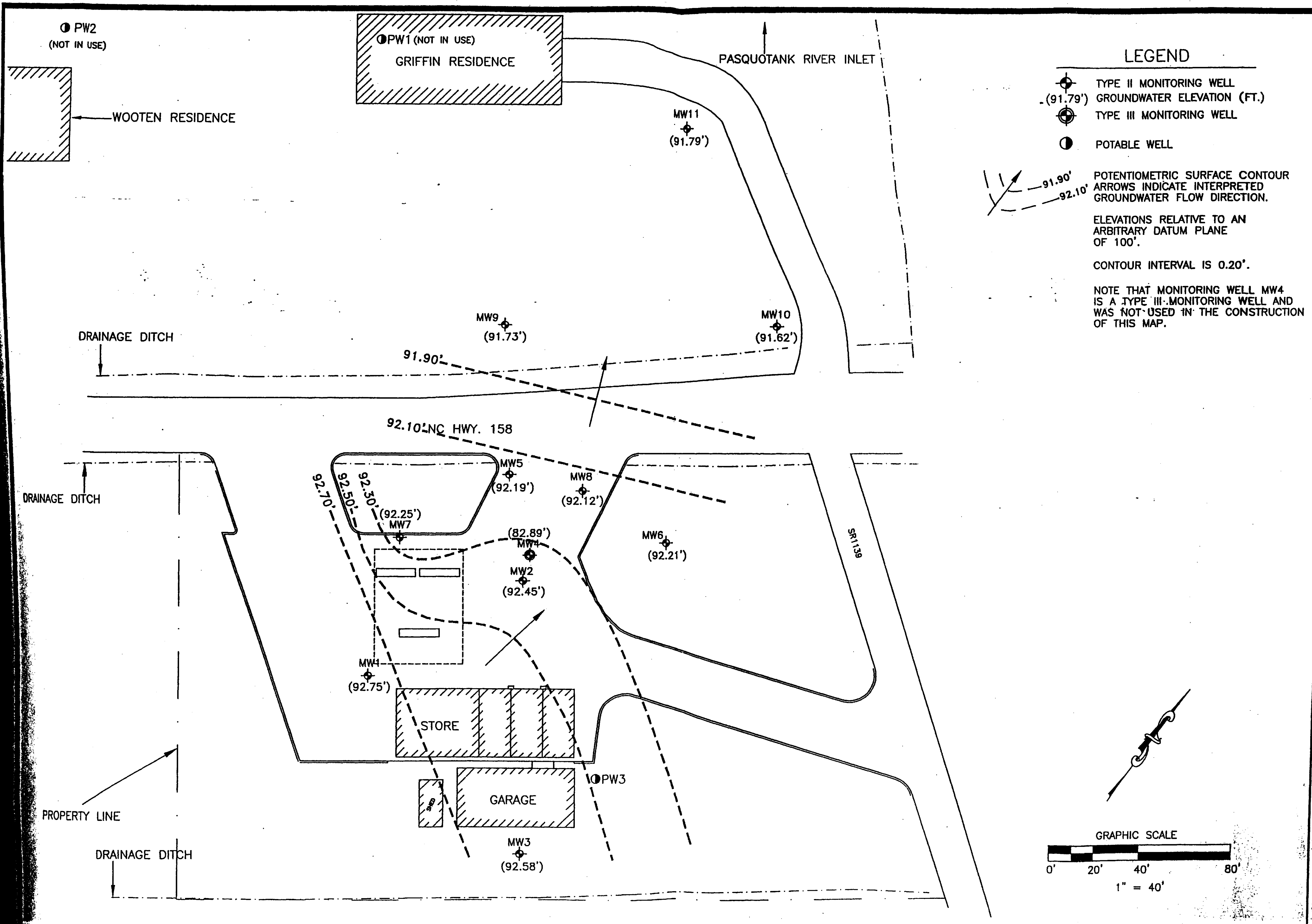

LEGEND

- TYPE II MONITORING WELL
- (91.79') GROUNDWATER ELEVATION (FT.)
- TYPE III MONITORING WELL
- POTABLE WELL
- 91.90' 92.10' POTENTIOMETRIC SURFACE CONTOUR ARROWS INDICATE INTERPRETED GROUNDWATER FLOW DIRECTION.

ELEVATIONS RELATIVE TO AN ARBITRARY DATUM PLANE OF 100'.

CONTOUR INTERVAL IS 0.20'.

NOTE THAT MONITORING WELL MW4 IS A TYPE III MONITORING WELL AND WAS NOT USED IN THE CONSTRUCTION OF THIS MAP.

POTENTIOMETRIC SURFACE MAP (7/2/01)
CAMDEN SHELL
US HIGHWAY 158 AT S.R. 1139
QUALITY OIL COMPANY, LLC.
CAMDEN, NC

PROJECT NO: 02694	CHECKED BY: MJB/JRG	FIGURE NO.: 5
SCALE: 1" = 40'	DRAWN BY: JML/RDK	DATE: 8/7/01

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