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# HOLCOMB CREOSOTE COMPANY YADKINVILLE, NC

## RCRA CORRECTIVE ACTION PLAN for GROUNDWATER CONTAMINATION

PREPARED BY

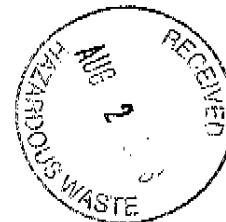
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WINSTON-SALEM, NC

JULY 1996

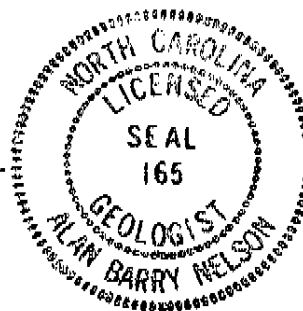
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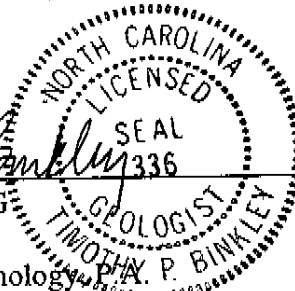


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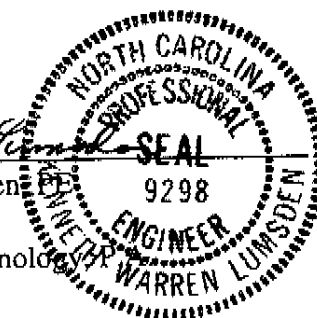
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**HOLCOMB CREOSOTE COMPANY  
YADKINVILLE, NORTH CAROLINA  
CORRECTIVE ACTION SYSTEM DESIGN**

**PART ONE: BACKGROUND INFORMATION**

**1.0 INTRODUCTION AND PURPOSE**

Holcomb Creosote Company is a wood preserving plant located in Yadkinville, North Carolina (Figure 1). The facility is classified as a Resource Conservation and Recovery Act (RCRA) TSDF Hazardous Waste disposal site due to the presence of two hazardous waste management units that were closed in the 1980's. Figure 2 is a USGS topographic map of the site and vicinity. Figure 3 is a site map showing the locations of the hazardous waste management units. The hazardous waste management units (HWMUs) were closed with contaminated soils remaining at each unit. Groundwater assessment investigations and on-going groundwater monitoring indicate that releases of hazardous constituents from the HWMUs have resulted in groundwater contamination in a limited area downgradient of the HWMUs. This report outlines a Corrective Action Plan (CAP) and provides system design data and plans for the proposed Corrective Action System (CAS) to remediate groundwater contamination at the Holcomb Creosote Company site, as stipulated in the Post Closure Permit for the HWMUs issued in the fall of 1995.

**2.0 PREVIOUS REPORTS, PERMITS AND PROJECT DOCUMENTS**

Table 1 is a list of the major reports, permits and other project documents related to the hazardous waste management program at the facility.

Table 1. Report, Permits and Project Documents	
Title	Date
Part A Permit	1982
Groundwater Sampling & Analysis Plan	1982 (Revised 1988, 1992, 1994)
Groundwater Assessment Plan	1982 (Revised 1985)
Site Contingency Plan	1982
Lagoon Closure Plan	1983
Lagoon Post Closure Plan	1987
Landfarm Closure Plan	1985 (Revised August 1986, December 1986 and November 1988)
Landfarm Closure Certification/Post Closure	1989
Groundwater Assessment Phase I	1986
Groundwater Assessment Phase II	1987
Groundwater Assessment Phase III	1987
Groundwater Assessment Phase IV	1987
Report of Aquifer Tests	1990
Findings of the Groundwater Assessment	1990, 1992
Initial Post Closure Permit Application	1987
Post Closure Permit Addendum I	1991
Post Closure Permit Addendum II	1992

Post Closure Permit Addendum Response	1994
F034 Waste Minimization Plan and Storage	1992
Annual Groundwater Reports	1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995
Post Closure Permit Issued	1995

### 3.0 CURRENT STATUS OF SITE AND WASTE MANAGEMENT ACTIVITIES

#### 3.1 Surface Impoundment

The surface impoundment area is considered to be a closed hazardous waste management unit (HWMU). This unit, which was an interim status HWMU containing K001 wastes, was closed in 1985 following the removal of sludges and some contaminated soils. These materials were landfarmed on another portion of the site under the provisions of an agreement with the NC Division of Health Services (DHS), Solid and Hazardous Waste Management Branch.

Subsequent groundwater monitoring and assessment downgradient of the surface impoundment confirmed the release of hazardous constituents to the shallow regolith aquifer. Based on soil testing at closure, it does not appear that contaminated soils reside in the unsaturated zone at the area of the old impoundment. However, it is possible that regolith aquifer materials are contaminated with hazardous constituents.

#### 3.2 Landfarm

During closure of the surface impoundment, K001 wastes and contaminated soils were landfarmed on an approximate one-half acre tract of land east of the plant under a plan approved by DHS. Due to apparent shock loading of the on-site soils, during the landfarming, bacterial degradation of the sludges and contaminated soils could not be accomplished in the time allotted under interim status. Consequently, the landfarm was closed with waste in place in order to avoid obtaining an operating permit for the unit. The landfarm was capped with a low permeability clay and vegetated. Therefore, the landfarm is considered a closed HWMU.

On-going groundwater assessment studies have not clearly determined whether the landfarm is a true source of groundwater contamination or whether the plume that is present in the landfarm area has been caused by releases from the surface impoundment.

#### 3.3 Drip Pad

The drip pad and sump were originally classified as Solid Waste Management Units (SWMUs) by an EPA contractor. Due to new regulations covering drip pad liner and collection systems, initiated in the early 1990's, the facility changed its operating procedures so that the treated wood remained in the treatment cylinder for a period of 24 hours prior to removal. The old tramway, collection sump and soils in the vicinity of the cylinder were removed, disposed of as hazardous waste, and a

poly liner placed below the tram way. Additionally, a shelter was constructed over the entire area. The treated wood is now removed from the cylinder after the 24 hour period and placed in temporary storage within the coverage area of the roof. These activities are outlined in the F034 Waste Minimization Plan and Drip Pad Contingency Plan which was approved in 1992. Therefore, we consider the drip pad to be a remediated SWMU that will be investigated under the provision of the Post Closure Permit concerning new SWMU's.

### **3.4 Solid Waste Management Units**

Figure 3 provides a list of, and shows the locations of, the SWMU's identified at the facility by the EPA contractor. Under the terms of an agreement with the Division of Solid Waste Management, a RCRA Facility Investigation Workplan (RFI) will be developed for these units in calendar year 2000. This strategy was based on the fact that all the SWMU's lie upgradient of the active groundwater plume and the groundwater monitoring system. Therefore, any releases to the groundwater system from the SWMU's should be addressed by active remediation within the existing plume. This strategy allows the facility to immediately direct funds towards the remediation of the groundwater plume which should result in positive improvement in environmental quality at the site.

## **4.0 CORRECTIVE ACTION OBJECTIVES**

The corrective action program selected is designed to limit the migration of hazardous constituents in the groundwater system that have resulted from releases from the hazardous waste management units and to reduce to acceptable concentrations, the constituents that are currently within the limits of the contaminant plume. Achievement of these objectives will rely on enhancement of the existing microbial population to biodegrade the contaminants through nutrient stimulation and subsequent reproduction.

## **5.0 DEVELOPMENT OF THE CORRECTIVE ACTION PROGRAM**

The remainder of this corrective action plan/system design document will focus on defining the hydrogeologic constraints on the remedial action options, document the latest groundwater and surface water quality, provide an evaluation of the suitability and potential for various remediation technologies, identify a specific remediation method, develop a design for the remediation system and finally, outline a monitoring program that will track the progress of remediation.



## **PART TWO: SITE INFORMATION AND DATA**

### **6.0 HYDROGEOLOGIC FRAMEWORK**

#### **6.1 Regional Geologic Setting**

The Holcomb Creosote site lies in the center of Yadkin County, approximately 2 miles north of the Town of Yadkinville, on US Highway 601. This area is located on the northern edge of the Inner Piedmont Belt, one of a series of northeast-southwest trending bands of rock units that lie in the Appalachian Piedmont. The Inner Piedmont Belt is characterized by gneisses, schists, and granites. Figure 4a is a regional geologic map of the northwest piedmont. Figure 4b illustrates the Lithotectonic Units in the area. The area lies on the southern edge of the Sauratown Mountain anticlinorium, a major structural feature in the area with an axial trace just south of the highest elevations of the Sauratown Mountains, about 1 mile north of, and parallel to, the Stoney Ridge fault zone (Fullagar and Butler, 1980). Controversy concerning the southwestern terminus of the Sauratown Mountain anticlinorium and the trace of the Yadkin Fault (Horton and McConnell, 1991) have been heavily debated in the literature. Reconnaissance geologic mapping and examination of geomorphic signatures conducted during the course of the geologic investigations at Holcomb Creosote, suggest the plant site sits on the western edge (hanging wall) of the Yadkin Fault; while the areas downstream of Dobbins Pond lie on the eastern segment (foot wall) of the fault as portrayed by Espenshade et al, 1975. This interpretation is based on extension of the axial trace of the fault, the extreme divergence of topography and the degree of stream dissection on opposite sides of the axial trace. Therefore, it appears that Dobbins Pond is strongly controlled by regional structure and geomorphology.

#### **6.2 Local Geology**

The geology of Yadkin County is quite diverse. Metamorphic and igneous rock units ranging in age from Precambrian to Paleozoic predominate. The Davie County Basin, a Triassic rift basin, lies to the south of Yadkinville. The rock units in the area exhibit a northeast-southwest trend which mimics the regional geology. The rock units increase in metamorphic grade from greenschist to amphibolite facies from southeast to northwest. Figure 5 is a Geologic Map of Yadkin County showing the distribution of the rock units.

#### **6.3 Site Geology**

Detailed mapping of the site geology is hampered by the lack of outcrops in the area. Figure 6 is a geologic map of the area within 1-2 miles of the plant site. The plant lies within a band of Precambrian (?) granite gneiss which intertongues with a biotite gneiss just north of Yadkinville.

Mapping of subsurface soil and geologic units has been completed from samples obtained during the installation of groundwater monitoring wells. Subsurface boring logs were developed from the soil samples, cuttings and rock cores. These logs were used to construct geologic cross-sections for the site. Figure 7 shows the location of the cross-sections and the key soil test borings/well logs used in their construction. Figures 7a and 7b are cross sections showing the subsurface soil and rock units to a depth of approximately 30 feet below the bottom of the shallow wells.

The subsurface at the site is characterized by weathered silts and clays that overlie partially weathered granite gneiss at depths of approximately 20-30 feet below land surface. The bedrock ranges from partially weathered rock and boulders to fractured rock to consolidated unfractured rock at depth. A small stream channel bisects the site between the former surface impoundment and the landfarm. Shallow sands flank this stream to a depth of about 8 to 12 feet.

The orientations of 37 local fractures were measured at the plant site and immediate vicinity. A rose diagram showing the fracture orientations is provided as Figure 7c.

In order to more closely define the depositional sedimentary sequence within the area between the surface impoundment and landfarm (the centroid of the groundwater contaminant plume), a series of shallow (less than 10 feet) hand auger borings were drilled in 1989. Samples from the hand auger borings were identified, described and submitted for microscopic and grain size analysis to identify sedimentary facies. Data from these analyses were used to develop two stratigraphic profiles that illustrate the complex depositional system in the stream valley between the two hazardous waste management units. These profiles are reproduced herein as Figures 8 and 9. The data from these stratigraphic profiles suggest that the small stream represents only the most recent manifestation of a fluvial/alluvial system. Significant variation in grain size, variable proportions of energy-sensitive components such as micas and larger clastic fragments imply that the vertical distribution of sediments represent lateral facies of a dynamic stream system. Basal samples contained evidence that sedimentation has proceeded over pre-existing regolith material, and that stream erosion and deposition has subsequently scoured and replaced the regolith with sediments. This interpretation suggests that the depositional/erosional influence of the stream may be much greater than is suggested by surficial materials. The stream-associated sedimentary deposits appear to be a major controlling factor in the movement of surface and groundwater, such that the area is dynamic and changes in response to surface water runoff from the plant area and stream flow from north of the plant. The presence of larger grained sediments within the regolith provides preferred pathways for the movement of groundwater to the swamp and allows for mixing between the surface and groundwater systems.

The sedimentary sequence and regolith between the surface impoundment and the landfarm form the unconsolidated geologic material in which the shallow groundwater aquifer resides above the

bedrock. Figure 10 is an isopach map showing regolith thickness and Figure 11 illustrates the depth to bedrock from the ground surface through a structure contour map of the top of bedrock.

## 6.4 Site Hydrogeology

### 6.4.1 Hydrogeologic Units

Heath (1980), describes the hydrogeologic framework of the North Carolina Piedmont as an unconsolidated shallow regolith aquifer that overlies a fractured bedrock. Hydraulically, this system acts as a reservoir and pipeline system. The saturated regolith is a reservoir that contains groundwater in the interstices between the individual grains of soil (primary porosity). The regolith aquifer is in hydraulic connection with a transition zone of higher permeability that lies just above the bedrock. The fractures, or secondary openings in the bedrock, serve as pipelines that transmit groundwater from the shallow regolith to the deeper portions of the bedrock along planes. The fracture frequency and density in the bedrock are more numerous in the shallow parts of the bedrock. High angle fractures in the bedrock typically do not extend below 250 feet. In some instances, a set of horizontal, stress relief fractures is present that can also transmit groundwater from the regolith. In this hydrogeologic system, groundwater flows from areas of positive relief that form recharge areas towards streams, springs and lakes that act as discharge areas. Therefore, the direction of groundwater flow typically mimics the topography, although in a more subdued form. Figure 12 and Figure 13 show conceptual views of the piedmont hydrogeologic system and the hydrologic regime, respectively.

Aquifer testing was completed during the groundwater assessment at the facility. Table 2 is a summary of the hydraulic parameters calculated from these tests.

Unit	Location	Source	Hydraulic Conductivity (ft/day)	Transmissivity (ft <sup>2</sup> /day)	Storativity
Regolith	Observation well 2	pump test calculation, drawdown	1.326	34 (saturated thickness ~ 26')	0.01131
Bedrock	Pumping well 9	pump test calculation, drawdown	.004	0.437 (saturated thickness ~ 100')	0.03467
Stream Sediment	hand auger boring SP1-4	Hazen, Masch & Denny conductivity calculations from grain size	28.33	340 (saturated thickness ~ 12')	-

The porosity of the regolith aquifer is approximately 30 percent. Groundwater velocity calculations based on solution of a variation of Darcy's Law indicate that groundwater moves to the east southeast at approximately 26 feet per year.

#### 6.4.2 Water Table Elevation and Direction of Groundwater Flow

During the course of the investigations at the facility, over 24 boreholes, wells, piezometers and hand auger borings have been drilled. These subsurface exploration points have shown that the hydrogeologic system at the facility conforms to the conceptual model of Heath (1980). The cross-sections and stratigraphic profiles cited above (Figures 7a, 7b, 8, and 9) show the various hydrogeologic units, depth to rock, and the elevation of the groundwater table. Figure 14 is a potentiometric surface map showing the elevation of the groundwater table and the direction of groundwater flow at the site based on April 1996 water level measurements. This map generally conforms to previous maps.

#### 6.4.3 Surface Water Hydrology

The stream that runs from north to south and empties into the wetland at the upper reaches of Dobbins pond is a first order stream that carries discharge during most of the year. The stream heads in a group of springs just north of the site. The discharge of the stream is generally less than .5 cubic feet per second (cfs). However, due to the recent construction of a church just north of the site, the stream carries a significant storm load for the size of its drainage basin. The stream also receives significant quantities of stormwater runoff from the plant site. The stream meanders slightly but is braided only near its entry to the marsh adjacent to Dobbins Pond. The stream margin riparian wetland and floodplain is approximately 30 feet across in its widest segment. The stream discharges and widens to an extensive wetland system at the head of Dobbins Pond. This wetland system extends from the north (plant site side of the pond) and also from a major tributary that enters the pond from the south. The wetland system on the north side of the pond is comprised of a heavy grass root mat that extends over 100 feet into the pond. Cattails, alder and other hydrophytic vegetation predominate. The distributary channel of the creek from the plant side is poorly defined; In contrast, the southern portions of the wetland appear to be in a transitory state due to the meandering of the tributary and the building of a vast sediment bar complex that extends northward into Dobbins Pond.

The pond is a 40 plus acre lake that extends east to Dobbins Pond Road. The outlet is controlled by a rock dam constructed on the southeast portion of the pond. The depth in the upper reaches of the pond have decreased significantly in the past 20 years due to the influx of large sediment from both tributaries that feed the lake. Depths in the upper reaches rarely exceed four feet, while the deeper portions of the lake, along the major stream thalwegs and at the dam, are 15-20 feet. The lake can be classified as temperate with low levels of eutrophication occurring during the summer. This eutrophication is due to lake stratification caused by varying temperature levels and the input of nutrients from agricultural and urban runoff. However, the overall health of the lake and its ecosystem appear to be typical of larger farm ponds in the northwest piedmont of North Carolina.

#### 6.4.4 Interpretation of Hydrogeologic System's Control on Groundwater Flow

As cited above in section 6.3, the sedimentary sequence along the stream between the surface impoundment and the landfarm has a major effect on groundwater transport due to the extreme heterogeneity of the aquifer and its anisotropic nature, both in the regolith and the fluvial system. In this portion of the site, the depth to groundwater is generally less than 1 foot below land surface during winter and spring, when the water table is high. During this period, some groundwater movement from the west side of the landfarm towards the stream may occur. However, during most of the year, the stream is not a significant groundwater discharge boundary. We believe that the fluvial geomorphic sequence within the floodplain allows for the mixing of ground and surface water during various times of the year as the stream system shifts from gaining to losing. Water table elevations indicate that groundwater from the surface impoundment and plant site may flow under the stream towards Dobbins Pond. Therefore, the most likely point for regional groundwater to discharge is the wetland at the mouth of the stream and the northern neck of Dobbins Pond east of the landfarm. However, south of the impoundment and landfarm, it appears likely that the shallow sands of the stream system may direct shallow flow toward the wetland at the west end of the pond.

### **7.0 GROUNDWATER QUALITY**

#### **7.1 Groundwater**

Groundwater monitoring at the site began in 1982 with the installation of three shallow regolith monitoring wells. Water quality data were collected under the provisions of the interim status requirements of 40CFR265. Following the first four quarters of monitoring, a statistical evaluation of the data indicated that groundwater contamination had occurred downgradient of the surface impoundment. Groundwater assessment was initiated to determine the magnitude and extent of contamination. Following the closure of the surface impoundment and the construction of the landfarm, additional wells were installed around the landfarm perimeter. Testing from these wells also showed contamination. The groundwater assessment was therefore, expanded and completed in 1992. During the period of the consent order, (1990-present), only limited groundwater monitoring has been completed. Based on the entire groundwater data set, Table 3 was developed to show the contaminants identified in each well and their range of concentrations during the monitoring period. The table is organized by hazardous constituent and shows the wells that are impacted by a particular contaminant and the range of concentrations. Figure 15 is a map of the site showing the horizontal extent of the contaminant plume based on the data in Table 3 and in Table 4 (discussed following Table 3).

Table 3. Identified Groundwater Contaminants			
Parameter	Well Number	Maximum	Minimum
		ppb	ppb
Naphthalene	2	13,000	880
	3	4,700	0.08
	5	16,000	10
	6	16,649	1,400
	7	4,386	<2,280
	12	13	<1
	14	20	0
Phenol	4	32	0
Flouranthene	3	1,000	23
Chrysene	3	32	<10
Ideno(1,2,3-cd)	3	11	0
Pyrene			
Benz (a)	3	110	0
Anthracene			
Acenaphthylene	2	72	0
	3	15	0
	6	155	0
	3	970	0.028
Acenaphthene	6	600	110
	7	660	<25
	2	16	0
	3	20	2.7
Benzene	7	3.3	0
	14	44	0
	2	180	91
	3	60	11
Toluene	6	230	0.025
	7	150	20
	2	86	0
	3	32	6.8
Ethyl Benzene	4	1	0
	6	235	0.025
	7	200	0.044
	14	15	0
Methylene Chloride	3	8.3	0
	5	22	0
	7	12	0
1,1,2,2-tetra-chlorethane	3	2.9	0
	5	4.4	0
	3	56	18
m-xylene	6	40	220
	7	500	120
	12	18	0
o,p. xylene	3	59	0.028
	6	820	0.351
	7	500	0.038

	12	16	0
Styrene	3	22	17
	6	108	0.123
	7	99	0.013
Carbon Disulfide	3	21	0
	7	12	0
Chromium	1	120	0
	3	0.347	0
	5	140	0
	12	29	0
	14	0.547	0
Benzo(b)Pyrene	3	34	0
2 Methylanthracene	3	1,100	60
	6	1,200	<1
	7	1,500	<1
Dibenzofuran	3	580	108
	6	370	293
	7	290	155
Fluorene	3	480	0.01
	6	240	191
	7	220	117
Phenanthrene	3	590	0.022
	6	210	174
	7	69	35
Anthracene	3	46	11
Pyrene	3	40	15
Bis (2-ethylhexyl) Phthalate	1	6	<1
	5	8	<1
	6	4	<1
	7	3	<1
	11	25	<1
	12	55	11
2-Methylphenol	3	19	<1
	6	5	<1
	7	4	<1
m,p, methylphenol	3	42	<1

Due to the sporadic nature of the groundwater sampling (because of the various testing schemes utilized at the site over the past 14 years) and to develop a baseline of current groundwater quality, groundwater samples were collected and tested in May 1996 by USEPA Methods 602 and 610 for a select group of wells that define the plume. The results of these tests are provided in Table 4 and are sorted by well. Equiconcentration maps were developed for a representative compound of volatile, semi-volatile and DNAPL type contamination. These plume maps are shown in Appendix A. These data will serve as the baseline concentrations against which the effectiveness of the remedial activities are measured.

Table 4: Recent Baseline Ground Water Quality Data										
Well ID >>	1	3	6	7	8	9	10	14	16	swmp 1
Compounds										
<i>Volatiles</i>										
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	<1	7	42	13	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	39	21	<1	<1	<1	<1	<1	<1
Xylenes	<1	37	261	139	<1	<1	<1	<1	<1	<1
Chlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2 Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,3 Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,4 Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methyl(T)butyl Ether	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Isopropyl Ether	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
<i>Semi-volatiles</i>										
Acenaphthene	11	216	732	941	281	180	249	390	243	72
Acenaphthylene	11	205	207	BDL	123	259	255	279	236	99
Anthracene	25	80	177	100	33	98	99	93	75	BDL
Benz[a]anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Benzo[b]fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Benzo[k]fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Benzo[ghi]perylene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Benzo[a]pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chrysene	17	55	BDL	BDL	BDL	12	22	8	5	BDL
Didenz[a,h]anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Fluoranthene	BDL	BDL	BDL	460	BDL	BDL	BDL	47	BDL	BDL
Fluorene	71	145	171	236	71	BDL	97	158	166	38
Ideno[1,2,3-cd]pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Naphthalene	8	201	174	205	441	46	242	269	235	106
Phenanthrene	BDL	53	BDL	264	BDL	BDL	BDL	BDL	BDL	BDL
Pyrene	BDL	62	228	347	BDL	59	BDL	45	BDL	BDL

## 7.2 Chemical and Physical Nature of Creosote Compounds

The existence of coal tar derivatives in groundwater, their transport and ultimate fate are controlled by the chemical and physical characteristics of the compounds. The diverse chemical and physical properties of coal tar constituents combine to produce a complex distribution of contaminants in groundwater. Table 5 provides a summary of the chemical and physical properties of the contaminants detected in the groundwater at Holcomb Creosote.



Table 5: Chemical and Physical Properties of Creosote				
Parameter	Density	Mol. wt.	Sol. in water	Half Life in GW
Naphthalene	1.0253	128.19	insoluble	258 days
Phenol	1.0722	94.11	soluble	7 days
Fluoranthene	1.252	202.26	insoluble	2.41 years
Chrysene	1.274	228.30	insoluble	5.48 years
Indeno (1,2,3-cd) Pyrene				4 years
Benz (h) Anthracene	---	228.30	slightly	3.73 years
Acenaphthylene	0.8988	152.21	insoluble	120 days
Acenaphthene	1.0242	154.21	insoluble	204 days
Benzene	0.87865	78.12	slightly	24 months
Toluene	0.8669	92.15	insoluble	4 weeks
Ethyl Benzene	0.8670	106.17	insoluble	228 days
Methylene Chloride	1.3266	84.93	slightly	8 weeks
1,1,2,2-tetra-chlorothane				45 days
m-xylene	0.8642	106.17	insoluble	8 weeks
o-xylene	0.8802	106.17	insoluble	12 months
p-xylene	0.8611	106.17	insoluble	8 weeks
Styrene	0.9060	104.16	insoluble	30 weeks
Carbon Disulfide	1.2632	76.14	soluble	
Chromium				
Benzo(b)Pyrene				
2 Methyl naphthalene	1.0058	142.20	insoluble	
Dibenzofuran	1.0886	168.21	slightly	35 days
Fluorene	1.203	166.23	insoluble	120 days
Phenanthrene	0.9800	178.24	insoluble	1.10 years
Anthracene	1.283	178.24	insoluble	2.52 years
Pyrene	1.271	202.26	insoluble	10.4 years
Bis (2-ethylhexyl) Phthalate				389 days
2-Methylphenol	1.02734	108.15	soluble	
3-Methylphenol	1.0336	108.15	slightly	
4-Methylphenol	1.0178	108.15	slightly	

Creosote is a distillate of coal tar which is an extremely complex mixture. Approximately 461 compounds have been identified in coal tar and over 200 of these are found in creosote. During the heating, cooking and distillation and blending of the fractions, temperature variations favor the formation of polynuclear aromatic hydrocarbons (PAHs). The bulk of PAHs in creosote contain one to four benzene rings, but also contain higher ringed compounds such as benzo[a]pyrene, benzo[b]fluoranthene and benz[a]anthracene. At least 274 separate compounds have been identified in creosote (Paige, 1985). The major constituents of creosote tend toward high molecular weights. The compounds with the higher molecular weights and low solubilities, and are typically recalcitrant and tend to remain in the groundwater system for long periods of time.

Of the 274 compounds found in creosote, 18 polycyclic aromatic compounds account for approximately 75% of the volatile creosote material (Paige, 1985). The United States

Environmental Protection Agency (USEPA) has evaluated creosote and has found sufficient evidence to indicate that the preservative is carcinogenic. In listing the waste as hazardous under the Resource Conservation and Recovery Act (RCRA), USEPA cited the following reasons:

1. Creosote contains significant concentrations of toxic PAHs and volatile organic compounds.
2. PAHs maybe toxic, mutagenic, teratogenic and carcinogenic.
3. Evaporation treatment of PAHs could lead to the release of hazardous constituents to the soil, surface water, ground water and air.

Creosote behaves quite differently when mixed with water due to some of its physical characteristics. One notable property of creosote is its specific gravity. The specific gravity of undifferentiated creosote is greater than that of water; therefore, the movement of dense phase creosote compounds through the groundwater system is quite different than dissolved pollutant transport. Another significant property of creosote is its solubility. Individual creosote compounds have solubilities ranging over eight orders of magnitude (Hult, 1984). The differences in solubility cause large variations in the proportion of each chemical that remains in a mixture of liquid hydrocarbons, dissolves into the groundwater, or is absorbed onto geologic materials. The proportions change with chemical concentrations in both space and time.

The health risks of exposure to low concentrations of coal tar compounds are poorly known, but several cases of pollution of municipal water supplies with coal tar and other volatile organic compounds have been documented (Hult, 1984, Yazicigil, 1981, and Bedient, 1984). A significant factor which affects the toxicity of the coal tar compounds is the fact that the original constituents can change through chemical reactions and biological processes to compounds that may be even more toxic than the original. However, this same factor may ultimately allow for the natural biodegradation to unharmed, naturally occurring compounds.

### **7.3 Occurrence, Behavior, and Transport of Coal Tar Compounds in Groundwater**

The coal tar derivatives have reached the unsaturated zone at the Holcomb plant site through three major pathways. These are:

1. Seepage through the bottom of the surface impoundment.
2. Surface water runoff from the plant site and storage areas.
3. Direct spillage of creosote onto the ground.

Hult (1984) recognized that organic contaminants in the groundwater occur in three forms--an aqueous phase (water containing solubilized and dissolved constituents), a hydrocarbon fluid phase (liquid mixture due to the immiscibility of the creosote) and a hydrocarbon solid phase (creosote sorbed onto a solid matrix both above and below the saturated zone). This classification

was based on his observations of soil cores and groundwater samples taken at a creosote plant in the St. Louis Park area of Minnesota. Previous investigations at Holcomb Creosote confirm that these three phases are present at this site. Figure 16 demonstrates the phases of organic contaminants and their distribution in the groundwater at Holcomb Creosote. Hult (1984) found that naphthalene constituted over 90% of the contaminants remaining in the soil zones. Previous investigations and monitoring of landfarm sites by Engineering Tectonics and Paige (1985) indicate that naphthalene, due to its high percentage of total creosote, is usually found as a major contaminant at creosote waste sites.

When coal tar compounds move through the vadose zone to the saturated zone, several processes occur that ultimately determine the phases and concentrations of the compounds in the groundwater. The first of these processes is sorption. Many organic contaminants are hydrophobic and their movement in the groundwater system is affected by this phenomena. Hem, 1970, states that sorption occurs at the surfaces at which waters are in contact with solid phases. The surface of a solid (i.e., soil or organic carbon fragments) is covered with a thin layer of tightly held molecules or ions taken up from the non-solid phase. This layer is held to the solid surface by physical and chemical forces. Sorption consists of the transfer of the contaminant from the liquid phase (groundwater) to the solid phase (soil). This phase partitioning process may be fully or partially reversible through desorption (Miller, 1984). Sorption tends to retard or slow the rate of solute movement relative to the common advection/dispersion rate of groundwater flow. Normally when a contaminant is introduced into the saturated zone, it tends to move in a manner governed by the overall flow system. This movement is typically characterized by a bulk advective flow component and is related to deviations from the bulk flow, i.e., dispersion (Miller, 1984). Sorption results in the attachment of the contaminants to the soil particles and tends to hold the contaminants in the aquifer system to serve as a long term source of contamination.

The impact of sorption and desorption on the transport of an organic contaminant is influenced by many variables including the physical and chemical characteristics of the soil and the contaminant, the presence of competing solutes, and concentrations and types of organic material in solution. Hem (1970) states that finely divided solids have a large surface area per unit volume and hence a considerable capacity for physical sorption. When sorption takes place without chemical bonding, as is the case with most organic compounds, the sorption is due to Van Der Waals forces. The rate at which the sorption or desorption of a contaminant by the soil structure approaches equilibrium with a groundwater system is an important consideration in determining the transport of the contaminant in the system. All systems tend toward equilibrium. However, the assumption that the achievement of local sorption/desorption equilibria for solutes in soil systems is instantaneous may be incorrect (Miller, 1984). There is evidence that the behavior of many organic solute/soil systems significantly deviates from instantaneous equilibrium concepts. It is more likely that

sorption systems with organics involves a two step relationship with a linear equilibrium-controlled process coupled with a first order rate process (Karickhoff in Miller, 1984). Thus, the kinetics are very important in the partitioning of contaminants between the water and the soil phases.

Clays have a greater sorption capacity than sands, resulting in an inverse relation between the factors of sorption and permeability (LeGrand, 1967). Thus the clays within the regolith at the Holcomb Creosote site may have sorbed a high volume of the coal tar compounds that are not highly soluble but continue to release contaminants as dissolved phase compounds over time.

The second mechanism that occurs when coal tar derivatives are introduced into the groundwater system is dissolution. As stated above, the solubilities of the coal tar derivatives are wide ranging. The solubility behavior of hydrocarbons is poorly understood. Many coal tar compounds are non ionic and exist as microscopic aggregates of individual monomers known as micelles (Hult, 1984). Micelles occur in the groundwater system and behave according to the following principles:

1. If the micelles exceed a critical pore size, they will be transported as if they were ideal solutes.
2. If the specific gravity of the micelles differ from the groundwater, the rate and movement of the micelles is different from the rate and movement of the groundwater.

In the saturated zone, the vertical and horizontal movement of hydrocarbon mixtures having fluid properties significantly different from those of the water results in irregular distribution of contaminated water and hydrocarbon fluid phases because the hydrocarbons may move at a rate and in a direction different from the groundwater. The coal tar compounds typically have specific gravities greater than that of water and a hydrocarbon fluid phase may tend to move vertically downward with respect to the groundwater (a "sinker"). At stratigraphic traps (i.e. zone between porous media and fractured bedrock) micelles can concentrate and reform as a hydrocarbon phase.

Johnson (1986) states that when fractures are present in the medium of interest, solutes will diffuse into zones of the aquifer matrix where the water is immobile and there is essentially no advective flow. This becomes a mechanism for retardation. Since no coal tar compounds have been found in the bedrock aquifer immediately downgradient of the old surface impoundment area at Holcomb Creosote, it is likely that the sinkers have come to rest along the contact between the saprolite and the bedrock in zones where groundwater movement is negligible and advection and dispersion are not occurring. Ehrlich (1982) states that because phenolic compounds are more soluble in water than PAHs, two phases occur when groundwater is mixed with coal tar compounds--one light aqueous phase rich in phenolics and the heavier sinker phase.

The third process that occurs between the coal tar compounds and the groundwater is chemical and biological in nature. Most individual contaminant compounds in the aqueous phase behave as

nonconservative solutes that react strongly with the porous media. Because each coal tar compound is soluble to some extent, those in the source material will be dissolved by water moving through it. Partitioning between hydrocarbon and aqueous phases will vary widely from compound to compound. When the compounds become dissolved in the groundwater, their individual physical properties become unimportant and their behavior follows the common advection/dispersion models. The chemical properties of the compounds become very important due to reactions to remove or alter the compounds. One of the most important chemical properties of the coal tar compounds is the ability for some of the lighter molecular weight compounds to become negatively charged and, therefore, have the ability for ionic exchange, since negatively charged particles will not sorb on to the neutrally or negatively charged soil organic matter (Johnson, 1986).

Biodegradation of the coal tar compounds is a significant factor in retarding their movement and reducing them to naturally occurring compounds. Microbial studies by Paige (1985) and Bedient (1984) indicate that soil microbe populations do exist that are capable of degrading selected organic compounds. With the slow velocity of the groundwater, these microbes could have a significant effect in degrading the concentrations of organics when nutrients and dissolved oxygen are present. Bedient (1984) states that experimental data from a coal tar compound contaminated site showed that, generally, 90% of the organics had been removed in the first five feet of unsaturated soil. The predominate compound that remains is naphthalene. This is due to the high molecular weight of this compound and its dominant percentage of the original creosote material. However, as will be discussed in detail in section 10.2.3, creosote is believed to be biodegradable by naturally occurring microbes.

Figure 17 is a conceptual model of the chemical, physical and biological processes affecting the transport of coal tar compounds at Holcomb Creosote. Based on this model, and calculations of retardation factors, and solute transport over the life of the facility, it becomes quite apparent that retardation of movement of the contaminant plume has played a major role in preventing significant migration over the 45 year lifetime of the plant.

#### **7.4 Effect on Remediation**

The physical and chemical characteristics that effect the transport of the coal tar compounds in the groundwater drastically impact any aquifer restoration methods proposed at the site. Since the contaminants are in three major phases, a single remediation technique may not result in cleanup of the entire site. Secondly, uncontaminated water entering the saturated zone can become contaminated water by the practical solution of the hydrocarbon fluids and by the release of compounds sorbed on the clay materials. Additionally, while some bedrock contamination has been identified at the site, overpumping the bedrock aquifer to cause a steeper gradient for the

contaminants to flow to a recovery well could result in significant bedrock contamination that may never be remediable. Because of the very low hydraulic conductivity of the regolith aquifer, recovery wells in this zone would have to be pumped at extremely low rates in order to avoid operational problems. This would result in the construction of dozens of wells to adequately capture and control the plume. Finally, the difficulties in locating sinkers where micelles have reformed as a hydrocarbon fluid phase, cannot be overstated. These sinkers could remain as secondary sources of contamination over long periods of time.

## 8.0 SURFACE WATER QUALITY

Monitoring of surface water at the site was conducted between 1981 and 1984. Water samples were obtained from the stream between the surface impoundment and lagoon and from Dobbins Pond. Figure 18 is a layout of the sampling locations for the stream and pond. Stream site 1 is upgradient of the closed surface impoundment. Stream site 2 is located adjacent to the closed surface impoundment and stream sites 3, 4 and 5 are located downgradient of the surface impoundment. The five pond sampling locations lie along the perimeter of Dobbins Pond. Pond sample points 1 and 2 were sampled more frequently because these represent discharges closest to the facility and the hazardous waste management units.

The surface water quality data for both the stream and Dobbins Pond have been organized into tabular form and are presented in Appendix B. The data are listed by parameter and include the sample location, the date of sampling and the concentrations. Table 6 is a "hits only table" for the surface water data and shows the highest concentration detected.

Table 6: Constituents Detected in Surface Water (Max. Conc.)			
Parameter	Date	Concentration (ppb)	Sample Location
Chromium	11/9/81	50	Stream 2
Phenol	1/20/84	156	Stream 3
Naphthalene	5/22/87	300	Stream 3
Fluoranthene	5/22/87	45	Stream 3
2-Methyl-Naphthalene	5/22/87	190	Stream 3
Anthracene	5/22/87	36	Stream 3
Acenaphthene	5/22/87	250	Stream 3
Fluorene	5/22/87	100	Stream 3
Toluene	5/6/87	12	Stream 3
Total Organic Carbon	7/22/87	25,000	Stream 3

In addition to the surface water quality data presented above and in Appendix B, surface water runoff from the plant was evaluated in the course of filing for an Industrial Stormwater Discharge Permit in 1992. A weir was placed at stream sampling point 2A. Water quality and quantity data were collected during a storm event on September 3, 1992. This storm event had a duration of 150 minutes during which .3 inches of rain fell. A total of 630 cubic feet of surface water passed

through the weir during the precipitation event. Two sets of samples were collected: a "first flush" sample collected 30 minutes after the precipitation began, and a second, composite sample from aliquots collected every 30 minutes for the duration of the storm. Data from these two storm events are presented in tables located in Appendix B. These data indicate that minimal concentrations of pollutants are presently entering the surface water from stormwater runoff. We attribute this to significant improvements in storage and handling of the treated wood as cited above in Section 3.3.

Based on the surface water database, it is apparent that only minor concentrations of creosote compounds have been detected in the stream and Dobbins Pond. The pollutants detected in the pond should have no adverse effect on fish or aquatic life. Lethal concentrations of phenol to minnows and rainbow trout are 20 and 6 ppm, respectively (Gutherie, 1980). None of the concentrations of the pollutants detected in the surface water at the site approach these concentrations. Therefore, we conclude that the natural wetland system must be acting as a bioreactor that degrades the compounds to virtually non-detectable concentrations before the groundwater and surface water discharge to Dobbins Pond.

## **9.0 POTENTIAL RECEPTORS AND CONTAMINANT MIGRATION PATHWAYS**

### **9.1 Potential Migration Pathways**

Hazardous constituents at the Holcomb Creosote site have three migration pathways. First, contaminants from both the closed surface impoundment and landfarm can migrate to the unsaturated zone and proceed downward by gravity to the shallow regolith aquifer. This migration takes place primarily between the two HWMUs and to the south of the landfarm. Once the contaminants are in the shallow groundwater aquifer, they can move laterally toward the stream and wetland and, during the winter and spring, when the water table is near the ground surface, can discharge to both the stream and wetland. Additionally, the heavier molecular weight compounds have a tendency to sink in the regolith aquifer and move to the fractures in the bedrock aquifer. All water table elevation data indicate that the groundwater discharges to the wetland and has the potential to migrate further east from the landfarm towards Dobbins Pond. Therefore, all contaminants should ultimately move to Dobbins Pond.

### **9.2 Exposure Potential**

There are no groundwater users located within the plume and none between the downgradient edge of the plume and Dobbins Pond. Further, a review of water users within a one mile radius of the plant indicates that all residences and businesses (with the exception of the new church upgradient of the site) are served by public water from the Town of Yadkinville which utilizes surface water as its source of supply. Therefore, there appears to be little potential for the contaminants to pose a human health risk because there is no complete migration/exposure pathway. The only potential

impact of the contaminants is on the aquatic ecosystem in Dobbins Pond. However, based on the concentrations of contaminants detected in the surface water system compared to lethal concentrations for aquatic life, there is little potential for adverse effect. The only effect observed at the facility is a tendency to stimulate algal blooms in the stream between the closed surface impoundment and the landfarm. These blooms are most likely related to the high organic carbon load entering the stream from the groundwater. Figure 19 is a map showing the location of the public water service area for the Town of Yadkinville.

### **9.3 Risk Assessment**

Based on the information cited above, it is our conclusion that the contaminant plume at the Holcomb Creosote site poses little significant risk to human health or the environment at the current levels of contamination in the ground or surface water system. Therefore, we believe there is no basis for accelerated remedial action at the site.

## **10.0 GROUNDWATER REMEDIATION CONCEPTS**

### **10.1 Introduction**

Site hydrogeology, the fluvial stream system, and the contaminant types present at the site severely limit the types of groundwater remediation that could effectively reduce contaminant concentrations in the shallow regolith and/or the bedrock aquifers. Following is an analysis of various groundwater corrective action measures that were considered for the Holcomb Creosote site.

#### 10.1.1 Discussion of Remedial Alternatives for Groundwater

The objectives of the corrective action plan for the groundwater contamination are to reduce the concentration of dissolved contaminants in ground water and to prevent migration of the plume to a point of exposure in concentrations that are above regulatory levels. These objectives may be accomplished by: 1) altering plume flow by pumping recovery wells and treating the pumped water at the surface, or; 2) altering plume chemistry by removing volatile organic compounds, by air sparging and in-situ biodegradation utilizing, constructed and natural wetlands or some combination of these. The following sections discuss both pump and treat and remediation methods that alter plume chemistry.

#### 10.1.2 Technologies that Alter Plume Flow: Pump and Treat

Three important considerations have a bearing on the viability of pump and treat methodology: 1) the effectiveness of the technology based on hydrogeologic constraints; 2) cost, and; 3) effluent disposal.

Pump and treat technology has been used extensively in the Piedmont and throughout the country at sites contaminated by hazardous waste. A pump and treat system relies on extracting water from



the saturated zone, treating it at the surface, and discharging the water as an effluent. Plume migration is slowed or halted by creating a physical reversal in the slope of the water table caused by the cone of depression and capture zone. However, there is little evidence to suggest it has been effective in significantly reducing contaminant concentrations to within regulatory limits, even after years of remediation (National Research Council, 1994).

At the site, the water table gradient appears to be moderate from north to south towards a discharge point at Dobbins Pond. However, due to the extremely low permeability of the regolith, small available drawdown and very low transmissivity, recovery wells would be required to be installed on 20 foot centers throughout the plume in order to recover the contaminated groundwater and to halt its migration. These factors would result in logistical problems associated with installing numerous recovery wells, ancillary piping and control equipment, extensive trenching, and crossings beneath the stream. Additionally, a sophisticated treatment system would be required and an NPDES permit would be required in order to discharge the effluent. It is questionable whether the existing stream would qualify as a receiving stream for the effluent due to its low flow and proximity to Dobbins Pond.

The estimated cost for the system described above is on the order of \$300,000 for capital cost and installation. The design and construction supervision is estimated at \$30,000. The high costs associated with this option are due to the need for multiple wells, extensive piping, and sophisticated treatment systems.

Groundwater pump and treat systems are typically very slow in reducing the contaminants to an acceptable level. Therefore, we estimate that the system would operate for a minimal period of ten years and still may not adequately reduce the contaminant levels. However, the ten year duration is used for estimating the O & M plus monitoring costs. Under this scenario, the annual cost incurred for the system is on the order of \$30,000, which includes carbon replacement, treatment of the strippers to reduce/eliminate biofouling, and remove iron, power costs, and providing suitable QA/QC monitoring. The total O & M costs for the pump and treat system for the duration of the remediation period is estimated at \$300,000. Thus, the total estimated cost for this remedial option is \$630,000.

#### 10.1.3 Technologies that Alter Plume Chemistry: Air Sparging

Air sparging consists of injecting clean air under pressure into the groundwater system via injection wells or horizontal pipes. Air bubbles flow through the contaminated groundwater, displacing water from the soil porosity and stripping volatile organic constituents that are converted to a vapor phase. Air sparging thus constitutes in-situ air stripping. Sparging has the potential to remove a

significant portion of the volatile contaminants in-situ and provide increased oxygen levels for naturally occurring biogenic activity that can degrade the semivolatile and recalcitrant compounds.

Sparging points extend below the seasonal low water level in each well and are connected to a central distribution header that serves all wells. The sparging system receives clean air under pressure from a compressor. Each connection, either at the well head or at the junction with the header for the system, is equipped with a pressure regulator and a shutoff. The gauges are included to determine pressure variations within the system; the shutoffs are used to re-configure the system periodically to reduce the chance of preferential channels forming, and to allow for maintenance. In this manner, the plume area can be more effectively treated.

While sparging may oxygenate groundwater only to the solubility limits of air at groundwater temperature (8 to 10 mg/l), Ardito and Billings (1990) noted that biodegradation may proceed in low oxygen environments after initiation of degradation. Therefore, the oxygen supplied by air sparging may provide an adequate supply to augment the onset of biotic degradation.

Based on GeoSci's experience at other sites, 2 inch PVC pipe appears to be appropriate for air lines to the sparging points. Once head pressures are overcome, a key issue in sparging technology appears to be bubble size, with smaller bubbles producing better results than larger ones. Qualitative bench scale studies indicate that smaller holes in the sparging points produce smaller bubbles. The system recommended for consideration at the Holcomb Creosote Site includes K-V Associates Micropore sparging points for production of tiny bubbles.

The capital cost for an AS system as cited above is estimated at \$80,000 including an engineering cost of \$10,000. It is estimated that the annual operation and maintenance costs for the sparging system is \$20,000 which includes performance monitoring within the groundwater plume on a quarterly basis, plus developing an annual report. Therefore, the total cost for the system is estimated at \$180,000 in an operational period of five years.

#### 10.1.4 Enhanced In-situ Bioremediation

A review of recent literature resulted in locating a plethora of research dealing with the natural biodegradation of creosote compounds. Kiilerich and Arvin, (1996) compiled data from 44 sites contaminated with creosote compounds to determine whether in-situ bioremediation was a viable option for remediating contaminated aquifers. Based on their studies, it was evident that, in 90 percent of the cases, concentrations in the contaminant plume within 50 meters downgradient of the source area had been reduced from 3 to 50 times the concentration at the source. This summary reinforces the studies of Paige, 1986, Godsey and Goerlitz, 1986, Mueller, et al , 1989, Madsen, 1991 and others. Therefore, when the effectiveness of bioremediation is considered against other possible remedial schemes, the bioremediation concept is most favorable provided the site is suited

for the growth and degradation of the contaminants. Thus, if we could identify a means for evaluating site conditions required for biodegradation and specific tests could be conducted at the site to verify that these conditions do, in fact, exist at the site, bioremediation could be expected to be a suitable remedy for groundwater contamination at the site. Table 7 is a matrix of traditional remediation concepts reviewed and considered for the site early on in the groundwater assessment.

Table 7: Evaluation of Remedial Options for Groundwater				
Remedial Alternative	Advantages	Disadvantages	Capital Cost	Annual O&M
Pump & Treat	Changes hydraulic gradient to slow plume movement	Must dispose of waste-water; no remediation of vadose zone or cone of depression about pumping well(s)	\$300,000	\$30,000 (based on a 10 year operational period, the total O&M costs are estimated at \$300,000)
In-situ bioremediation	Uses natural systems for remediation. Low capital and O&M costs	System design parameters difficult to analyze for artificial wetlands.	\$30,000 (does not include AS)	\$10,000 (includes modified compliance groundwater monitoring; \$50,000 based on 5 years.
Air Sparging	Modifies plume characteristics; Enhances biodegradation	Must provide relief venting for sparge air and vapors	\$80,000	\$20,000 (based on a 5 year operation, the total O&M costs are estimated at \$100,000)

## 10.2 Hydrogeologic Parameters Affecting Remediation

The centroid of the contaminant plume is located in a riparian wetland between the closed surface impoundment and the landfarm. The depth to the water table in this area ranges from less than six inches to 3 feet below land surface in response to seasonal recharge. Additionally, due to the seepage of contaminants into and within the wetland area, some contaminants are transported as surface water to the lacustrine fresh water wetland at the head of Dobbins Pond. Therefore, there is evidence of mixing of shallow groundwater with surface water in the wetland area.

Within the riparian wetland, the aquifer materials are primarily silts and clays which contain small sand lenses within the aquifer matrix. These lenses were formed by deposition in the stream system. There is evidence of rapid facies change within this area. Therefore, the shallow aquifer responds as a heterogeneous and anisotropic aquifer with very low transmissivity that greatly hinders the effectiveness of traditional groundwater recovery.

The pumping tests conducted at the site clearly indicate that the permeability, transmissivity and specific yield of the water table aquifer are extremely low. Yields from long term pumping of traditional vertical wells are estimated to be in the .2 gpm range. At this low pumping rate, the radius of the cone of depression is less than 20 feet. Therefore, a well field consisting of numerous, low yielding wells would need to be placed in the contaminant plume to "capture" the contaminated groundwater.

Finally, due to the geochemical nature of the contaminants and the low permeability of the aquifer materials, groundwater movement is slow. Thus, much of the contaminant mass is held within the soil matrix by physical properties near the old impoundment area and would not move quickly to recovery wells. This results in the inability of the groundwater system to be quickly remediated by pump and treat measures.

#### 10.2.1 Previously Proposed Corrective Action System

Due to the major constraints on typical pump and treat systems for remediation of the aquifer at the site, a combination of oxidation, bioremediation, aeration and wetland polish was proposed as a Corrective Action Program in the 1991 Post Closure Plan Addendum. A general layout and conceptual system design elements are shown in Figures 20a and 20b. After further review and consideration, certain modifications have been made to the system. In the 1991 plan, a collection gallery was to be installed on both sides of the stream which would carry groundwater towards the wetland at Dobbins Pond. The groundwater would then be collected and pumped back to an infiltration basin located near the old surface impoundment. The infiltration basin would allow for the mixing of the collected groundwater, flushing of the contaminants from the impoundment area to the stream system, and also direct discharge of effluent to the stream. In order to maximize growth of microorganisms that would biodegrade the contaminants, nutrients were to be fed into the infiltration basin. Additionally, a floating aerator was to be located within the infiltration basin and a series of terraced rip-rap "spillways" would allow for further oxidation prior to discharge to the stream. Air sparging wells were also proposed to provide additional oxygen to the aquifer to stimulate biological reproduction. Finally, a cutoff wall was proposed at the terminus of the horizontal collectors to prevent discharge of contaminants to the bedrock aquifer. The existing wetland system was to be used for a final polish.

After identifying the permitting requirements for the remedial system outlined above, the capital costs, anticipated operation and maintenance costs, and more recent research on in-situ bioremediation, we have modified the system to eliminate and/or replace certain unit processes with an overall goal of maintaining and enhancing the existing microbial population within the aquifer system.

#### 10.2.2 Evaluation of Suitability of In-situ Bioremediation as Remedial Option

Based on the evaluation presented above where environmental risks, site constraints, costs, ease of construction, effectiveness and length of remediation were considered, enhanced in situ bioremediation using existing and constructed wetland cells appear to be the most suitable remediation system for the Holcomb Creosote site.

In order to determine whether the site is suitable for enhanced bioremediation, the site was evaluated for the presence of the six basic requirements for biodegradation identified by Bedient et al, 1994. These criteria are:

1. Presence of appropriate organisms that have the ability to flourish and degrade the contaminants of concern.
2. Presence of an energy source such as organic carbon which is used by the organisms for cell maintenance and growth.
3. A carbon source that can be used in conjunction with energy to generate new cells.
4. Presence of an electron acceptor for the reduction of the contaminants. Typically, oxygen is the electron acceptor in aerobic environments, while methane becomes an electron acceptor in anaerobic systems.
5. A source of nutrients to stimulate the reproduction of the organisms. The most common nutrients are nitrogen, phosphorous and calcium. Commercial fertilizers can be used as nutrients in cases where the natural nutrient supply has been depleted.
6. Acceptable environmental conditions. Typically, neutral pH, moderate to warm temperatures, low salinity, and the absence of high concentrations of heavy metals represent a suitable environment for the organisms to grow and degrade the contaminants.

#### 10.2.3 Biofeasibility Study

In order to determine whether these six elements are present at the site, a Biofeasibility Study was conducted by Bioremediation Research, Ltd. of Pinnacle, North Carolina. The complete Biofeasibility Study is provided herein as Appendix C. The goals of the study were to:

1. Determine whether microbes are present within the soil column at the site that have developed resistance to, and are at the same time able to metabolize the creosote contaminants.
2. Determine whether these microbes can be purified and characterized on artificial media.
3. Determine whether sufficient nutrients are present at the site to support passive remediation or whether nutrient additions and/or air sparging is required.

A total of 9 soil samples (Figure 21) were collected within the centroid of the contaminant plume at depths ranging from 8 to 24 feet below land surface, well within the shallow regolith aquifer. The aquifer matrix was placed in a flask with creosote to determine whether any microbes were present. The samples from the flasks were streaked onto prepared agar plates and incubated. A visual examination of the growth of the microbes on the agar plates indicated that only 1 of the 9 samples did not show any microbial growth.

Samples from individual microbial colonies were then transferred to new agar plates for growth and identification. Five bacterial strains capable of reducing the creosote compounds were identified. Soil cores were also tested for pH and the presence of nutrients (phosphorous, potassium, ammonia nitrogen and nitrate.) This testing indicated that there may be a need for the

addition of nutrients to the system to maximize growth, but nutrients are sufficient for some degree of bioremediation.

In order to determine whether electron acceptors are present in the groundwater, dissolved oxygen (DO) measurements were made at each monitoring well. This testing (summarized in the BioRem Report) showed typical DO levels for shallow groundwater systems (range: 6.05 to 6.0 ppm). Finally, to determine the potential for growth and degradation of the creosote compounds in the shallow groundwater, the remediating strains were tested for growth with sterile groundwater, sterile tap water and nutrients, and basic media plus creosote.

The results of the study demonstrate that in 8 of 9 soil cores collected directly in the shallow contaminated aquifer, there is at least one strain of bacteria that is able to tolerate all of the creosote constituents and metabolize some portion of the creosote constituents. Because these strains were purified directly from the contaminated cores, there must be sufficient nutrients present to support growth at some level. Further, there seems to be enough dissolved oxygen to support remediation in all of the wells except those in the area of the lagoon (wells 2, 3, 6, 7 and 9). Oxygen depletion in this area can be solved by air sparging.

Therefore, we conclude that strains of bacteria have evolved within the contaminated aquifer materials at the site that are capable of tolerating significant levels of creosote contamination, and are capable of metabolizing some portion of the mixture of compounds contained in the creosote. Additionally, these microbes are common fastidious organisms that can be cultured and identified by standard microbiological methods. Finally, there are sufficient nutrients present to support the passive remediation of the creosote contaminants over some period of time, and, with sparging of some wells, the site is most likely capable of significant bioremediation by in-situ bioremediation.

By comparing the results of the Biofeasibility Study to the six points identified by Bedient et al (1994) as being required for in-situ biodegradation, we can conclude that:

1. Micro-organisms are present that are capable of growth, reproduction and degradation of the creosote contaminants.
2. The presence of organic carbon in the aquifer was confirmed early on in the RCRA investigations. Total Organic Carbon (TOC) concentrations greater than 10,000 ppm were measured from the groundwater monitoring wells.
3. The creosote contaminants contain carbon as do the bacteria. Further, the groundwater and aquifer matrix contain a carbon fraction.
4. Dissolved oxygen is the most typical electron acceptor in shallow groundwater systems. Acceptable levels of DO (range: 0.05 to 6.0 ppm) were measured in the contaminated aquifer with the exception of the immediate vicinity of the closed surface impoundment. Air sparging in this area can successfully add oxygen to the system.
5. The presence of nutrients was confirmed by the feasibility testing.

6. While the groundwater was slightly acidic, it did not prevent the growth or reproduction of the microorganisms or interfere with their ability to degrade the creosote compounds.

Based on these criteria, we have selected an enhanced bioremediation system consisting of air sparging and wetland treatment as the most suitable remedial action for the site.

### **PART THREE: PROPOSED REMEDIATION**

## **11.0 REVISED REMEDIATION SYSTEM**

### **11.1 Remediation Concepts**

As the testing for the biofeasibility began to show that indigenous bacteria were present in the aquifer throughout most of the site, and that the existing wetland system significantly reduced the contaminants prior to entering Dobbins Pond, the concept of passive bioreactors began to develop. Coupled with low operation and maintenance costs and the successful use of existing and artificial wetlands to treat groundwater, we began to abandon some of the previous unit processes and to focus on enhancing the natural biological systems at the site. In order to evaluate possible unit processes to enhance the existing system, we identified the following requirements:

1. Due to the complex fluvial system in the stream/groundwater system, mixing of ground and surface waters could enhance the movement of nutrients, oxygen and microbes into the contaminated aquifer. This could be accomplished by creating a subsurface flow wetland cell in the riparian floodplain between the landfarm and surface impoundment.
2. Air sparging is needed in the area just downgradient of the old surface impoundment, where the highest concentrations of contaminants reside. Sparge wells into the transitional material between the shallow and bedrock aquifers may also accelerate DNAPL transformation.
3. Sweetening of the groundwater through natural means may help offset the slight acidity of the groundwater.
4. Aerobic conditions throughout the area of the plume will enhance the rate of degradation.
5. Utilization of the existing wetland system as a final polish bioreactor is desirable and enhances the concept of ecological engineering.
6. Any system must be able to be constructed at least partially, by the plant personnel because of financial constraints.
7. The system must have a low operation and maintenance cost.
8. A passive system is preferred over an active one.

### **11.2 Description of System**

The revised corrective action system will consist of two wetland cells, one constructed and one natural that will serve as bioreactors. The existing wetland will be augmented by the construction of a new wetland cell that will flood the area between the surface impoundment and the landfarm. The floodwaters will not extend into any closed hazardous waste disposal units. In order to allow for mixing of the ground and surface waters, a series of cylindrical chimney drains will be

constructed prior to the filling of the constructed wetland. These chimney drains will be filled with limestone to provide for natural pH adjustment. Air sparging wells will be installed in and just downgradient of the surface impoundment and south of the landfarm.

The two wetland cells will be separated and the water levels controlled by a wooded dike structure located just south of the downgradient edge of the closed surface impoundment. This structure will be constructed of wooden timbers that can be removed or added to control water levels in the upper wetland.

This concept utilizes the effectiveness of the existing wetland system to treat the contaminated ground and surface water which enters the hydrologic system from the plant. Further, it serves as a stormwater treatment system and provides remediation of any releases from existing SWMU's.

## **12.0 CORRECTIVE ACTION SYSTEM DESIGN DATA**

### **12.1 Wetlands**

The ability of wetlands to remove organic chemical contaminants is well documented (Hammer, 1989, Morishi, 1993 and Kadlec and Knight, 1996). The primary consideration for the efficiency of the wetland system to remove contaminants is the hydraulic retention time. Various means of calculating retention times including plug flow, energy loss and flow through porous media have been documented by Kadlec and Knight, 1996.

#### 12.1.1 Wetland Size and Configuration

Figure 22 shows the currently delineated wetland area and Figure 23 shows the layout of the proposed wetland cells. Cell 1, is a portion of the existing wetland that has been impacted by the plume. It is approximately 200 feet long and 60 feet wide at its maximum dimensions. Cell 1 is a natural subsurface flow wetland, with minimal flow through channels, containing a heavy root mat of hydrophytic grasses, alders and cattails. Cell 1 is only a small portion (.3 acres) of the total 2 acre biomass that comprises the entire natural wetland system at the site. Because contaminants have not been regularly detected beyond the area of SWMP 1, we consider the downgradient limit of the wetland to define the area of water quality polishing and contaminant reduction. Using the reduced portion of the entire wetland, the hydraulic retention time based on velocity calculations using a variation of Darcy's law for flow through saturated porous media, is greater than 100 days, (based on the highest hydraulic conductivity calculated from pump test data). Seidel, (1976), indicates reduction of phenolic compounds in wastewater with initial concentrations of 100 mg/l to 0 mg/l in approximately 6 days in a subsurface flow wetland with cattails. Srinivasan and Kadlec, (1995) indicate similar results with surface flow wetlands. Their research also indicated greater removal efficiencies where the substrate contained significant organic matter. They noted little effect on reduction with water depth in the wetland.



Wetland Cell 2 will be a constructed subsurface flow wetland. The water level in this cell will be controlled by a wooden gate structure located northwest of monitoring wells MW-15 and MW-16. This structure will be discussed further in Section 12.1.3. This cell is classified as a subsurface flow wetland even though one to two feet of standing water will exist over the area of inundation. The subsurface flow and mixing which makes the cell a subsurface flow wetland is due to the fluvial sedimentary system and the vertical mixing drains. The retention time in Cell 2 is estimated to be greater than 150 days. This number was calculated using hydraulic conductivity values derived from grain size analysis completed on the sediments within the stream system.

In order to enhance the electron acceptors in this cell, horizontal aerators will be installed just above the substrate. The aerators will be connected into the air sparging system. The specific design of the aerators are discussed further in Section 12.15.

#### 12.1.2 Vertical Drains

It is critical to allow mixing of surface and ground waters within the area of Cell 2. Some mixing occurs naturally during various parts of the year depending on the position of the water table and whether the stream is gaining or losing. To augment mixing, we propose to install eight vertical chimney drains in the area of Wetland cell 2. The layout of these drains are shown on Figure 23. These drains will be filled with porous limestone to facilitate vertical mixing of surface and groundwaters and to provide pH adjustment. Use of limestone for pH adjustment has been cited by Brodie et al, 1993. A schematic drawing of a typical chimney drain is shown in Figure 24. Each drain will consist of a 12 inch diameter borehole drilled to a minimum depth of 10 feet below land surface. The boreholes will be backfilled with a porous limestone. The porosity of the drains will be several orders of magnitude greater than the surrounding regolith and will allow for the mixing of surface waters (with high levels of dissolved oxygen) and the underlying groundwaters. The limestone will act as a natural buffer to the slightly acidic groundwater which will enhance the reproductive capacity of the microbial population.

Mixing in the chimney drains will be by gravity, permeability gradients and contaminant concentration gradients. Additionally, contaminants that are mobilized by the air sparging will have a preferred pathway to the upper zones of the wetland due to the extreme difference in permeability in the fluvial sediment mass and the chimney drains.

#### 12.1.3 Wetland Outlet Control System

A treated wooden gate system will be installed just northwest of Monitoring Wells MW-15 and MW-16. Figure 25 is an oblique view drawing of the outlet works. The gates will control the level of the water in Wetland Cell 2 by the addition/removal of wooden planks. This type of outlet works is commonly used by the Soil Conservation Service in controlling water levels in farm

ponds and wetland systems where the drainage area and impoundment areas are small. A staff gage will be installed in the outlet works to allow for the monitoring of the water levels and to guide the need for water level adjustment. Figure 26 is a detailed schematic of the gate.

#### 12.1.4. Transplanting of Wetland Vegetation in Cell 2

Wetland vegetation, including grasses, cattails and alders will be transplanted from the natural wetland to the artificial wetland cell during the spring after the cell is constructed. Use of naturally occurring flora that have already been acclimated to the surface and groundwater contaminants should result in a high survivability rate.

### **12.2 Air Sparging System**

#### 12.2.1 Overview

The air sparging (AS) system will introduce oxygen below the water table (vertical AS points) and in shallow surface waters (horizontal AS lines) to aid the bioremediation of petroleum contaminants by naturally occurring bacteria. The figures listed in Table 8 illustrate the AS system and details.

Table 8: Air Sparging System Figures	
Figure 27	Air Sparging System Layout
Figure 28	Air Sparging System Schematic
Figure 29	Detail of Deep and Regolith Vertical Air Sparging Points
Figure 30	Detail of Vertical Air Sparging Vault
Figure 31	Section A-A' Trench with Backfill

#### 12.2.2 Engineering Design

The AS system will consist of one equipment house and five AS subsystems. Table 9 shows the piping requirements. Table 10 shows the AS blower requirements. The vertical AS points are designed for injection of 3 CFM AS/point, using K-V Associates Micropore sparge points. The horizontal AS system is designed to provide air approximately 30-35 CFM per branch. The AS air will discharge from the horizontal pipes through holes approximately 1/4 in. dia. that are spaced along the pipe about every 13 feet in Wetland Cell 1 and about every 25 ft. in Wetland Cell 2. Control of flow through the holes can be accomplished by means of manually operated valves. By closing all valves, water can be pushed out of the horizontal AS system. After pressurization, the horizontal AS system can be brought on line by opening the valves sequentially. In a similar manner, the vertical AS system will be brought on line by sequentially opening the valves at the vertical AS system vaults.

Table 9: General Piping Requirements for Air Sparging System			
Air Sparging Subsystems	Distribution Piping	AS Piping	TOTAL
Deep Vertical AS	250 ft.	4 DVAS points x 25 ft. = 100 ft.	350 ft.
Regolith Vertical AS-West	225 ft.	8 RVAS points x 15 ft. = 120 ft.	345 ft.
Regolith Vertical AS-East	750 ft.	14 RVAS points x 15 ft. = 210 ft.	960 ft.
Wetland-1 Horizontal AS	250 ft.	2 WHAS lines x 125 ft. = 250 ft.	500 ft.
Wetland-2 Horizontal AS	Incl. above	3 WHAS lines x 225 ft. = 675 ft.	675 ft.

Table 10: Air Sparging Blower Requirements		
Air Sparging Subsystems	Blower, or similar*	Operating Capacity**
Deep Vertical AS	1 ea. GAST Oilless Model 6066 Rotary Vane, 5 HP	4 DVAS points x 3 CFM/point = 12 CFM Subsystem total at 13 PSIG, 12 CFM
Regolith Vertical AS-West and Regolith Vertical AS-East	2 ea. GAST Oilless Model 6066 Rotary Vane, ganged, 2 x 5 HP	8 RVAS-W points x 3 CFM/pt. = 24 CFM 14 RVAS-E points x 3 CFM/pt. = 42 CFM Subsystem total at 8 PSIG, 66 CFM
Wetland-1 Horizontal AS and Wetland-2 Horizontal AS	1 ea. EG&G Rotron Model EN6 Regenerative, 5 HP	2 WHAS lines x 35 CFM/line = 70 CFM 3 WHAS lines x 35 CFM/line = 105 CFM Subsystem total at 1.45 PSIG, 175 CFM

\* The EG&G Rotron Model EN-6 regenerative blower is explosion-proof. This application does not require explosion-proof motors and controls.

\*\* System flow rates for sparging are designed for all AS points and horizontal lines to be active at any time.

### 12.2.3 Radius of Influence and Sparging Injection Depth

The groundwater table is about five feet below grade. The Regolith Vertical AS points, when installed approximately 10 feet below the average water table will provide a radius of influence (ROI) of about 10 feet. The Deep Vertical AS points, when installed approximately 20 feet below the average water table will provide a ROI of about 20 ft., as ROI can be expected to approximately equal the depth of injection (Kerfoot, 1992). Experience with similar installations suggests that this is a reasonable criteria.

Air sparging can cause the water table to rise near the injection points. Because the area being remediated is a wetland, any rise in the water table may increase the areal extent of the wetland. The flow rates and system configuration are designed so that the local rise of the water table will be kept to a minimum. Sparging injection pressures are kept in the range of 1.5 to 2 times the "breakout" pressure (the pressure that is required to overcome the hydraulic head) to allow air to move out of the sparging point into the saturated zone.

### 12.2.4 AS Blower Components

Each blower will be equipped with inlet air filtration, a silencer on the flow bleed-off at the outlet, a check valve (to prevent reversed flow), a bleed-in valve and a pressure relief valve. Controls will allow either or both of the ganged blowers to operate simultaneously.

### 12.2.5 Piping Specifications

Piping specifications are shown in Table 11.

Table 11: Piping Specifications		
Application	Backfilled, Buried, not Exposed	Exposed, not Backfilled, not Buried
Deep and Regolith Vertical Air Sparging Piping	Meet or exceed ASTM D-1784 (materials) and D-2466 (dimensions) PVC, schedule 40, socket fittings, solvent welded. Trunk: 4 in. dia. Branch: 3 in. dia. Wellhead: 3 in. dia. Downwell: 2 in. dia.	Meet or exceed ASTM A53 for carbon steel pipe, threaded fittings.  Trunk: 4 in. dia. Branch: 3 in. dia. Wellhead: 2 in. dia. At blower: 2 in. dia.
First twenty feet of piping at blower discharge	Meet or exceed ASTM A53 for carbon steel pipe, threaded fittings.	Meet or exceed ASTM A53 for carbon steel pipe, threaded fittings, unpainted in equipment house; coated with bitumastic in wellheads.
Downwell access	NA	Aluminum cam-lock cap 2 in. dia. in vertical leg of tee.
Deep and Regolith Vertical Air Sparging Points	K-V Associates Micropore sparging point, 30 inches long x 2 inches diameter. RVAS points set approximately 15 ft. below grade (about 10 ft. below water table). DVAS points set approximately 25 ft. below grade (about 20 ft. below water table.)	NA
Pressure regulator at wellhead	NA	See Shutoff Valve.
Shut-off valve at wellhead	NA	Ball, size 2 in. dia.
Horizontal AS System: Distribution piping	For burial in trenches: Meet or exceed ASTM D-1784 (materials) and D-2466 (dimensions) PVC, schedule 40, socket fittings, solvent welded. Trunk: 6 in. dia.	For crossing pipe bridge: Meet or exceed ASTM A53 for carbon steel pipe, threaded fittings.  Trunk: 4 in. dia. Branch: 3 in. dia.
Air sparging piping:	NA	For shallow submersion in wetland:  Wetland Cell 1: 2 in. dia. Wetland Cell 2: 3 in. dia. PE 3408 HDPE (High Density Polyethylene) AS holes in pipe to be drilled.
Manual flow control valves	NA	Main branch at pipe bridge: Ball, size 3 in. diameter. Individual AS holes: Ball, size 1/2 in.

### 12.2.6 Equipment House

The equipment house, to be built by Holcomb Creosote, will have the following features:

- Interior dimensions 20 ft. L x 12 ft. W x 8 ft. H.
- 4,000 psi reinforced concrete slab with ramp at entrance.
- Wood timber or aluminum frame construction, either with aluminum skin.
- Insulation equivalent to R-12.
- Double doors, center of 20 ft. wall, each thirty (30) inches wide and individually lockable.
- Interior lighting.
- Externally mounted red light to indicate system fault.
- Thermostatically controlled, motor-driven, ventilation.

### 12.2.7 Instrumentation and Controls

System flow and pressure instrumentation will sense locally in the equipment house. A "Schrader" valve located inside the vault of each sparging point will allow manual checking of pressures at the wellhead. There will be no centralized pressure monitoring or control for the individual vertical air sparging points. System flow and pressure instrumentation for the horizontal air sparging system will also sense locally in the equipment house. There will be no provision for measurement of flow or pressure in the horizontal air sparging lines downstream from the equipment building. Dwyer Series DS-200 Flow Sensors with dwyer inclined manometer for flow measurement will be used for total subsystem flow. Other instrumentation requirements are summarized in Table 12.

Table 12: Instrumentation			
Sensing Location (# of sensing points)	Parameter, units	Range	Accuracy
Each Blower Inlet	Temperature, degrees F	0-125	+ or - 5%
Each Blower Outlet	Temperature, degrees F	0-300	+ or - 5%
Each Blower Outlet	Sparging pressure, pounds per square inch gauge (PSIG)	0 to 25	+ or - 2%
Each Blower Outlet	Flow, cubic ft per minute (CFM)	0 to 100	+ or - 2%
Vertical wellhead by manual gauge applied to Schrader valve	PSIG	0 to 25	+ or - 2%

A control panel mounted on the exterior of the equipment house will include Hand-Off-Auto switches and status lights for the AS blowers. A timer will provide automatic restart after power failure. A seven-day electronic timer with battery back-up will allow programming for variable on-off timing.

### 13.0 REQUIRED PERMITS

Discussions with the US Army Corps of Engineers indicates a General Wetland Activity Permit No. 8 will be required for the activities related to remediation of a hazardous waste site in a wetland. Well construction permits will be required for the air sparging wells. At this time, it is not anticipated that any air quality permits will be required.

### 14.0 SCHEDULE OF IMPLEMENTATION

Table 13 shows the schedule for implementation of the remediation system.

Table 13. Schedule of Remedial Action System Implementation		
Activity	Begin Date	Completion Date
Obtain General Wetland Permit	January 1997	June 1997
Install Air Sparging System	July 1997	August 1997
Install Vertical Drains	August 1997	September 1997
Construct Control Systems	July 1997	September 1997
Construct Wetland Outlet	August 1997	September 1997
Fill Wetland	October 1997	December 1997
Transplant Wetland Vegetation in Cell 2	March 1998	April 1998
System Testing and Startup	January 1998	March 1998

## 15.0 PERFORMANCE MONITORING

Table 14 is a schedule of system monitoring for the remediation program. The modifications to the groundwater monitoring program will most likely require a modification of the Post Closure Permit.

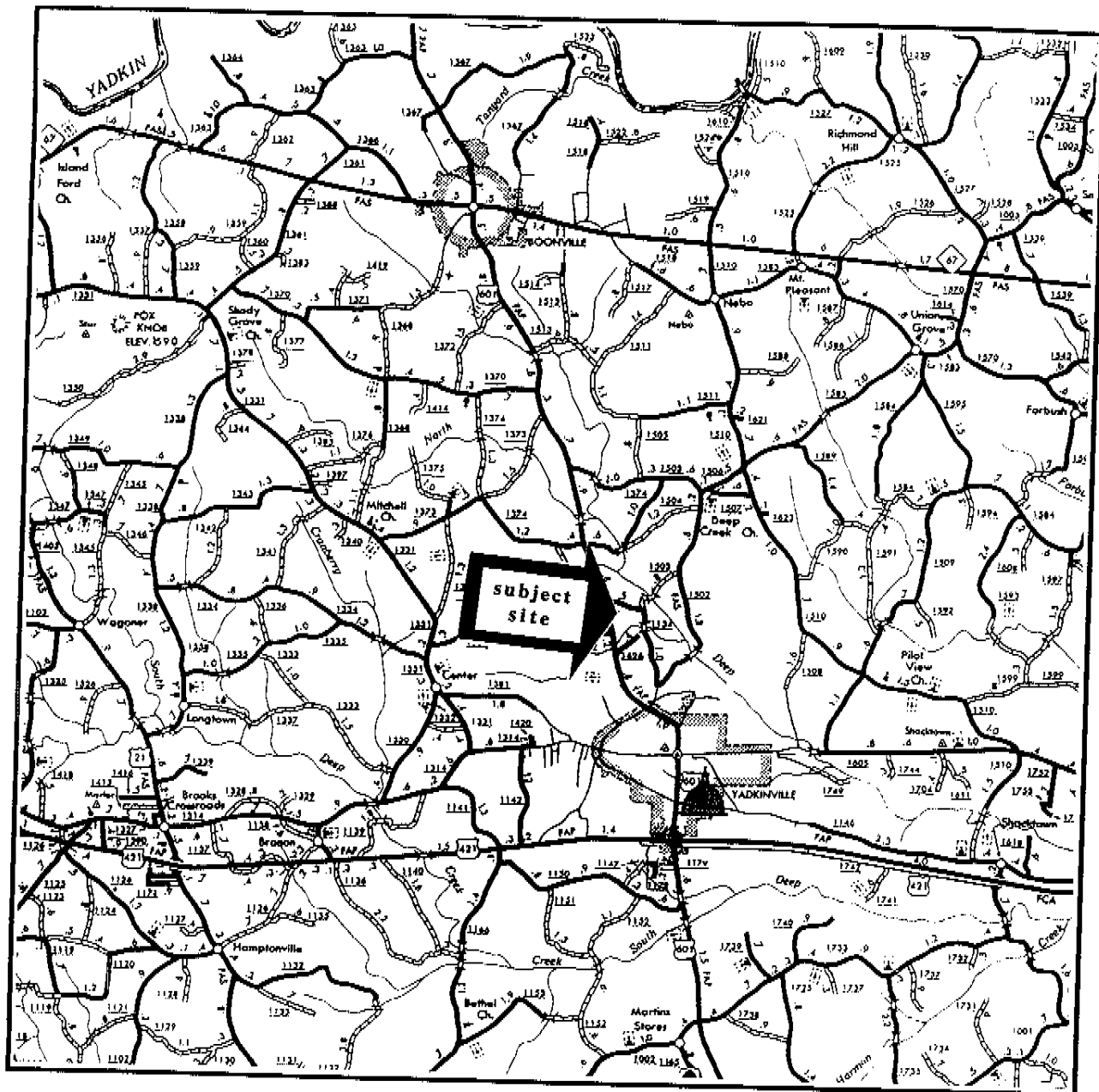
Table 14. Monitoring Plan									
KEY									
B: Before system startup		M: at startup + weekly for 2 months + monthly				R: before & after system reconfiguration			
Q: Quarterly		S: Quarterly first year + semiannually				A: Annually			
GS: Monitoring performed by GeoScience & Technology, P.A.									
Test >>>>>	Water level	Diss O <sub>2</sub>	pH	Water 602	Water 610	TOC	Nutrients	AS Press.	AS Flow
Work by>	GS	GS	GS	Lab	Lab	GS	GS	GS	GS
sample pt.									
MW1	BA	BA	BA	BA	A	A	A		
MW5	BA	BA	BA	BA	BA	A	A		
MW6	BA	BA	BA	BA	BA	A	A		
MW7	BA	BA	BA	BA	BA	A	A		
MW9	BA	BA	BA	BA	BA	A	A		
MW14	BA	BA	BA	A	BA	A	A		
MW15	BA	BA	BA	A	BA	A	A		
MW16	BA	BA	BA	BA	BA	A	A		
AS 1	BA	BR	BR	B	BA			MR	MR
AS 5	BA	BR	BR	B	BA			MR	MR
AS 10	BA	BR	BR	B	BA			MR	MR
AS 15	BA	BR	BR	B	BA			MR	MR
AS 20	BA	BR	BR	B	BA			MR	MR
Strm 1	BA	BA	BA	BA	BA			MR	MR
Strm 2	BA	BA	BA	BA	BA			MR	MR
Strm 3	BA	BA	BA	BA	BA			MR	MR
SWMP 1	BA	BA	BA	BA	BA			MR	MR
SWMP 2	BA	BA	BA	BA	BA	MR	MR		
SWMP 3	BA	BA	BA	BA	BA	MR	MR		
Weir	BA	BA	BA	BA	BA	MR	MR		
AS System						MR	MR		
Wetland	BA	BA	BA	BA	BA	MR	MR		
Wetland	BA	BA	BA	BA	BA	MR	MR		
Dobbins	BA	BA	BA	BA	BA	MR	MR		
Dobbins	BA	BA	BA	BA	BA	MR	MR		
Dobbins	BA	BA	BA	BA	BA	MR	MR		
Dobbins	BA	BA	BA	BA	BA	MR	MR		

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## FIGURES





Map Source: North Carolina County Maps,  
C.J. Puetz, Puetz Place, Lyndon Station, WI.

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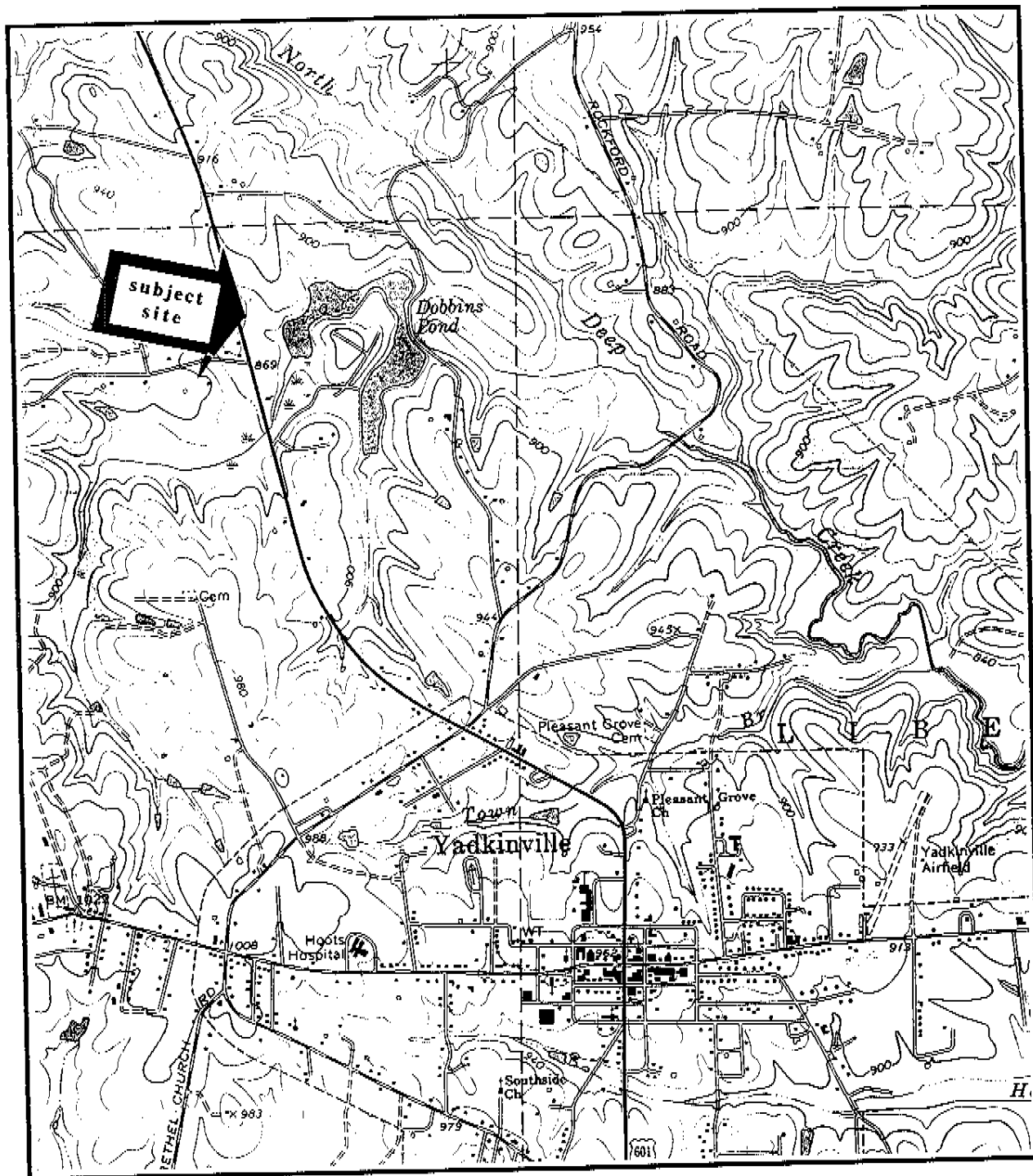
Holcomb Creosote Company, Yadkinville, NC

### Site Location Map 1 (County Road Map)

Job#: 95.116 Drawn by: TPB App'd: ABN

1 inch = 2 miles

Figure 1



Map Source: U.S.G.S. Yadkinville, NC  
7.5' Topographic Quadrangle Map, 1987.

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Holcomb Creosote Company, Yadkinville, NC

**Site Location Map 2**  
(U.S.G.S. Topo Quadrangle)

Job#: 95.116 Drawn by: TPB App'd: ABN

1:24,000

Figure 2

# LEGEND

Permanent groundwater monitoring well

Well point

Piezometer

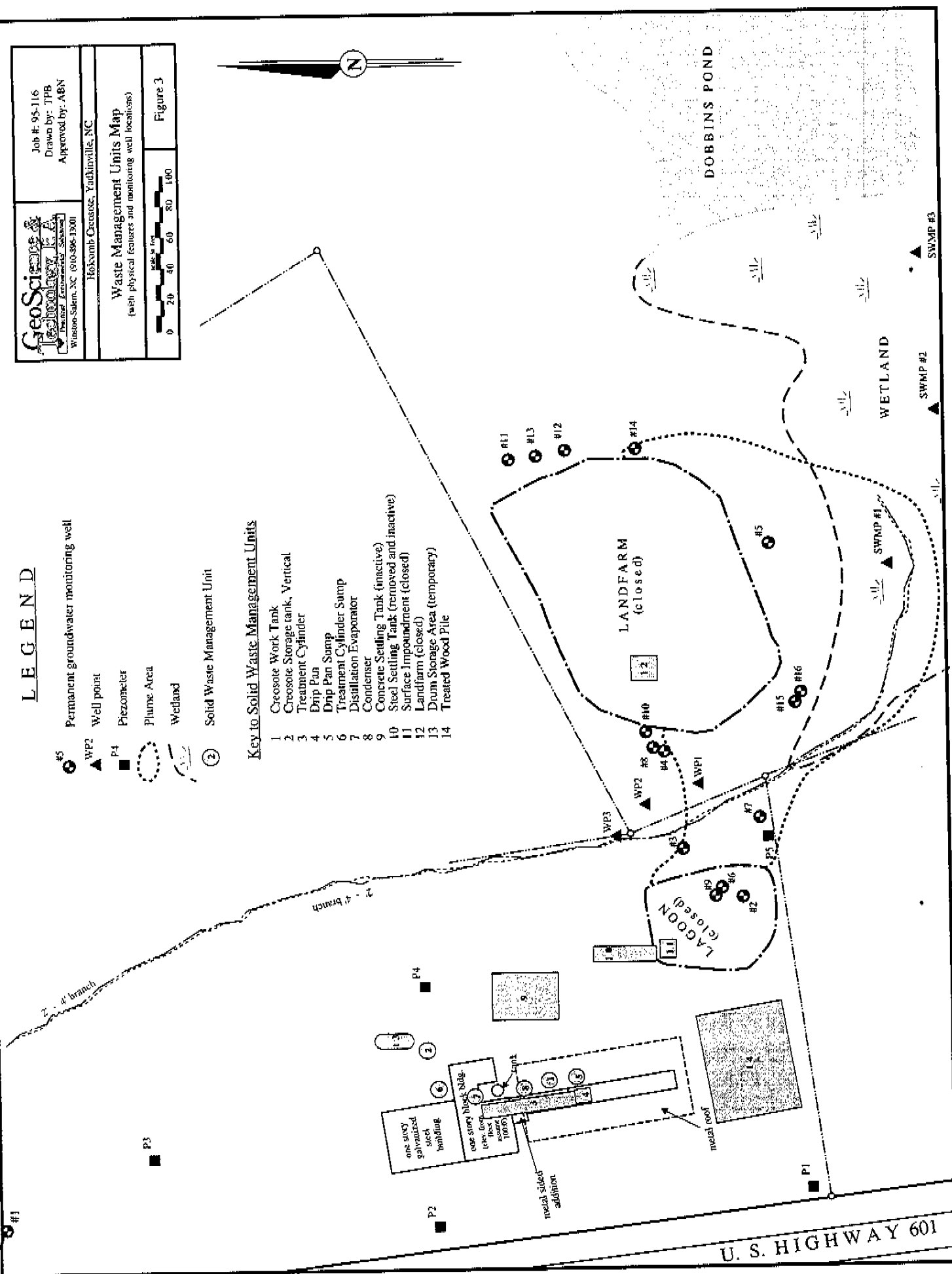
Plume Area

Wetland

Solid Waste Management Unit

## Key to Solid Waste Management Units

- 1 Ceresote Work Tank
- 2 Ceresote Storage tank, Vertical
- 3 Treatment Cylinder
- 4 Drip Pan
- 5 Drip Pan Sump
- 6 Treatment Cylinder Sump
- 7 Distillation Evaporator
- 8 Condenser
- 9 Concrete Settling Tank (inactive)
- 10 Steel Settling Tank (removed and inactive)
- 11 Surface Impoundment (closed)
- 12 Landfarm (closed)
- 13 Drum Storage Area (temporary)
- 14 Treated Wood Pile



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 Winston-Salem, NC 27103-9913

Job #: 95-116  
 Drawn by: TPB  
 Approved by: ABN

**Waste Management Units Map**  
 (with physical features and monitoring well locations)

Figure 3



Holcomb Creosote Company, Yadkinville, NC

Job #: 95-116

Drawn by: TPB

App'd by: ABN

## Regional Geologic Map

Scale: 1:250,000

Figure 4a

Map Source: Geologic Map of the East Half of the Winston-Salem Quadrangle, North Carolina-Virginia, Espenshade et al, 1975, Department of the Interior, United States Geological Survey.

### Metamorphosed Sedimentary and Volcanic Rocks

### Intrusive and Plutonic Rocks

### Sedimentary Rocks

Triassic

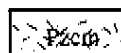


**Diabase**  
Fine to medium grained, gray, forming dikes a few inches to several hundred feet.



**Clastic Sedimentary Rocks**  
Tan, gray, to maroon shale, siltstone, sandstone and arkose of non-marine origin; thin coal beds locally.

PreCambrian and Paleozoic



**Mafic Rocks of the Charlotte Belt**  
Mainly gneiss, metagabbro and metadiorite.

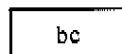


**Granitic Rocks of the Inner Piedmont Belt**  
Mainly gneiss, biotite-muscovite quartz monzonite and granodiorite.

PreCambrian



**Elk Park Plutonic Group (Pcec) Cranberry Gneiss**



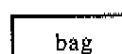
**Gneiss and schist of the Charlotte Belt**  
Interlayered biotite-muscovite-feldspar gneiss and augen gneiss.



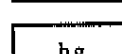
**Chlorite schist**



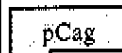
**Amphibolite**  
Layered, hornblende locally



**Biotite gneiss and biotite-amphibolite gneiss**



**Henderson Gneiss**  
biotite augen gneiss typically containing microcline porphyblasts.



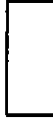










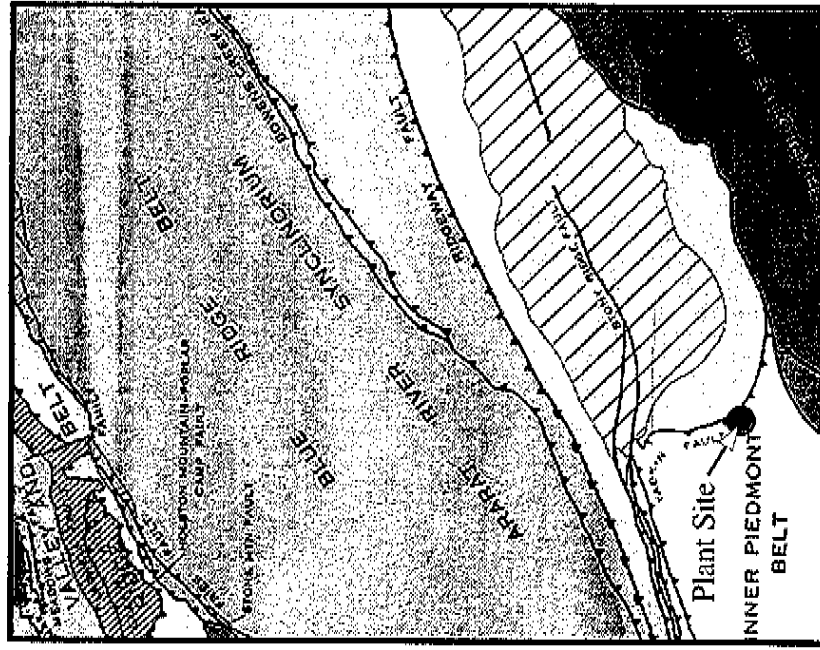
**Ashe Formation (pCag)** Typically fine grained biotite-muscovite gneiss interlayered with schist, phyllite, amphibolite. (pCaa) typically amphibolite and garnet amphibolite, and interlayered biotite-muscovite gneiss /schist.



**Biotite Gneiss**  
Fine grained biotite-quartz-plagioclase gneiss containing either muscovite or amphibole.

# Legend

-  Triassic basin
-  Charlotte belt
-  Inner Piedmont belt
-  Sauratown Mountains anticlinorium and Brevard fault zone
-  Smith River allochthon
-  Fries block of the Blue Ridge thrust sheets
-  Stone Mountain block of the Blue Ridge thrust sheets
-  Shady Valley thrusts
-  Laswell thrust sheet
-  Pulaski thrust sheet
-  Saltville thrust sheet



Map Source: Geologic Map of the East Half of the Winston-Salem Quadrangle, North Carolina-Virginia, Espenshade et al., 1975, Department of the Interior, United States Geological Survey.

Holcomb Creosote Company, Yadkinville, NC

Job #: 95-116

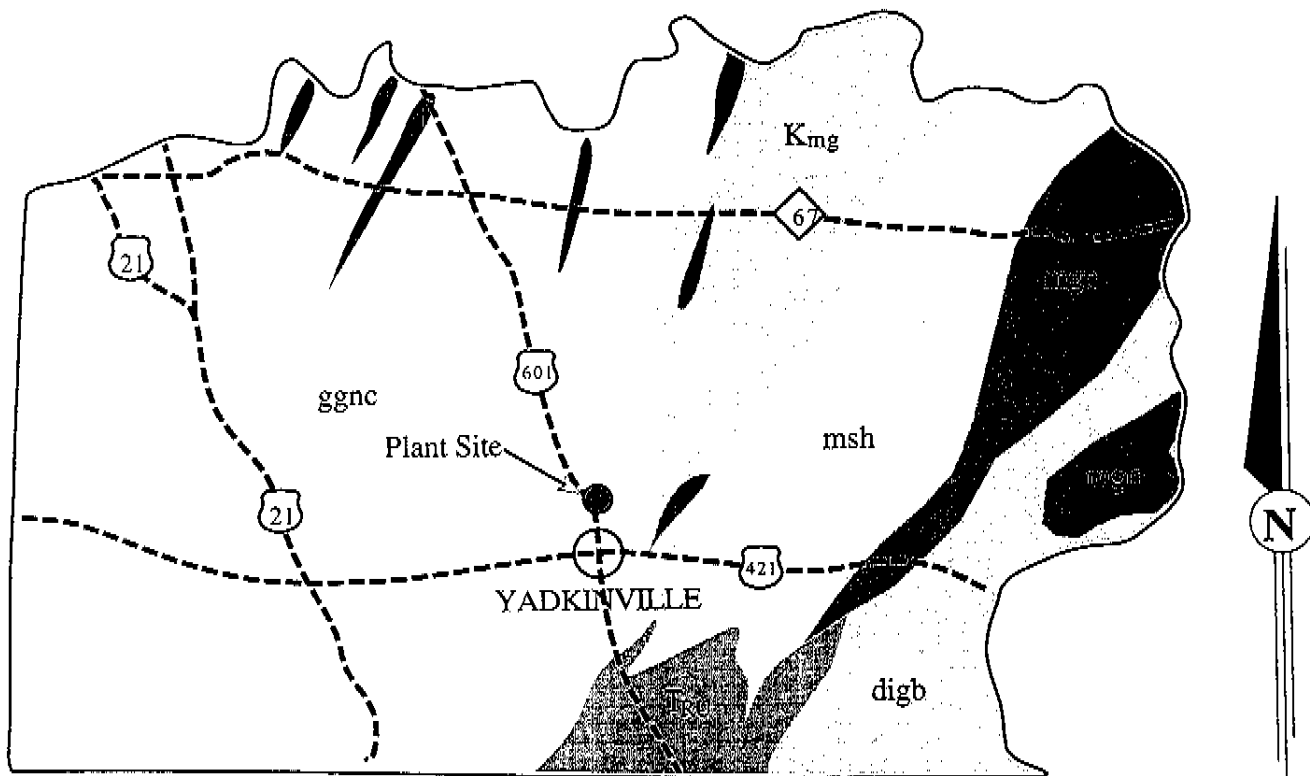
Drawn by: TPB

App'd by: ABN


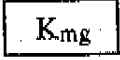
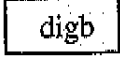
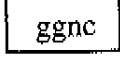

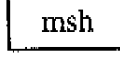

## Regional Lithotectonic Units

Scale: 1" ~ 15 miles

Figure 4b



### EXPLANATION

	Triassic undifferentiated	Triassic
	Kings Mountain Group	Lower Paleozoic (?)
	Diorite-gabbro	Paleozoic (?)
	Granite/granite-gneiss complex	
	Homblende gneiss	Precambrian (?)
	Mica schist	
	Mica gneiss	

Holcomb Creosote Company, Yadkinville, NC

Job #: 95-116

Drawn by: TPB

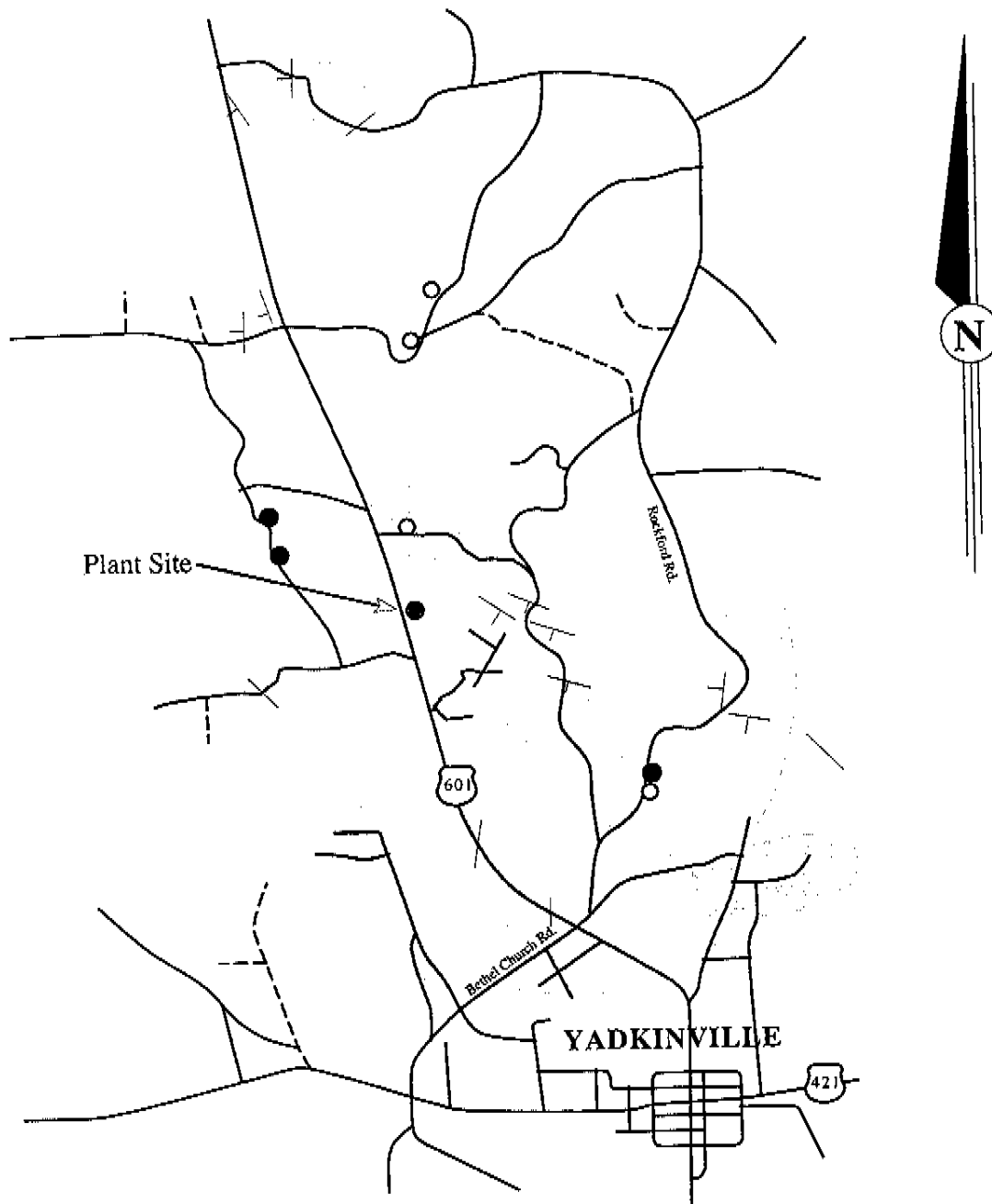
App'd by: ABN

Geologic Map of Yadkin County, NC

Scale: 1" ~ 4 miles

Figure 5

After Peace and Link, 1971.

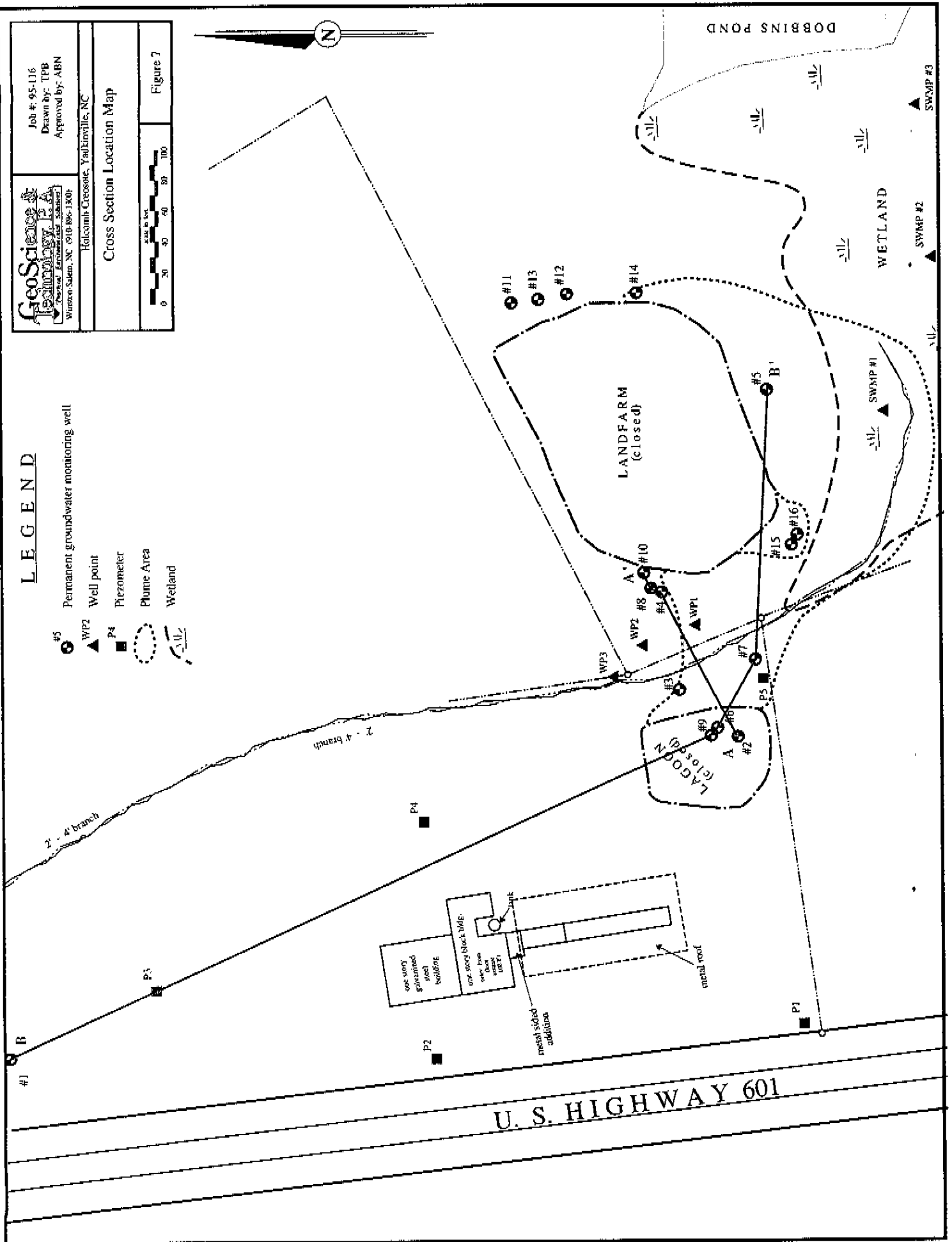


Base Map Source: U.S.G.S. Yadkinville, NC  
7.5' Topographic Quadrangle

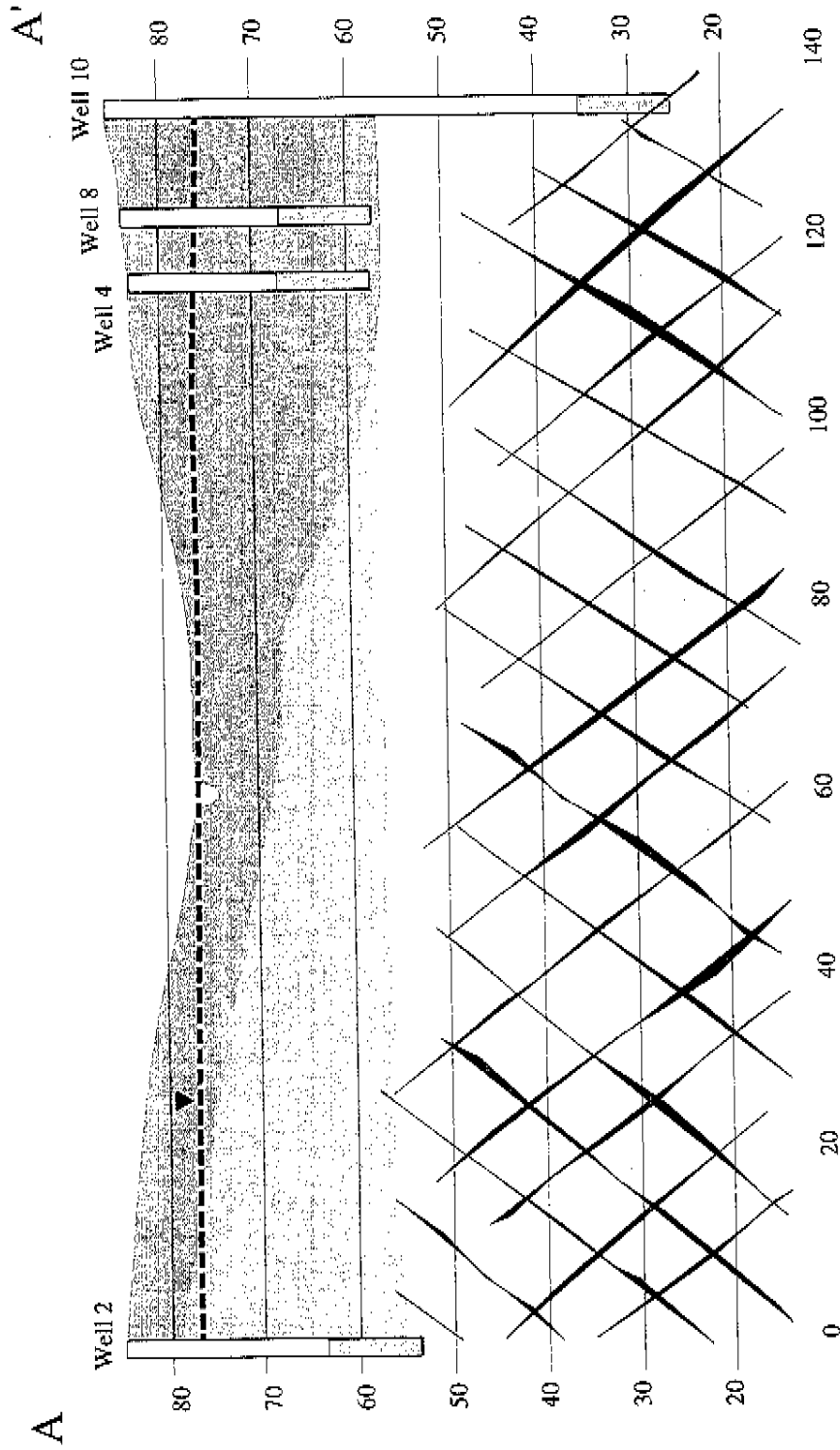


# LEGEND






- Permanent groundwater monitoring well
- Well point
- Piezometer
- Plume Area
- Wetland







#### EXPLANATION

-  red, brown, tan, grey micaceous sandy silt
-  mottled micaceous sand with a little silt
-  partially weathered granite gneiss
-  granite gneiss
-  regolith water table

Holcomb Creosote Company, Yadkinville, NC

#### Geologic Cross Section A-A'

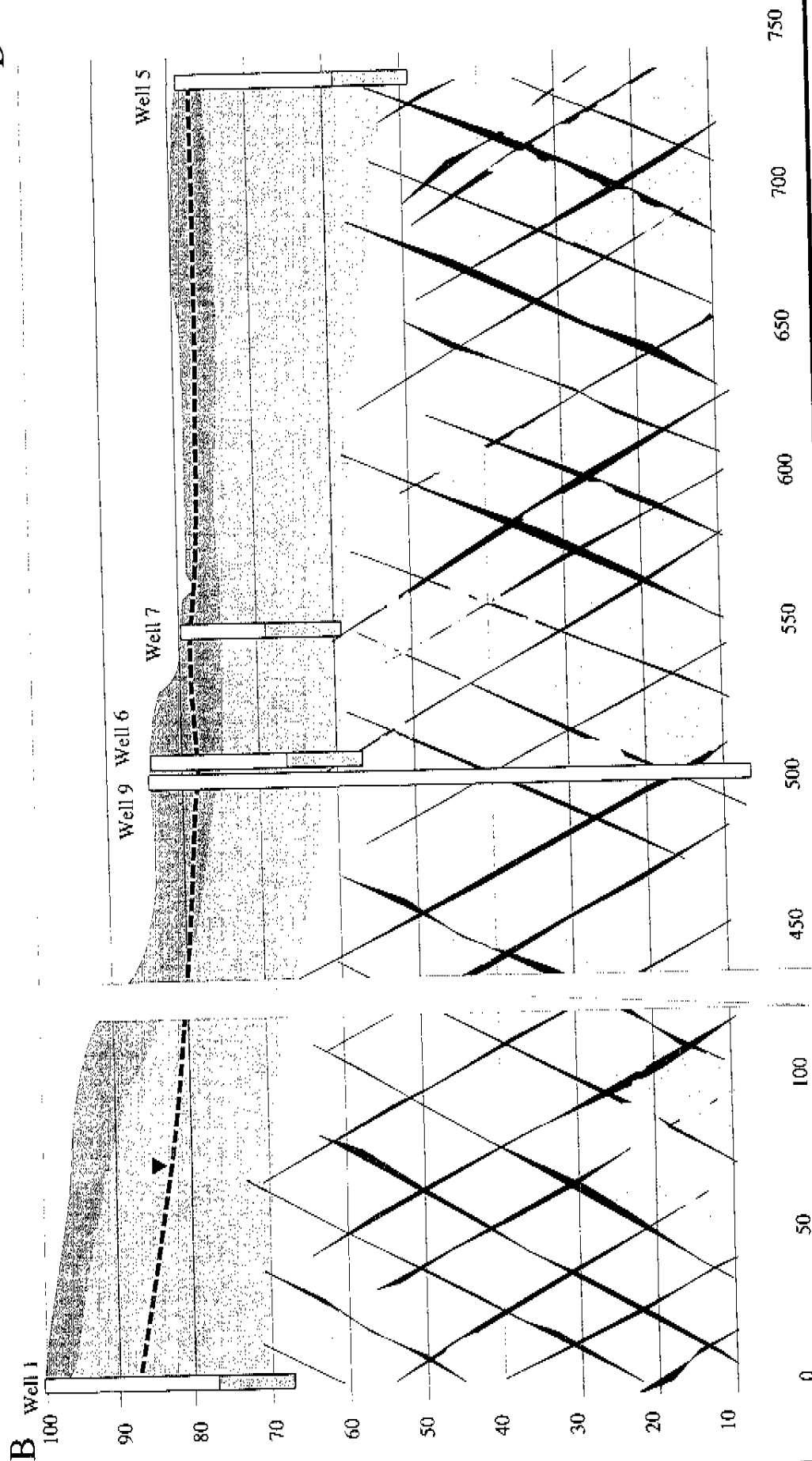
Job#: 95.116 Drawn by: TPB App'd: ABN

vertical scale: 1" = 20'  
horizontal scale: 1" = 20'

Figure 7a

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B'



# EXPLANATION

- red, brown, tan, grey micaceous sandy silt
- mottled micaceous sand with a little silt
- partially weathered granite gneiss
- granite gneiss
- regolith water table

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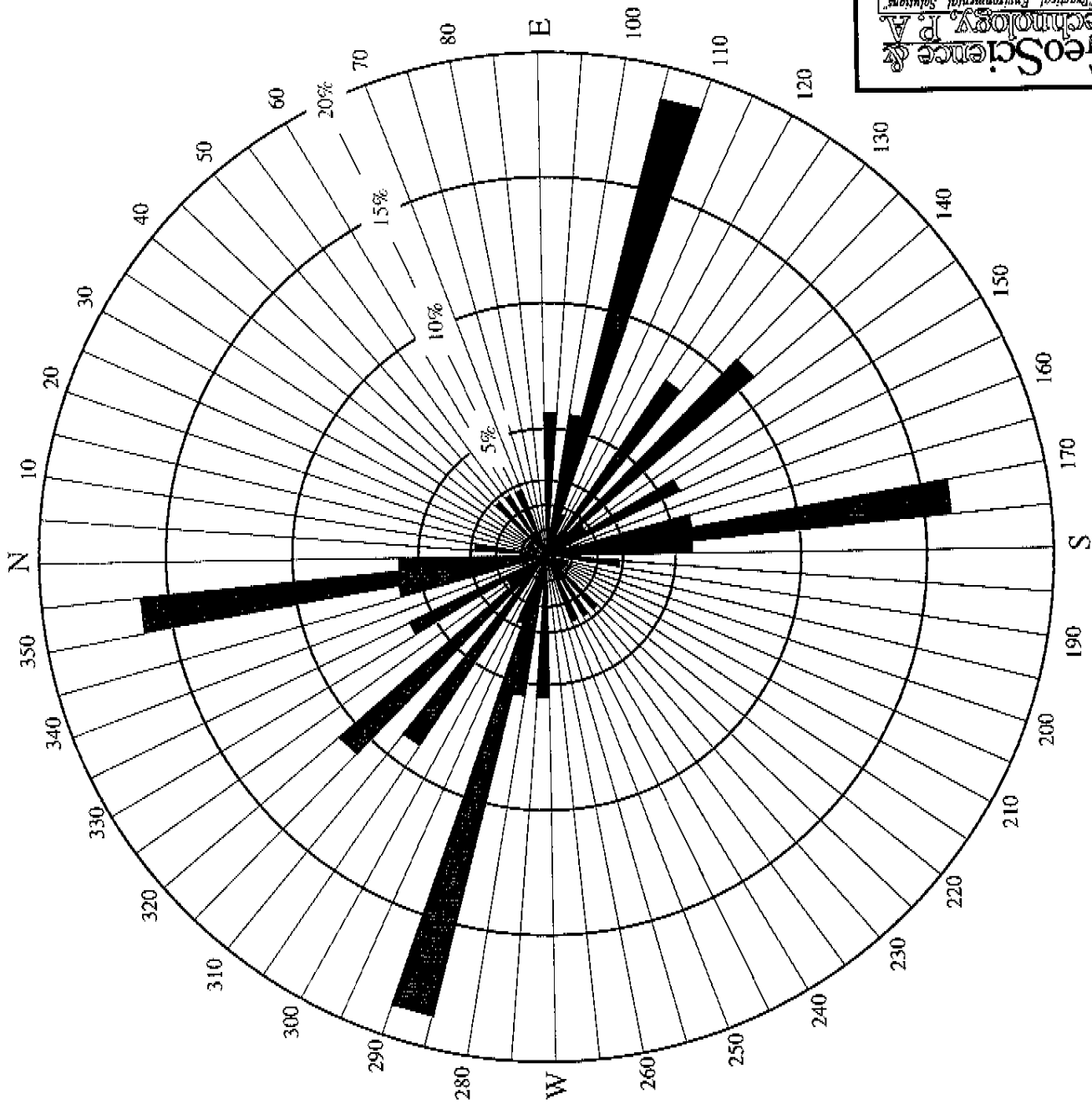
Holcomb Creosote Company, Yadkinville, NC

## Geologic Cross Section B-B'

Job#: 95.116 Drawn by: TPB App'd: ABN

vertical scale: 1" = 20'  
horizontal scale: 1" = 50'

Figure 7b



Note: Each radial division represents joint trace orientations falling within a five degree range. Shaded areas represent percentage of total number of measurements within a given five degree orientation range.

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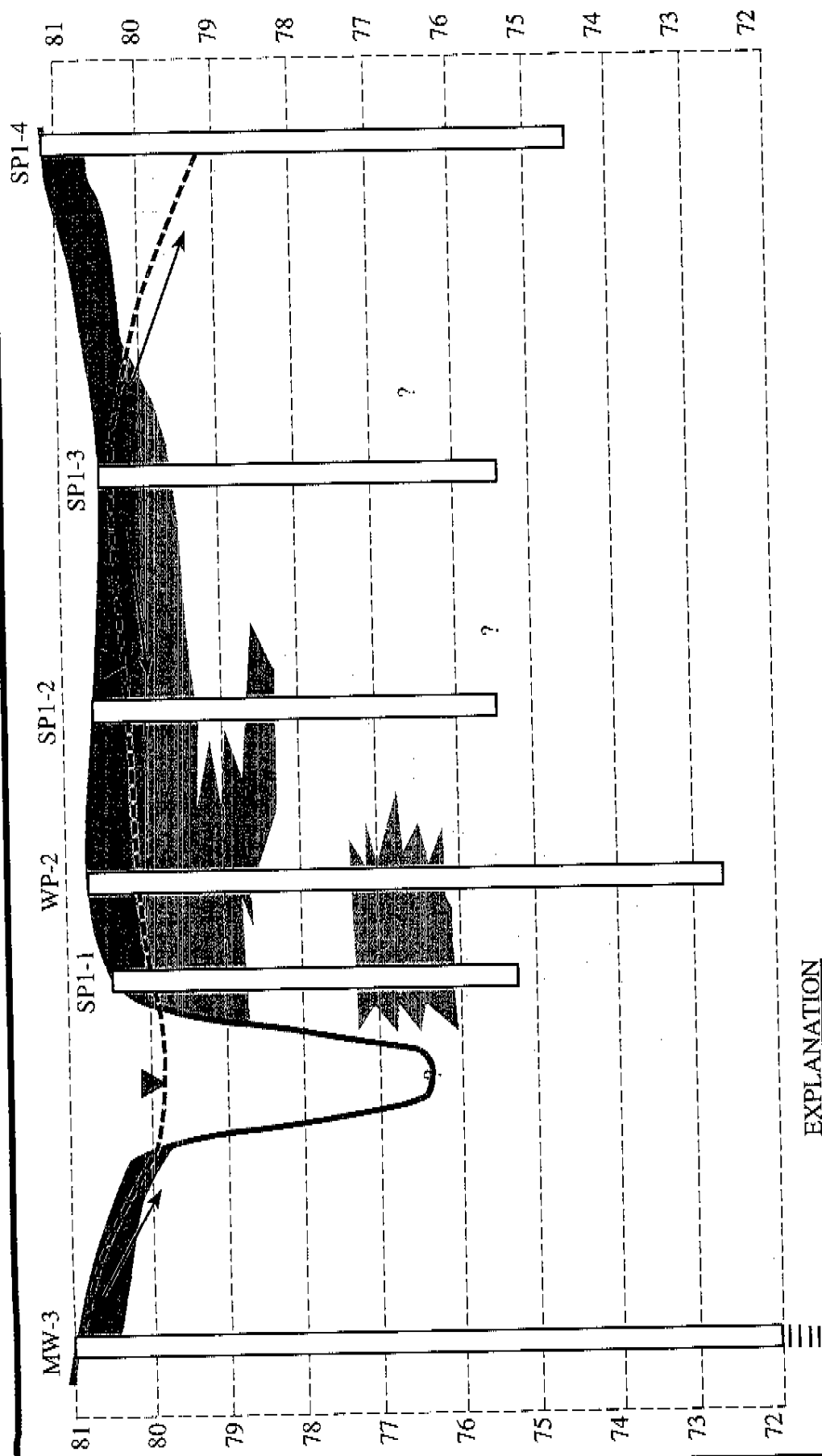
Winston-Salem, NC (910) 896-1300

Holcomb Creosote Company, Yadkinville, NC

### Rose Diagram of Joint Traces

Job#: 95.116    Drawn by: TPB    App'd: ABN

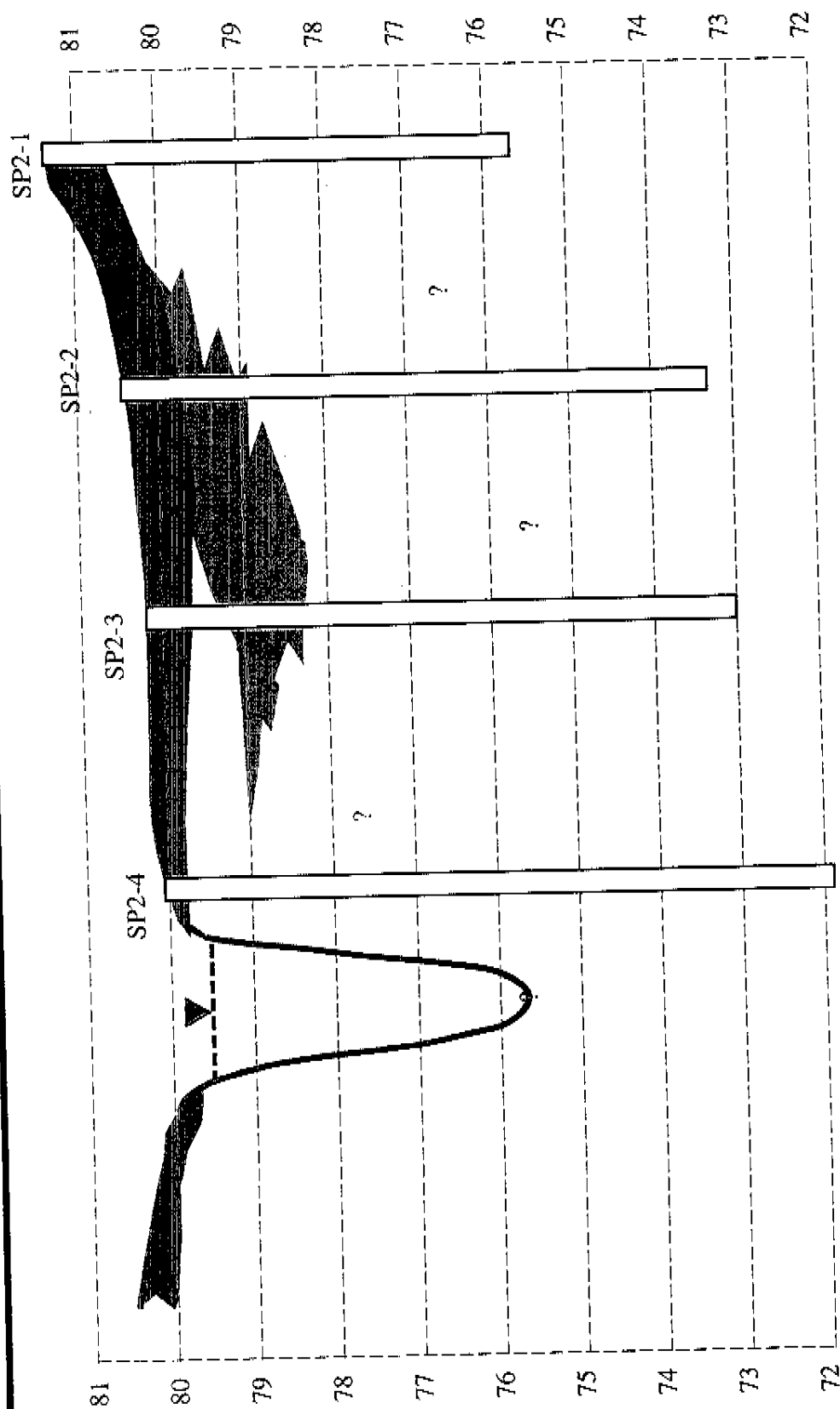
Figure 7c









# EXPLANATION

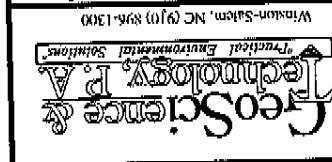
- Rooted organic topsoil
- Fine sand
- Medium sand
- Coarse sand
- Deeply weathered regolith
- Not sampled
- Groundwater table
- Flow line

<div> <div> Geoscientific &amp; Technology, P.A.  "Practical Environmental Solutions"  Winston-Salem, NC (919) 896-1300 </div> <div> Holcomb Creosote Company, Yadkinville, NC </div> </div>	
Stratigraphic Profile SP-1	
Job#: 95.116	Drawn by: TPB App'd: ABN
vertical scale: 1" = 2' horizontal scale: 1" = 8'	
Figure 8	



# EXPLANATION

-  Rooted organic topsoil
-  Fine sand
-  Medium sand
-  Coarse sand
-  Deeply weathered regolith
-  Not sampled



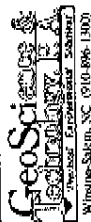
Holcomb Creosote Company, Yadkinville, NC

## Stratigraphic Profile SP-2

Job#: 95.116 Drawn by: TPB App'd: ABN

vertical scale: 1" = 2'  
horizontal scale: 1" = 8'

Figure 9



Job #: 95-116  
Drawn by: TPB  
Approved by: ABN

Holcomb Crossroad, Yadkinville, NC

Saprolite Isopach Map

Figure 10



## LEGEND

Permanent groundwater monitoring well

#5

Well point

WP2

Piezometer

P4

Plume Area

Wetland

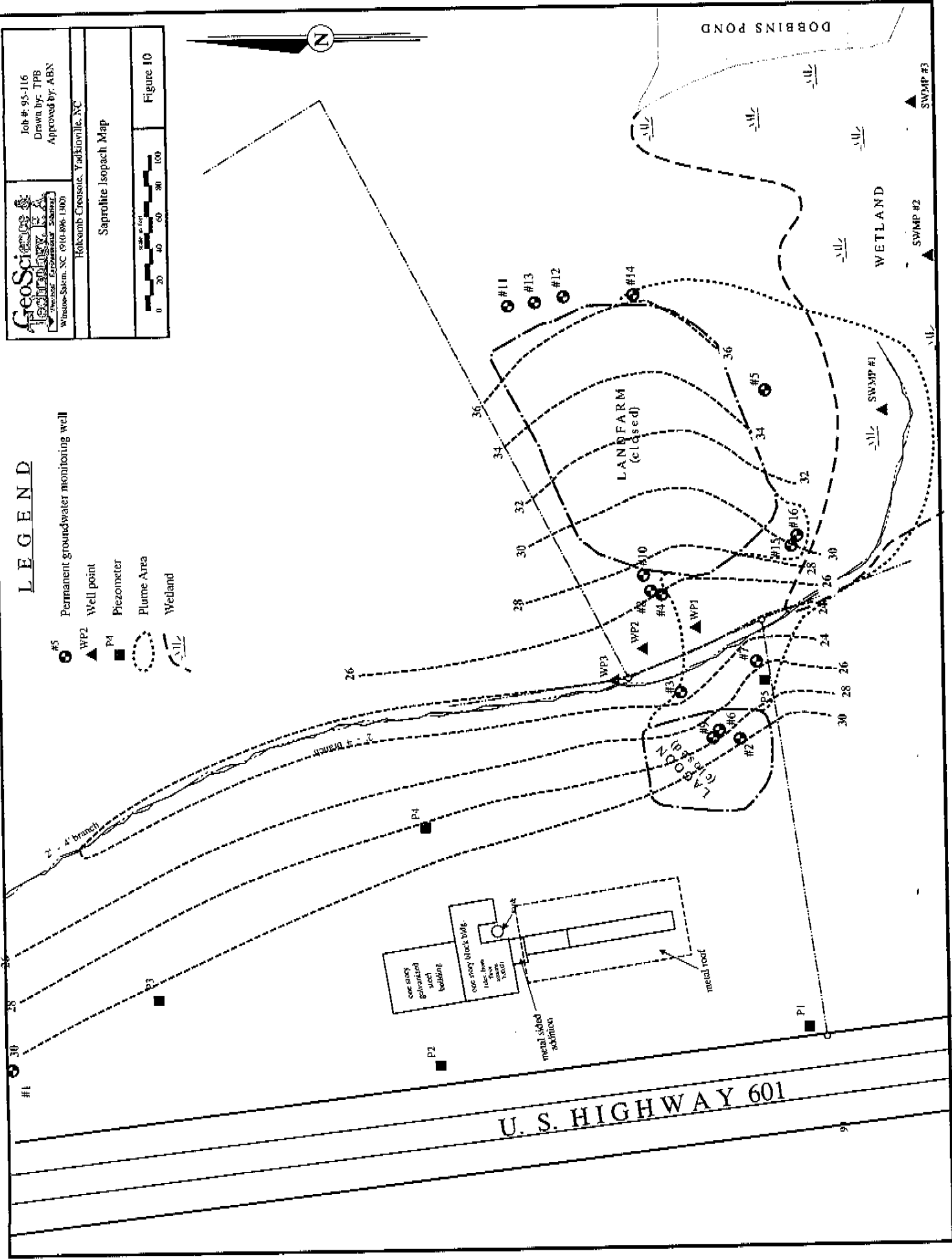
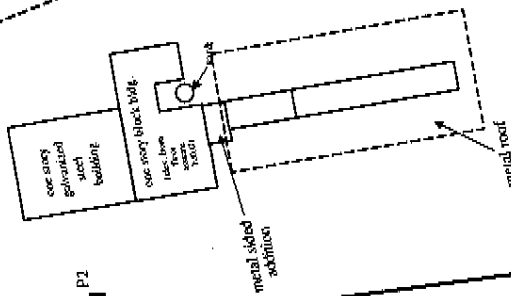
#5

WP2

P4

Wetland

U. S. HIGHWAY 601



# LEGEND

Permanent groundwater monitoring well

Well point

Piezometer

Plains Area

Wetland

#5

WP2

P4

Wetland

Wetland

#1

#2

#3

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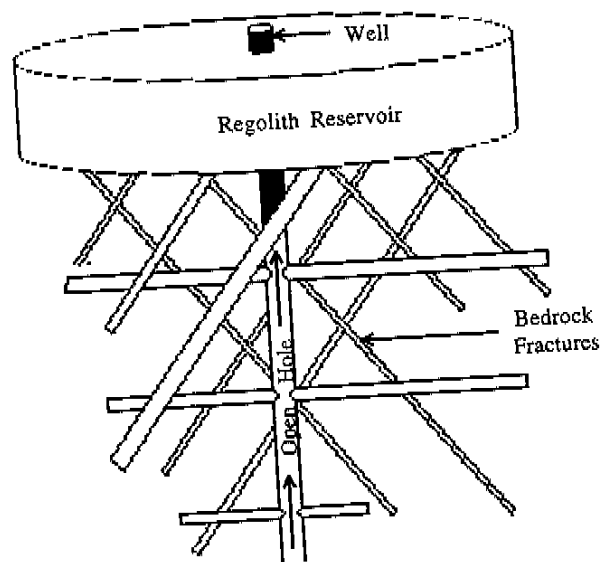
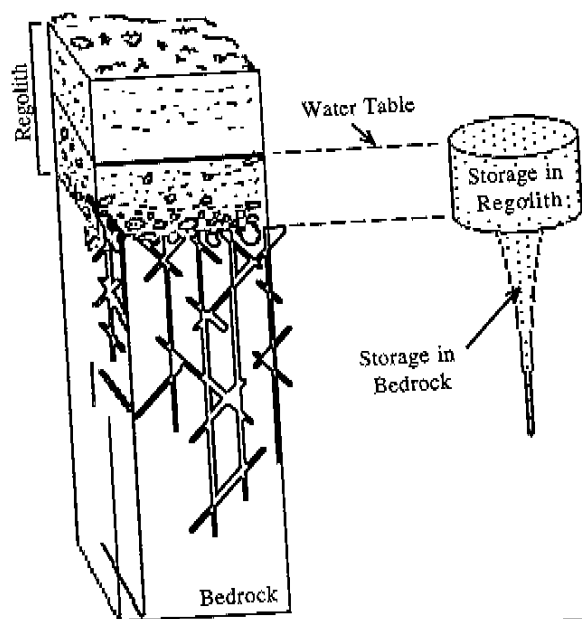
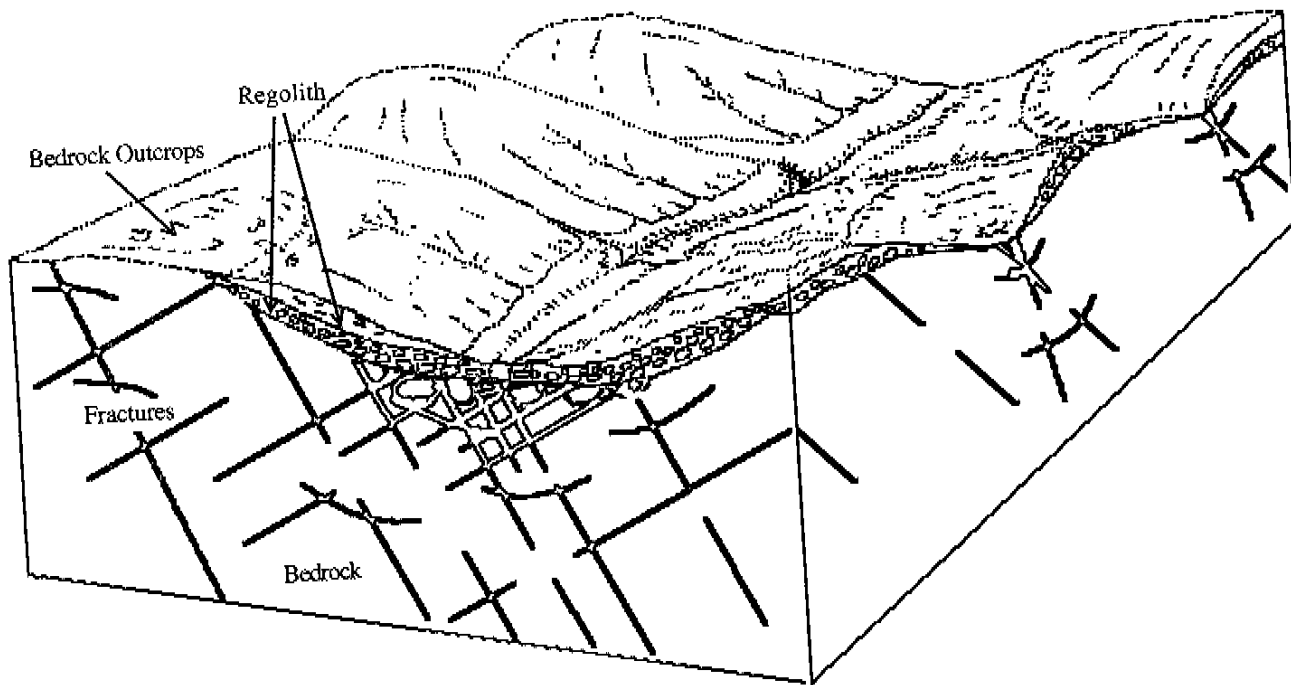
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Source: USGS Water Supply Paper  
2242, "Groundwater Regions of the  
U. S.," by R.C. Heath

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Technology, P.A.**  
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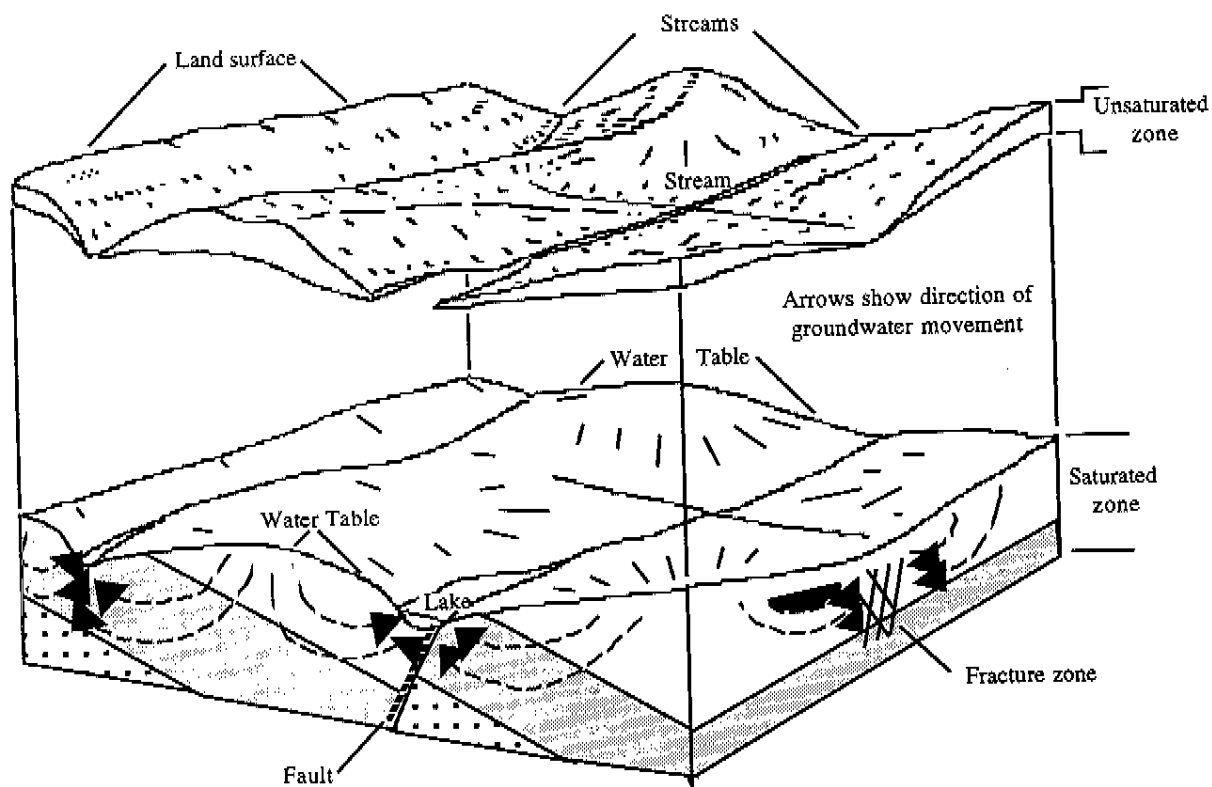
## Conceptual View of Piedmont Hydrologic System

Job#: 95.116 Drawn by: TPB App'd: ABN

no vertical scale

Figure 12





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	Conceptual View of the Hydrologic Regime	
	Job#: 95.116	Drawn by: TPB App'd: ABN
	no vertical scale	Figure 13

Source: "Cape Fear River Basin Study," 1983

**Geoscience & Technology**  
Practical Environmental Solutions

Job #: 95-116  
Drawn by: TPB  
Approved by: ABN

Holtcomb Orensone, Yulkinville, NC

### Potentiometric Surface Map

4112196



Figure 14

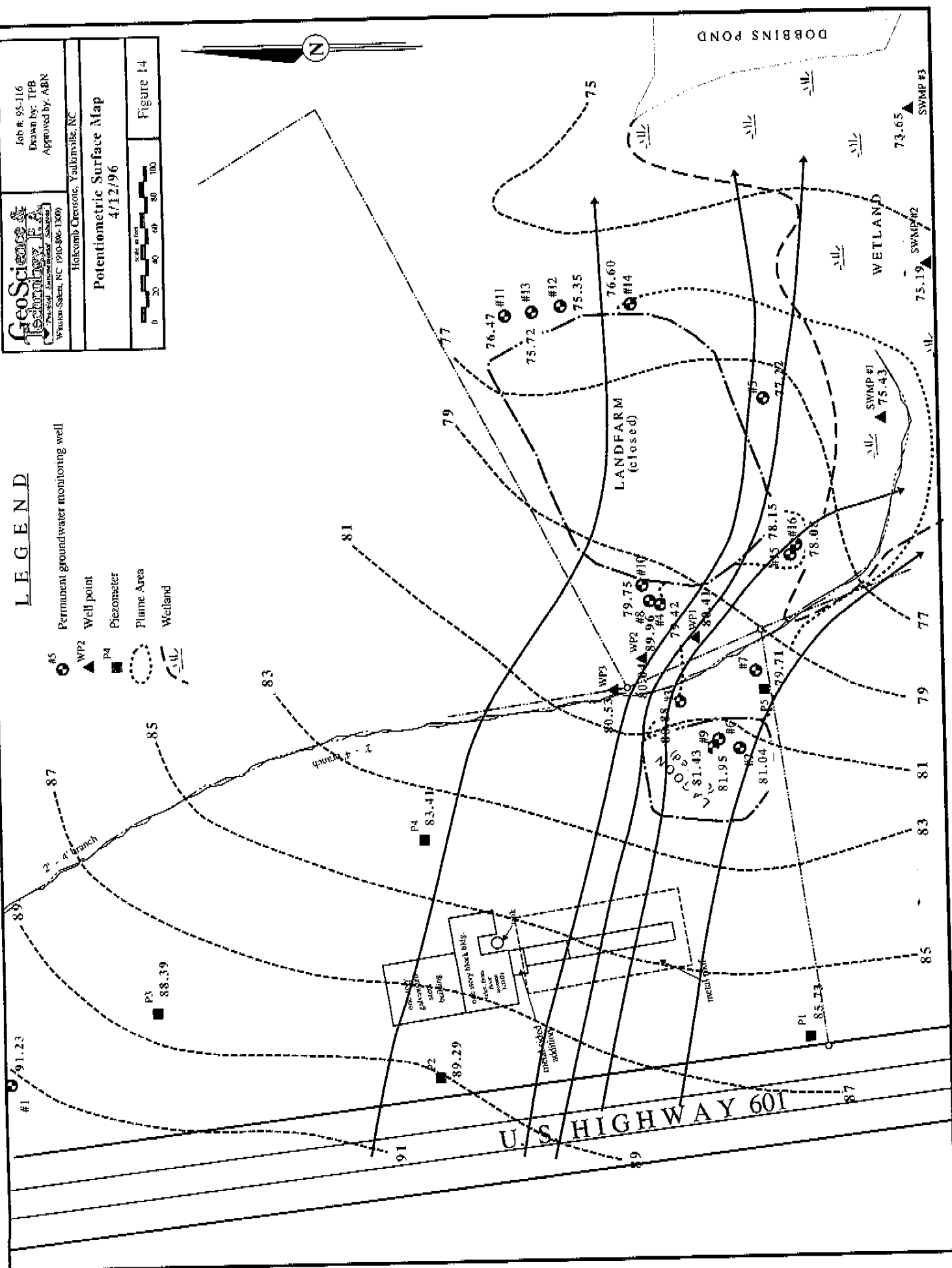
### Permanent groundwater monitoring well

Well point

## Piezometer

### Plaine Area

Wetland



# LEGEND

Permanent groundwater monitoring well

Well point

Piezometer

Wetland

Plume Area

Constituents detected during assessment monitoring

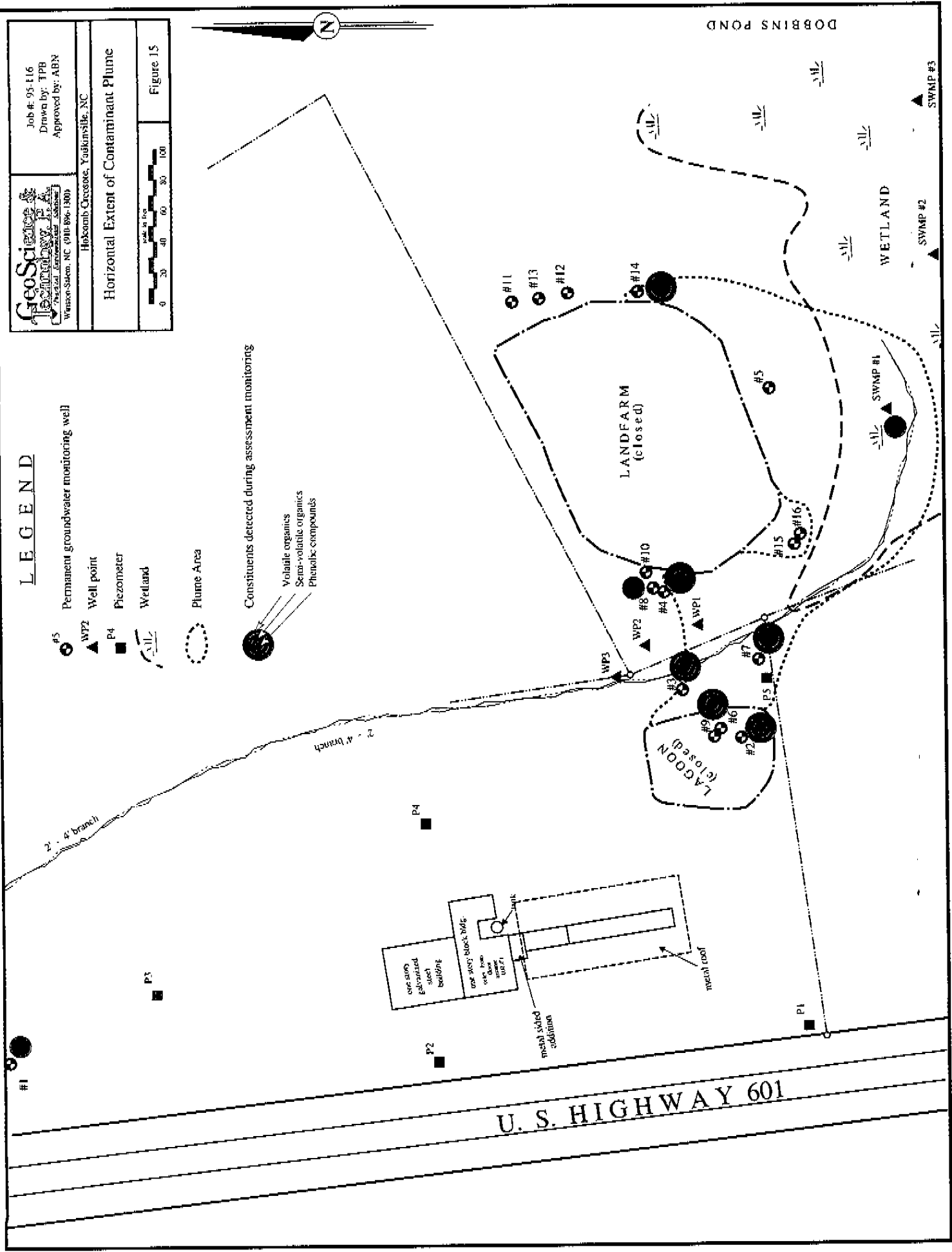
Volatile organics  
Semi-volatile organics  
Phenolic compounds

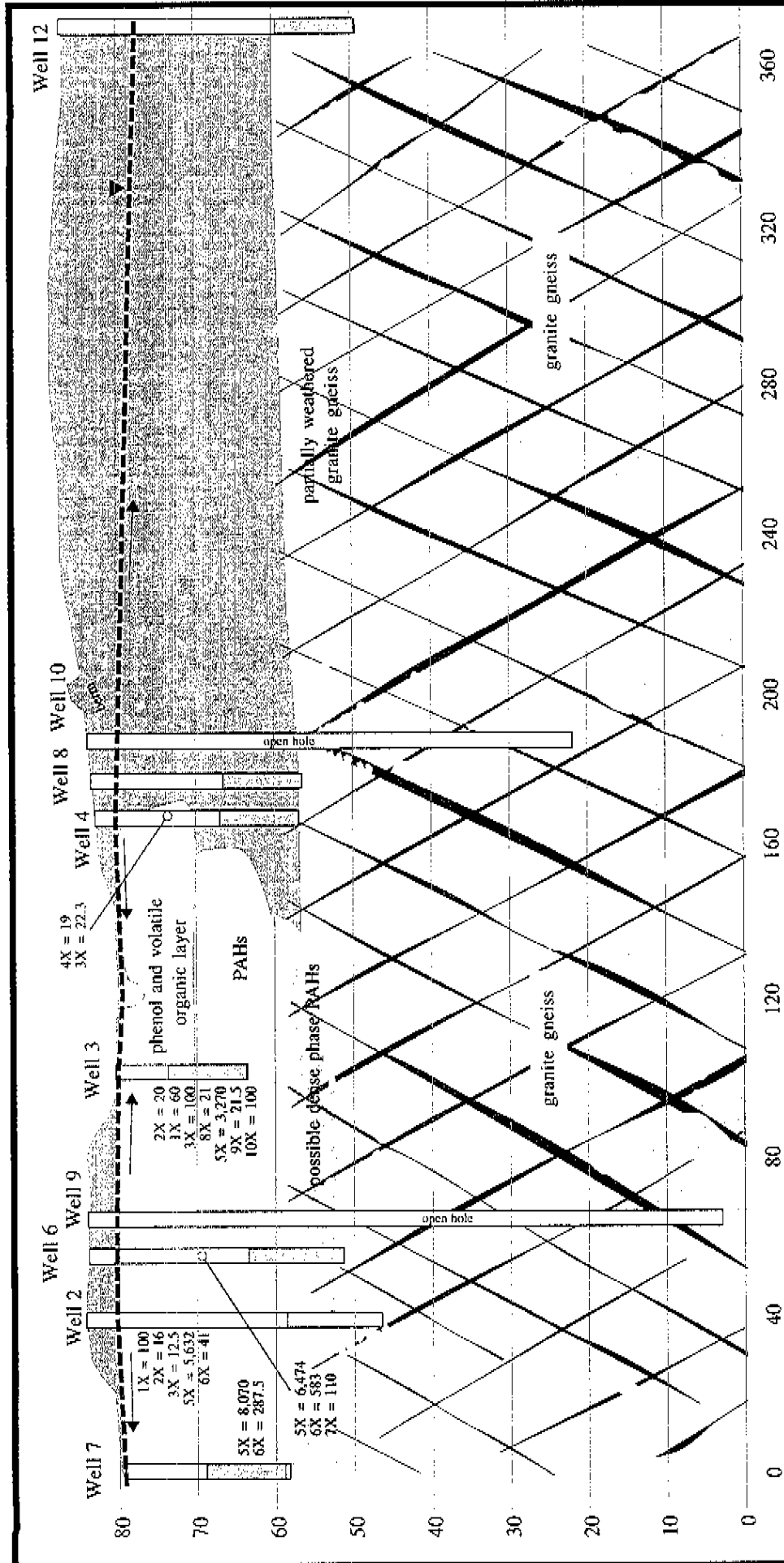
Job #: 95-116  
Drawn by: TPB  
Approved by: ABN

Hokebamb-Oreocoe, Yackinsville, NC

Horizontal Extent of Contaminant Plume

Figure 15





# EXPLANATION

- 1 - toluene
- 2 - benzene
- 3 - phenol
- 4 - 2,4, dimethylphenyl
- 5 - naphthalene
- 6 - acenaphthene
- 7 - acenaphthylene
- 8 - chrysene
- 9 - benz(a) anthracene
- 10 - fluoranthene
- X = average from monitoring events
- regolith, typically red, brown, tan, grey
- micaceous sandy silt
- partially weathered granite gneiss
- granite gneiss
- regolith water table

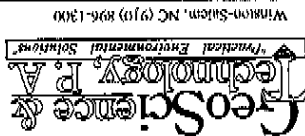
Holcomb Creosote Company, Yadkinville, NC

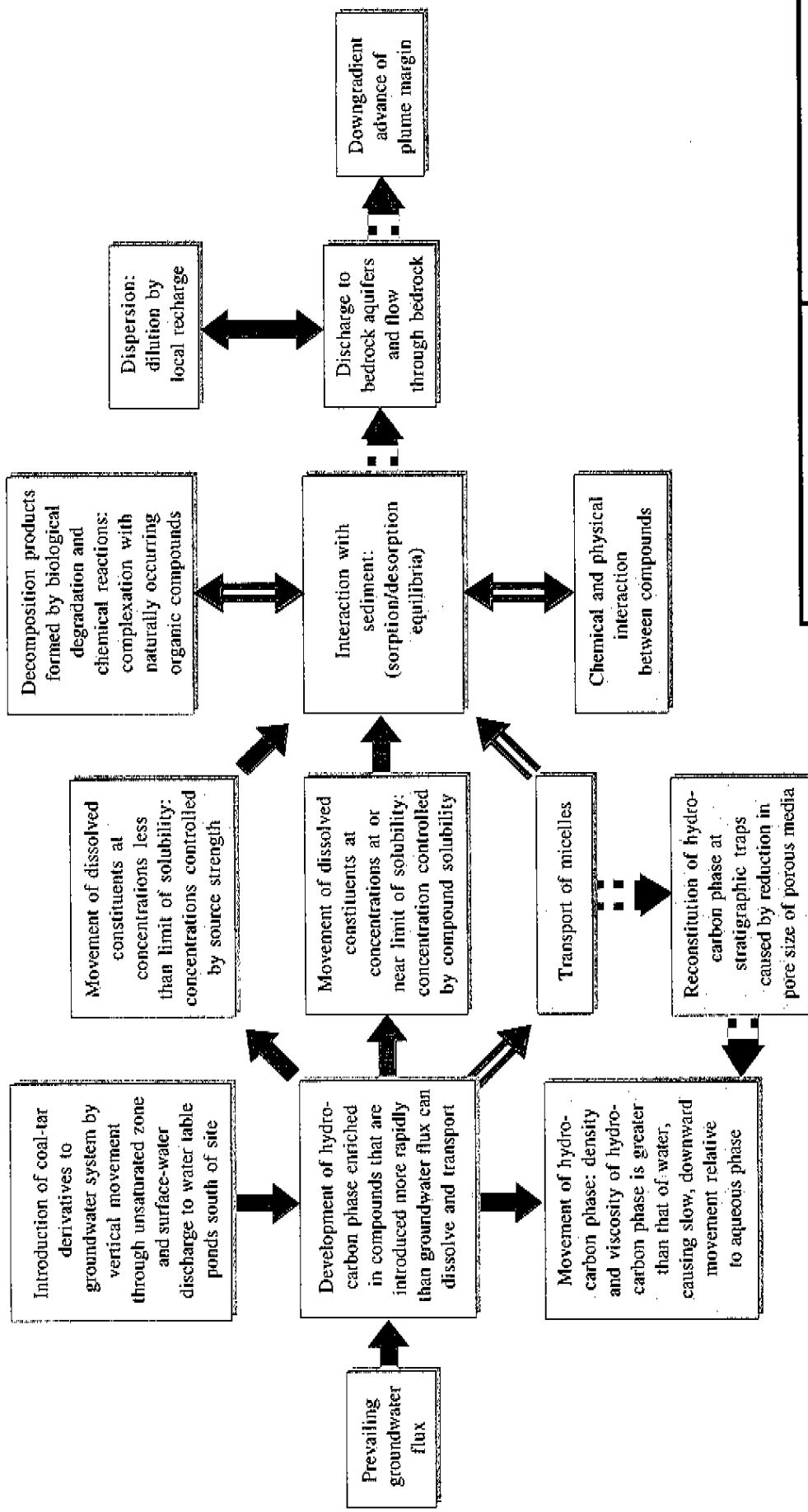
## Conceptualization of Vertical Distribution of Contaminants

Job#: 95.116 Drawn by: TPB App'd: ABN

vertical scale: 1" ~ 20'  
horizontal scale: 1" ~ 40'

Figure 16





# EXPLANATION

- Pathways where supporting evidence is substantial
- Probable pathway
- Possible pathway

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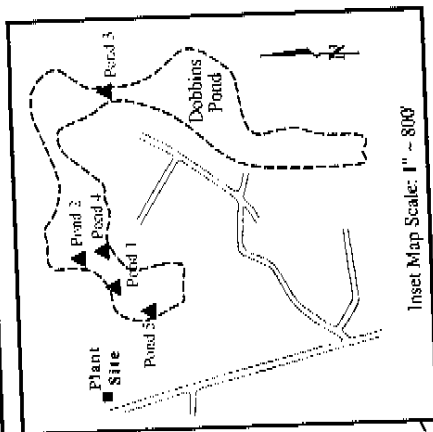
Job #: 95.116  
 Drawn by: TPB  
 Approved by: ABN

Holcomb Creosote, Yadkinville, NC

Conceptual Model of Chemical, Physical,  
 and Biological Processes Affecting Transport  
 and Potential Exposure Pathways

no scale

Figure 17



# LEGEND

Permanent groundwater monitoring well

Well point

Piezometer

Plume Area

Wetland

Stream Sampling Location

Pond Sampling Location

#5

WP2

P4

Stream #1

Pond #1

Stream #3

Pond #5

2' - 4' branch

Stream #1

P3

P4

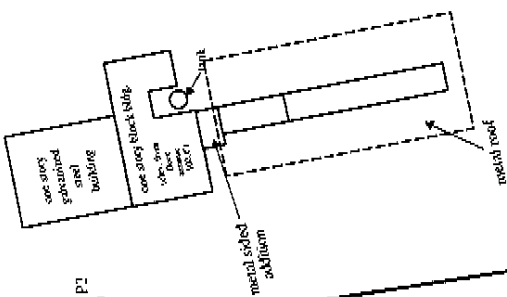
Stream #2

Stream #2A

2' - 4' branch

P4

P2



U. S. HIGHWAY 601

LANDFARM  
(closed)

LAGOON  
(closed)

WETLAND

SWAMP #3

SWAMP #2

SWAMP #1

Stream #3

Stream #1

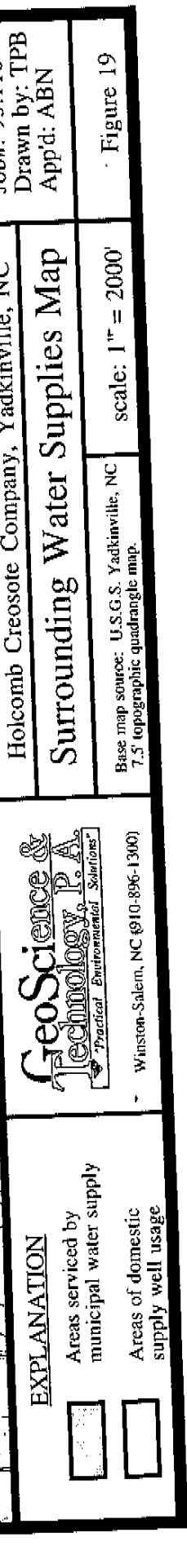
Stream #2

Stream #2A

Stream #1

Stream #3

Stream #1



Winston-Salem, NC (910-896-1300)

**Areas of domestic supply well usage**

Job #: 95-116  
Drawn by: TPB  
Approved by: ABN

Winston-Salem, NC (910-896-1300)

Halcornb Creosote, Yadkinville, NC

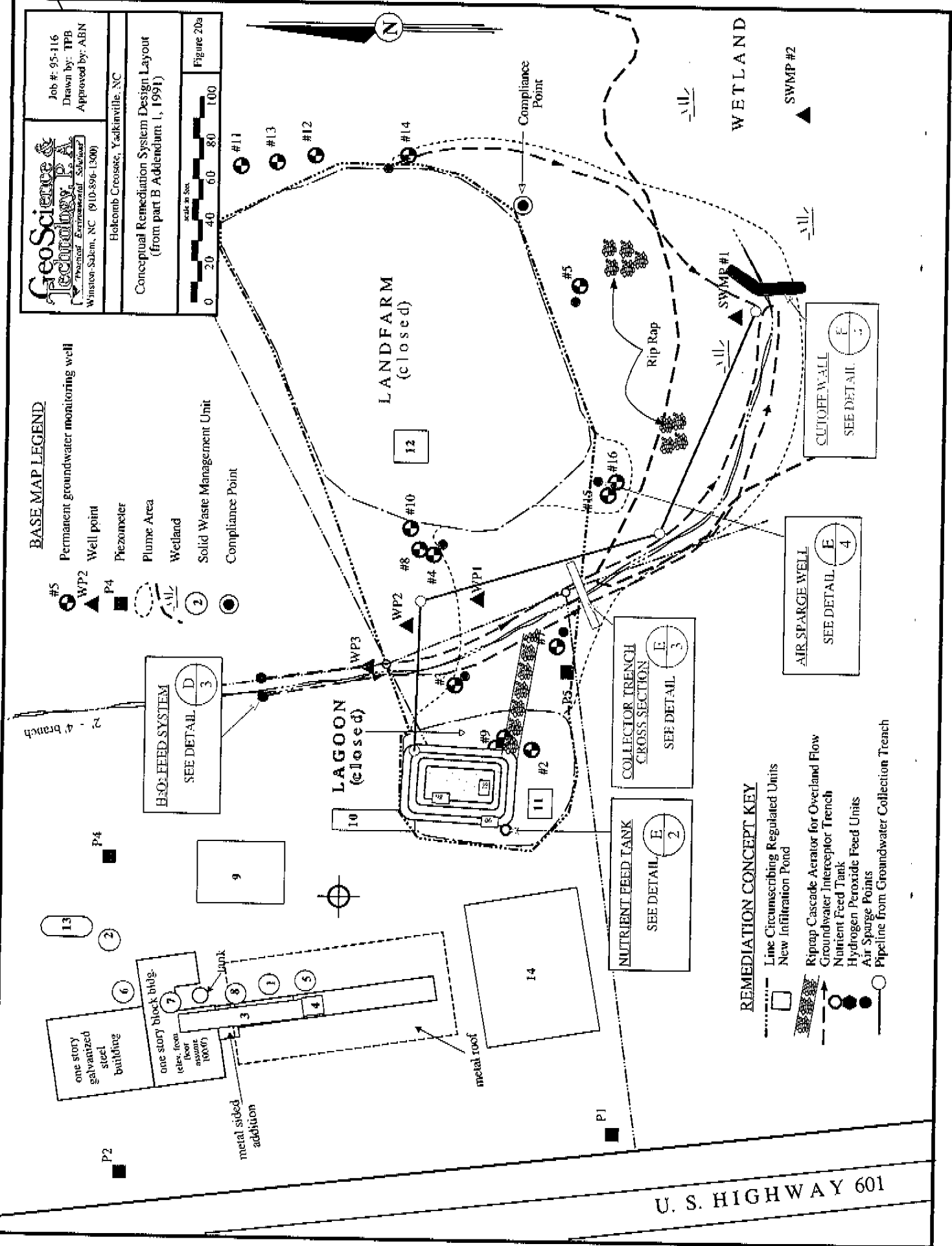
Conceptual Remediation System Design Layout  
(from part B Addendum 1, 1991)

Scale in Feet

Figure 20a

### BASE MAP LEGEND

- Permanent groundwater monitoring well  
Well point  
Piezometer  
Plume Area  
Wetland  
Solid Waste Management Unit  
Compliance Point

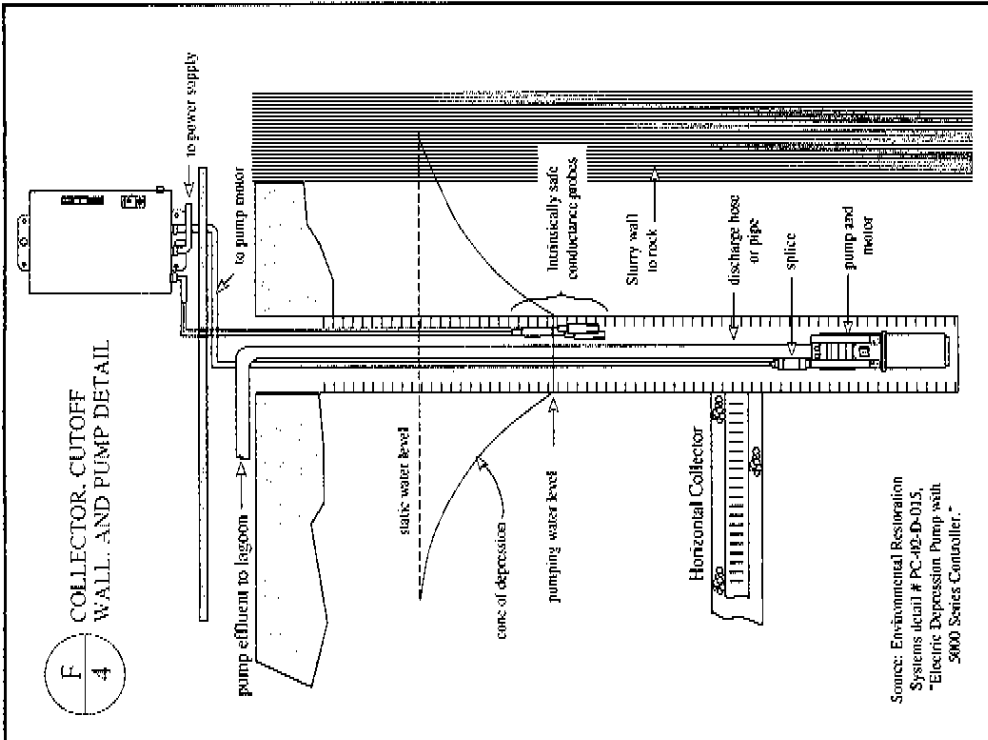
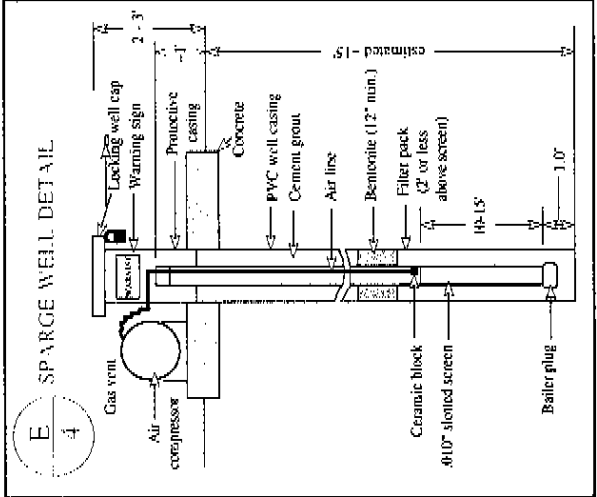
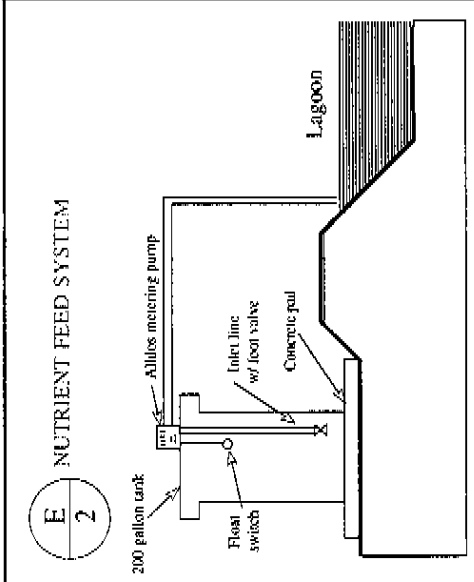
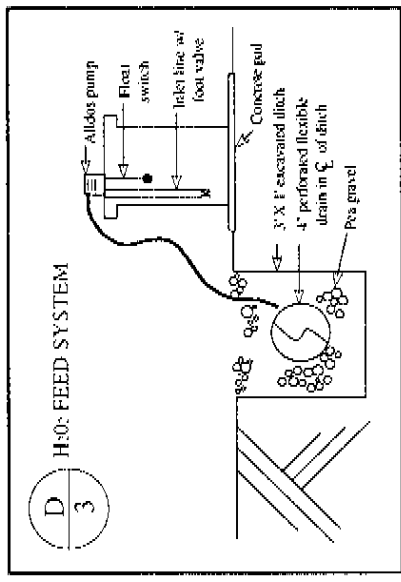


### REMEDICATION CONCEPT KEY

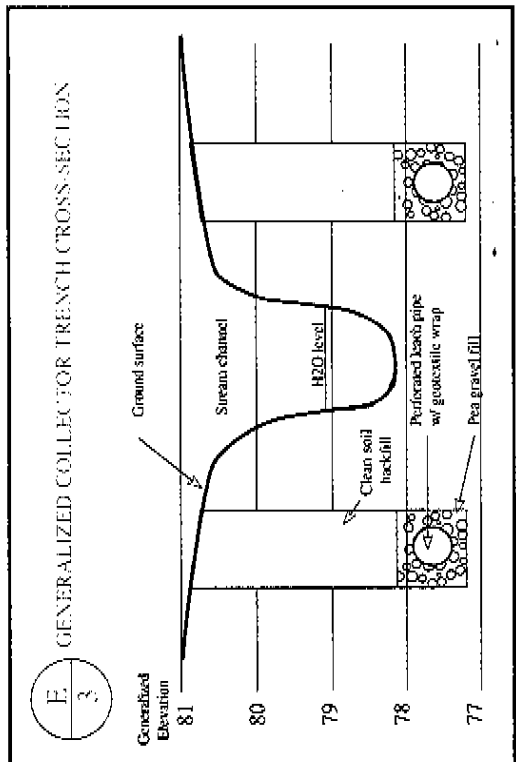
- 
- Line Circumscribing Regulated Units  
New Infiltration Pond  
Riprap Cascade Aerator for Overland Flow  
Groundwater Interceptor Trench  
Nutrient Feed Tank  
Hydrogen Peroxide Feed Units  
Air Spurge Points  
Pipeline from Groundwater Collection Trench

U. S. HIGHWAY 601





Source: Environmental Restoration Systems Unit # PC-42-D-015, "Electric Depression Pump with 5000 Series Controller."



<p><b>GeoScience &amp; Technology, Inc.</b> Winston-Salem, NC (910) 696-1300</p>	<p>Job #: 95-116 Drawn by: TPB Approved by: ABN</p>
<p>Holcomb Crosscut, Yadkinville, NC</p>	
<p>Details of Conceptual Remediation System (from Part B Addendum I, 1991)</p>	
<p>no scale</p>	<p>Figure 20b</p>



Job #: 95-116  
Drawn by: TPB  
Approved by: ABN

Holcomb-Crescent, Yorkville, NC

### Aquifer Sampling Points for Biofeasibility Study

Figure 21

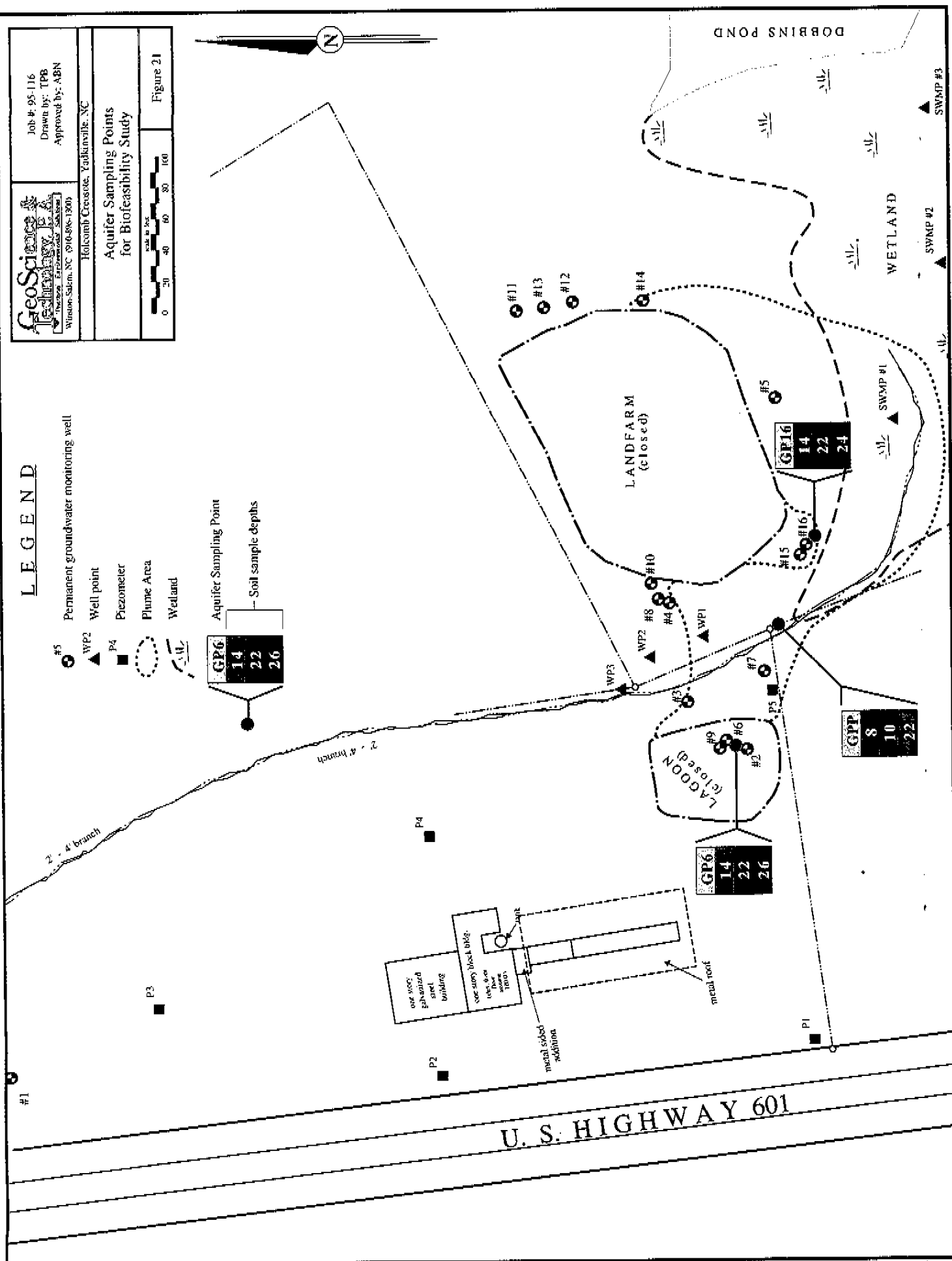


## LEGEND

- #5 Permanent groundwater monitoring well
- WP2 Well point
- P4 Piezometer
- Plume Area
- Wetland

Aquifer Sampling Point

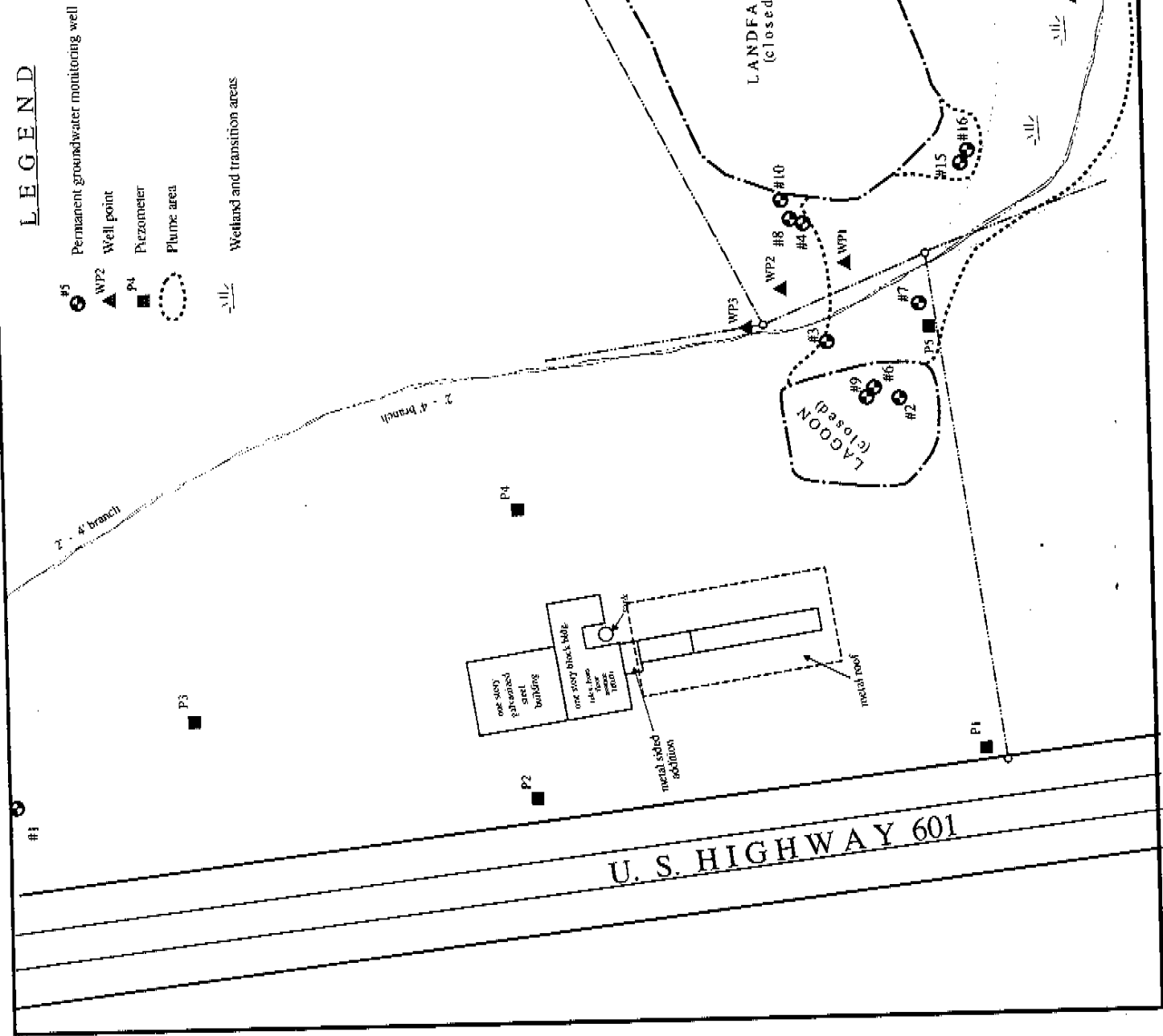
Soil sample depths



Job #: 95-116  
 Drawn by: TPB  
 Approved by: ABN

Holcomb Crocote, Yadkinville, NC  
 Delinated Wetland Areas

Figure 22



U. S. HIGHWAY 601

Job #: 95-116  
 Drawn by: TPB  
 Approved by: ABN

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 Winston-Salem, NC 27103-896-1300

Holcomb Creosote, Yadkinville, NC

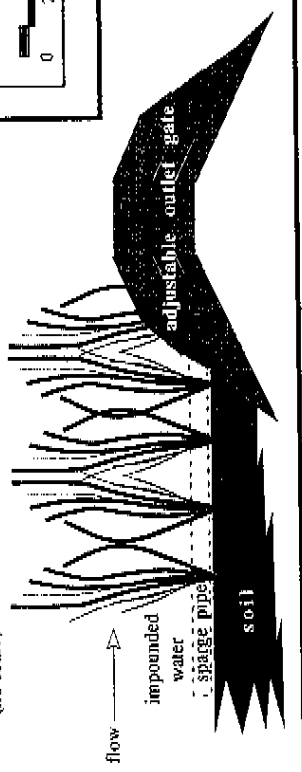
# Layout of Proposed Wetland Cells



Figure 23

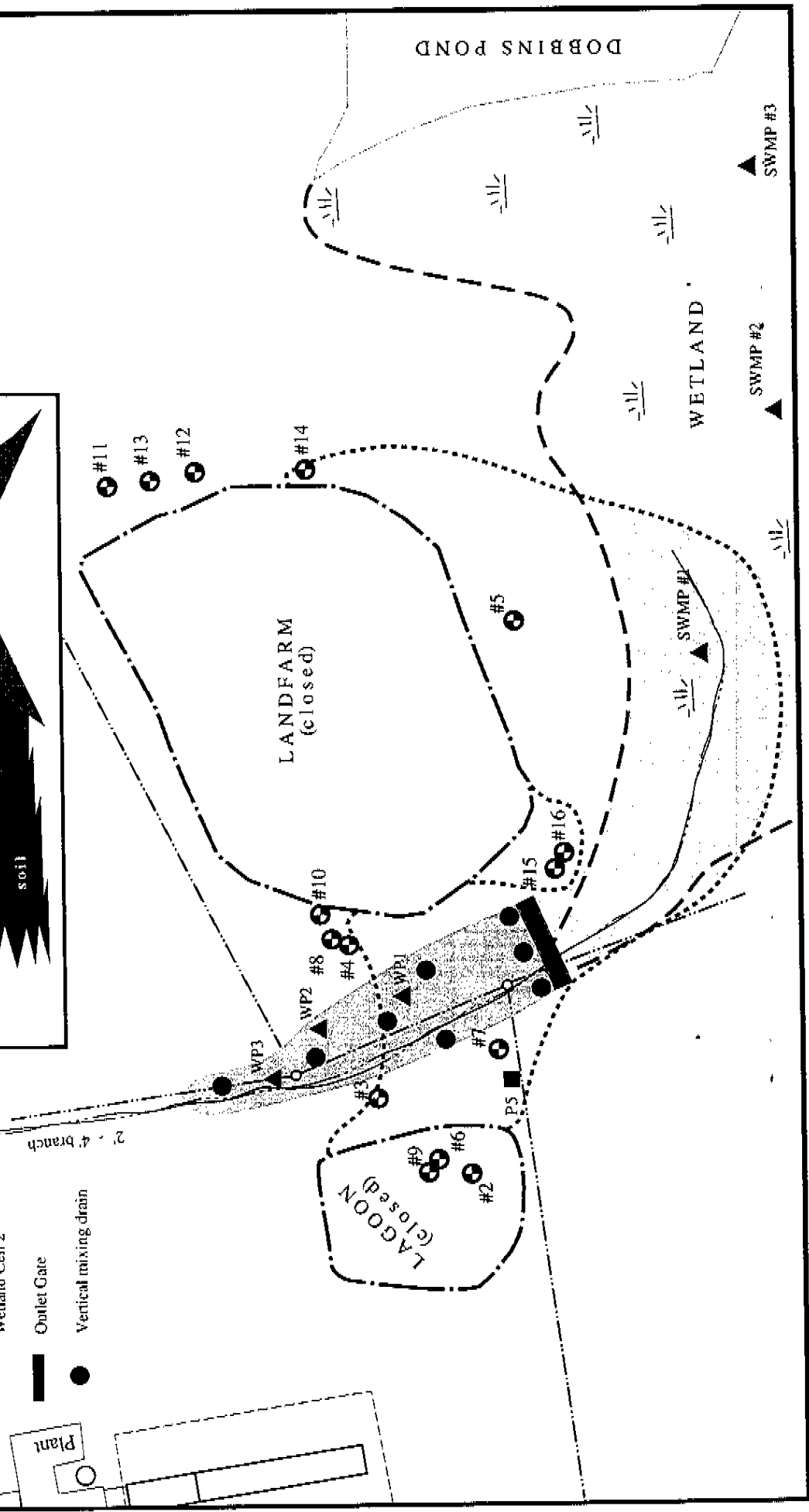
## Detail of Outlet Gate

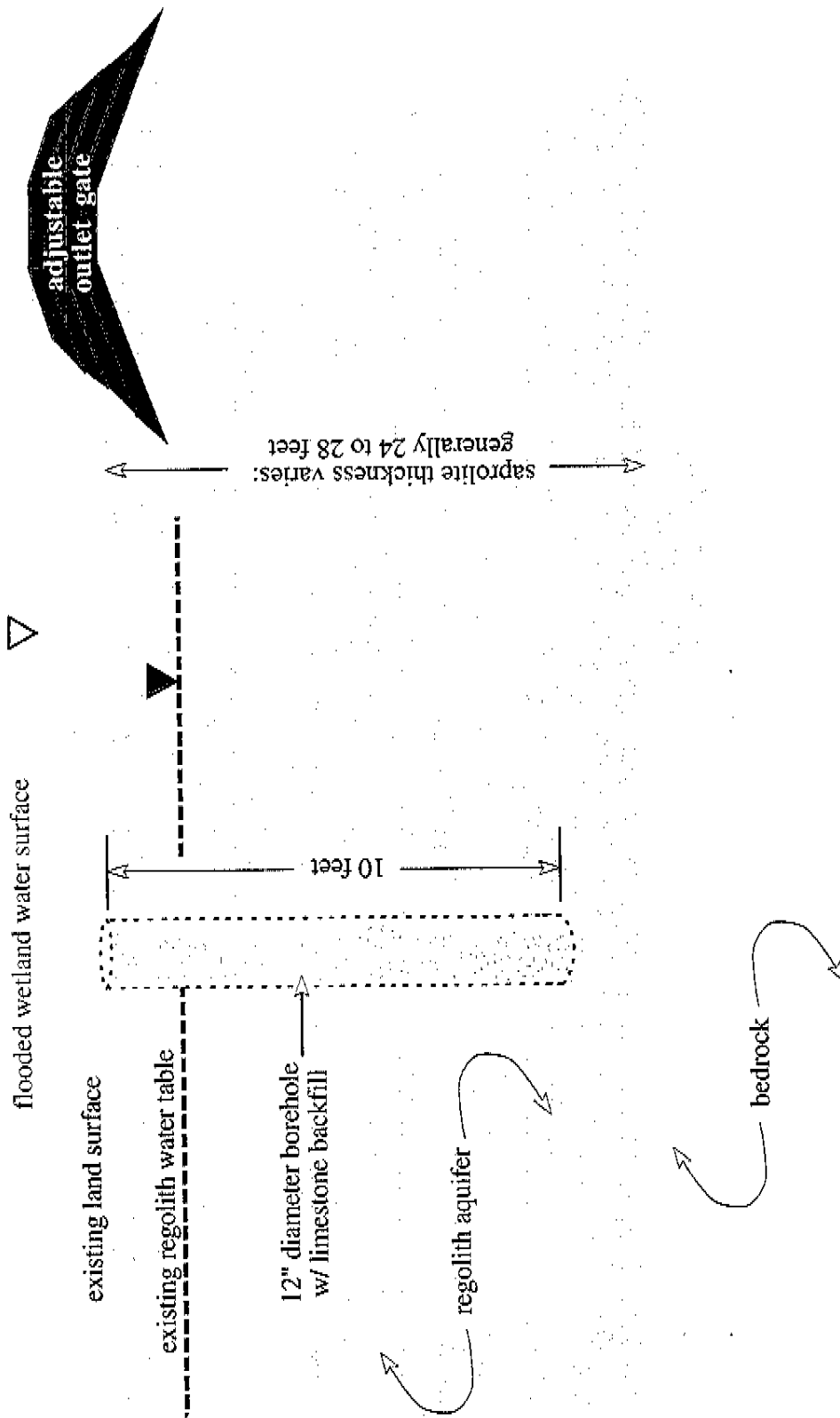
(no scale)



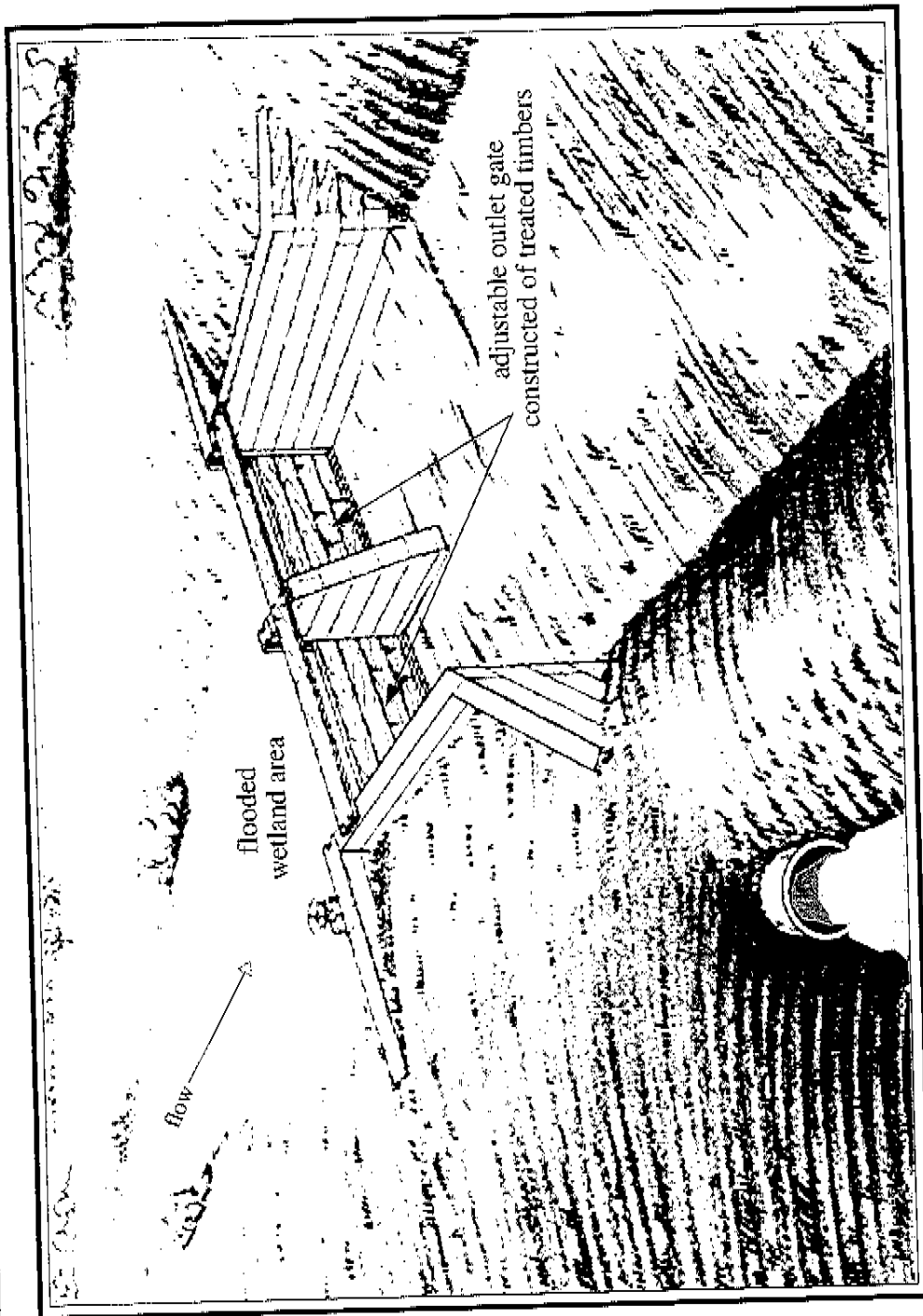
## LEGEND

- Permanent groundwater monitoring well
- Well point
- Piezometer
- Plume Area
- Wetland
- Wetland Cell 1
- Wetland Cell 2
- Outlet Gate
- Vertical mixing drain





<p><b>GeoScience &amp; Technology P.A.</b>  <small>Theoretical Environmental Solutions</small>  Winston-Salem, NC (910-896-1300)</p>	<p>Job #: 95-116  Drawn by: TPB  Approved by: ABN</p>
<p>Holcomb Creosote, Yadkinville, NC</p>	
<p>Schematic of Vertical Mixing Drains</p>	
<p>no scale</p>	<p>Figure 24</p>



**GeoScience & Technology, P.A.**  
Technical Engineering Solutions

Winston-Salem, NC (910-896-1300)

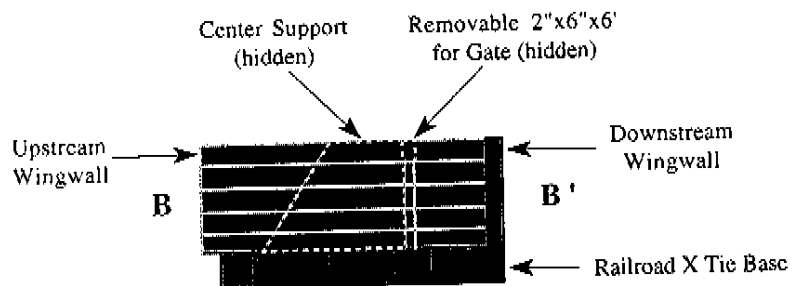
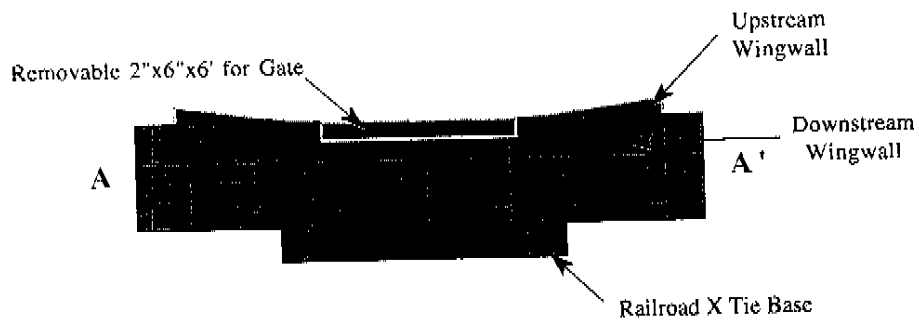
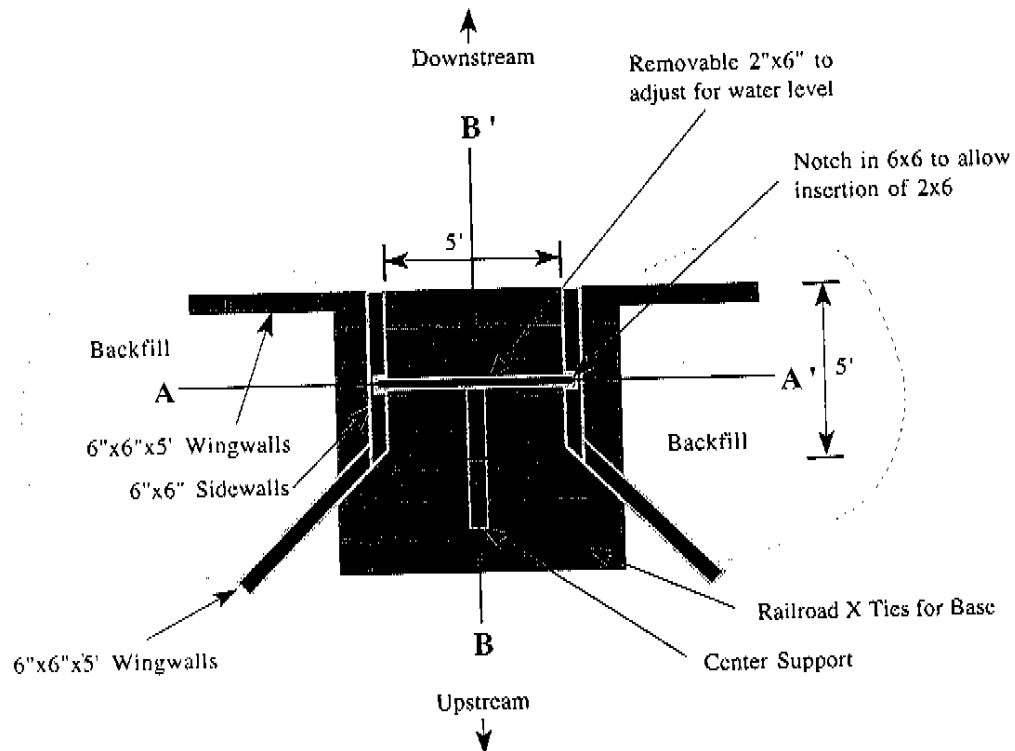
Holcomb Creosote, Yadkinville, NC

Job #: 95-116  
 Drawn by: TPB  
 Approved by: ABN

Illustration of Outlet/Overflow Structures

no scale

Figure 25



**GeoScience & Technology, P.A.**  
*"Practical Environmental Solutions"*

Winston-Salem (910) 896-1300

Job#: 95.116  
 Drawn: SW  
 App'd: ABN  
 Date: 7/25/96

Holcomb Creosote Company  
 Yadkinville, NC

Detail of Water Control Gate

Scale:  
 3/16" = 1 ft

Figure 26

# LEGEND

Permanent groundwater monitoring well

Well point

Piezometer

Plume Area

Wetland

Wetland Cell 1

Wetland Cell 2

Outlet Gate

Vertical mixing drain

Vertical air sparging point (screen ~ 15' below land surface)

Vertical air sparging point to top of bedrock (for DNAPL treatment)

Lateral air sparging line (above land surface, submerged)

#5

WP2

P4

#3

#4

#8

#10

#11

#12

#13

#14

#15

(lines in trenches)

GeoScience  
Environmental Services, Inc.  
Winston-Salem, NC (910-896-1700)

Job #: 95-116  
Drawn by: TPB  
Approved by: ABN

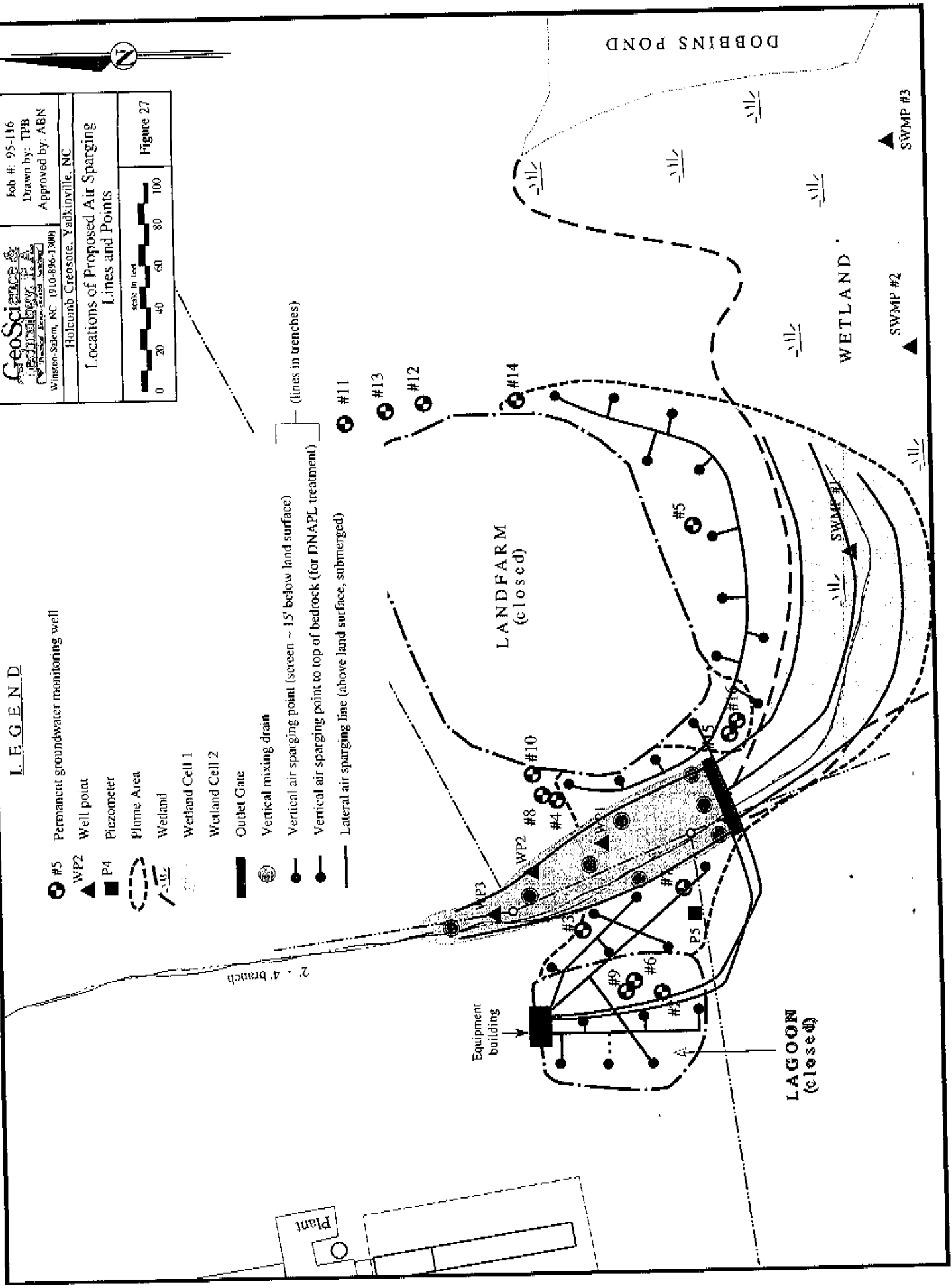
Holcomb Creosote, Yadkinville, NC

Locations of Proposed Air Sparging Lines and Points

scale in feet

0 20 40 60 80 100

Figure 27





## NOTES

Flow Sensors must be located at least 32 inches from pipe joints, elbows or protrusions into pipe which might alter flow.

Thermometers must be located no more than 36 inches from flow sensor in same instrumentation group.

## Legend

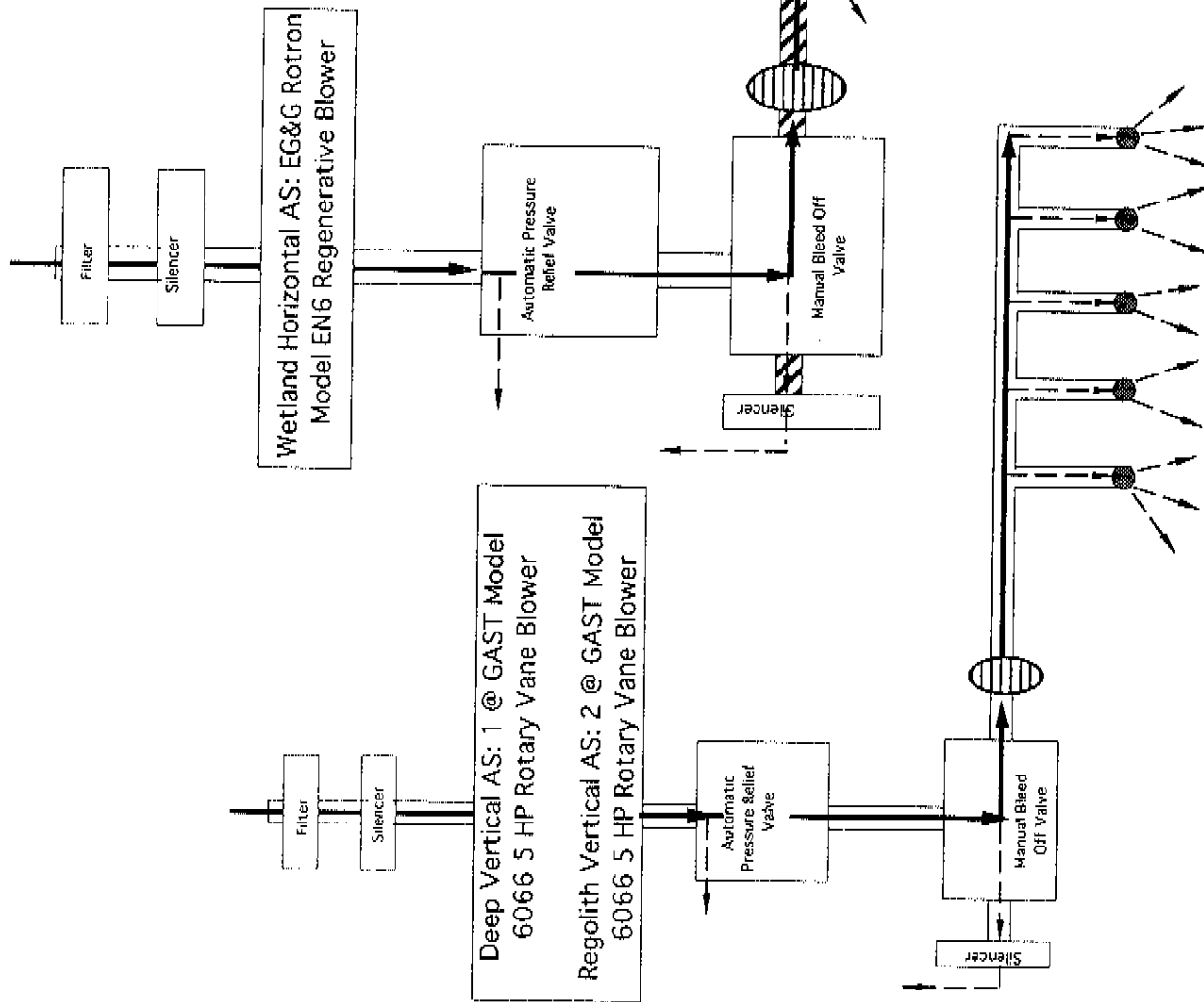
Instrumentation Group: flow sensor, pressure sensor, thermometer

Air Sparge subsystem air flow

Relief air flow

Sparge Points : Schrader valve, ball valve and cam-lock cap at each vault

Wetland Horizontal AS line.



Holcomb Creosote

Job #: 95-116

Drawn: KWL

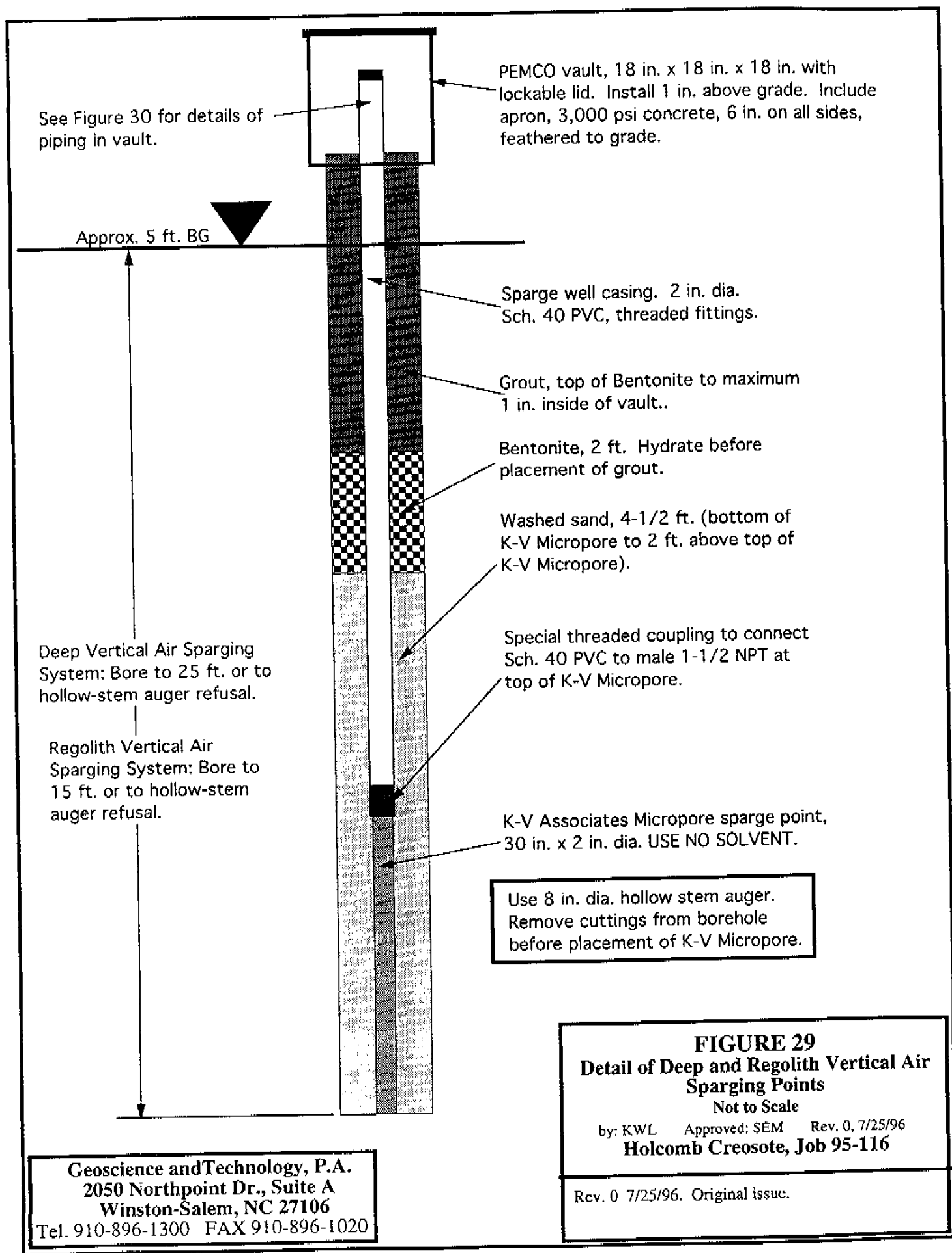
App'd: SEM

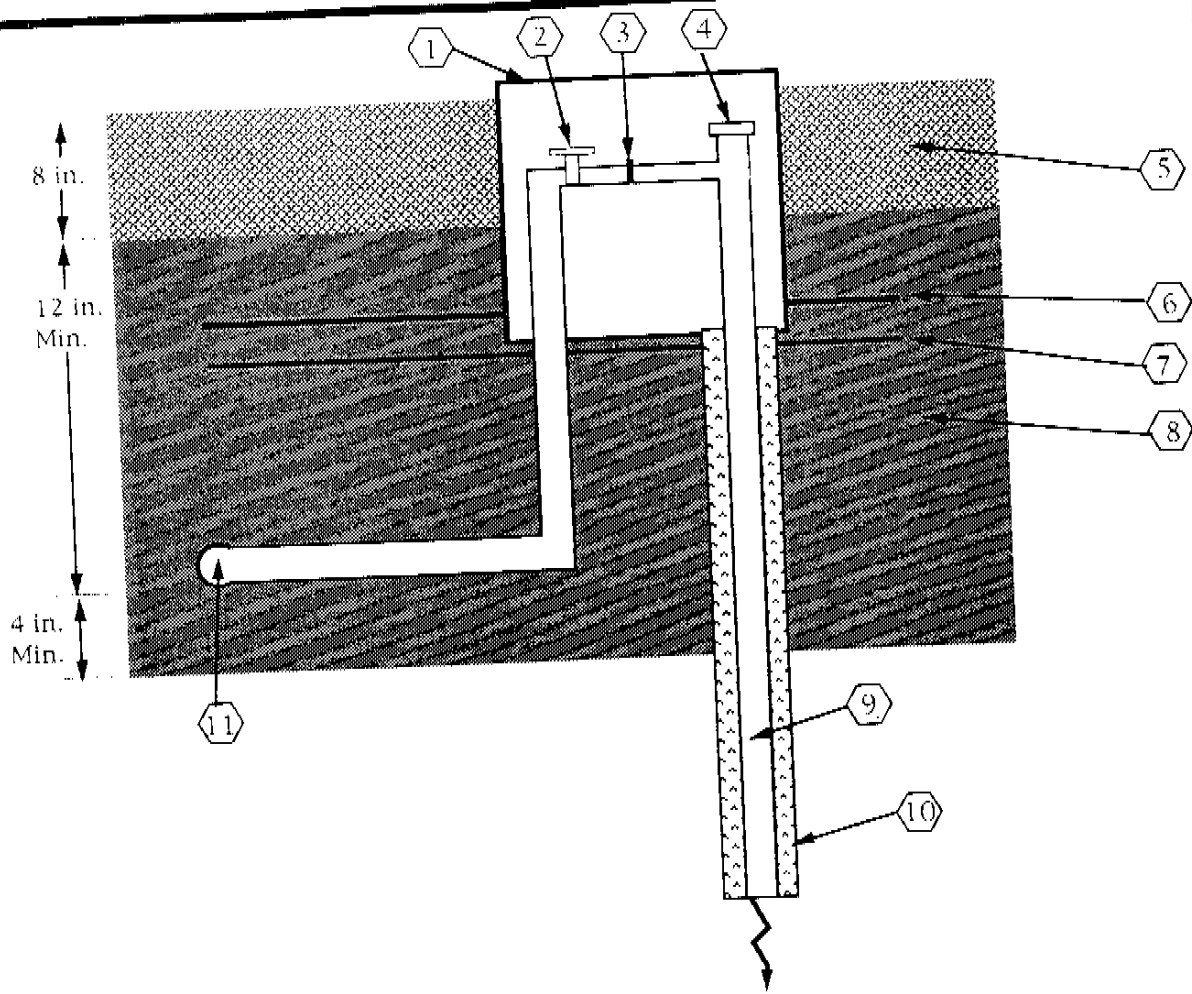
## Remediation System Schematic

NOT TO SCALE

Figure 28

Rev. 0 7/25/96



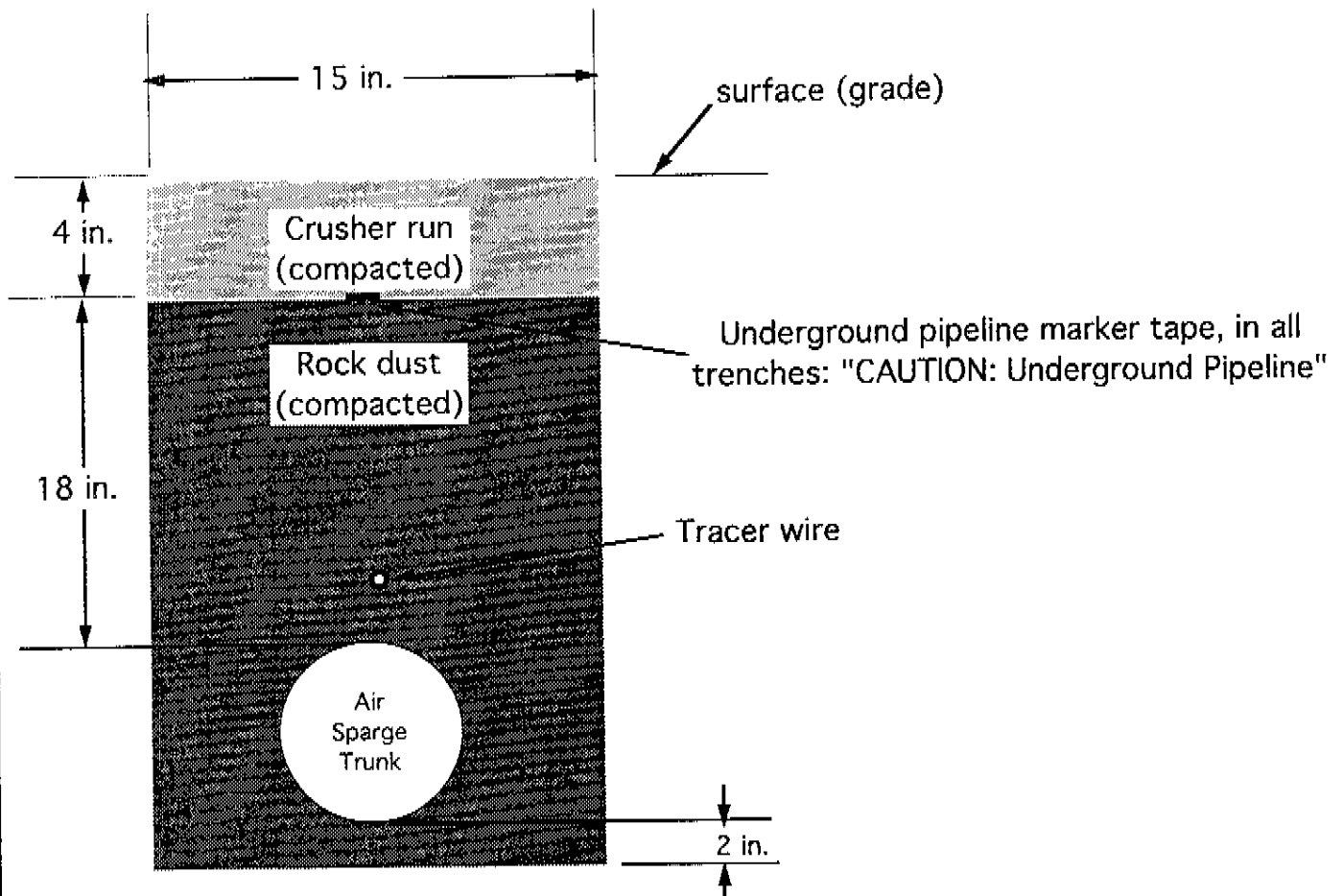


- ① Vault, 18 in. L x 18 in. W x 18 in. D
- ② Ball or butterfly valve
- ③ Schrader Valve
- ④ Cam Lock Cap
- ⑤ Crusher run.
- ⑥ Marker tape: "CAUTION: Underground Pipeline."
- ⑦ Tracer wire.
- ⑧ Rock dust, compacted.
- ⑨ Sparge downwell
- ⑩ Neat cement grout
- ⑪ Sparge pipe.



2050 Northpoint Blvd. Suite A  
Winston Salem, NC 27106  
Tel (910) 896-1300 FAX (910) 896-1020

Holcomb Creosote		
Job #: 95-116	Drawn: KWL	App'd: SEM
<b>Detail of Vertical Air Sparging Vault</b>		
 Scale: 1 inch = 1 foot		Figure 30 Rev. 0 7/25/96



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 Winston-Salem, NC 27106  
 Tel (910) 896-1300 FAX(910) 896-1020

Holcomb Creosote		
Job #: 95-116	Drawn: KWL	App'd: SEM
Section A-A' Trench with Backfill		
<p>0 1/2 1</p> <p>Scale: 1 inch = 1/2 foot</p>		<p>Figure 31</p> <p>Rev. 0</p> <p>7/25/96</p>

## APPENDICES

**APPENDIX A**  
**Plume Maps based on 6/96 Groundwater Quality Data**  
**6/96 Laboratory Report**

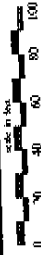


Job #: 95-116  
Drawn by: TFB  
Approved by: ABN

Wilson, Sirm, NC 910-596-1300

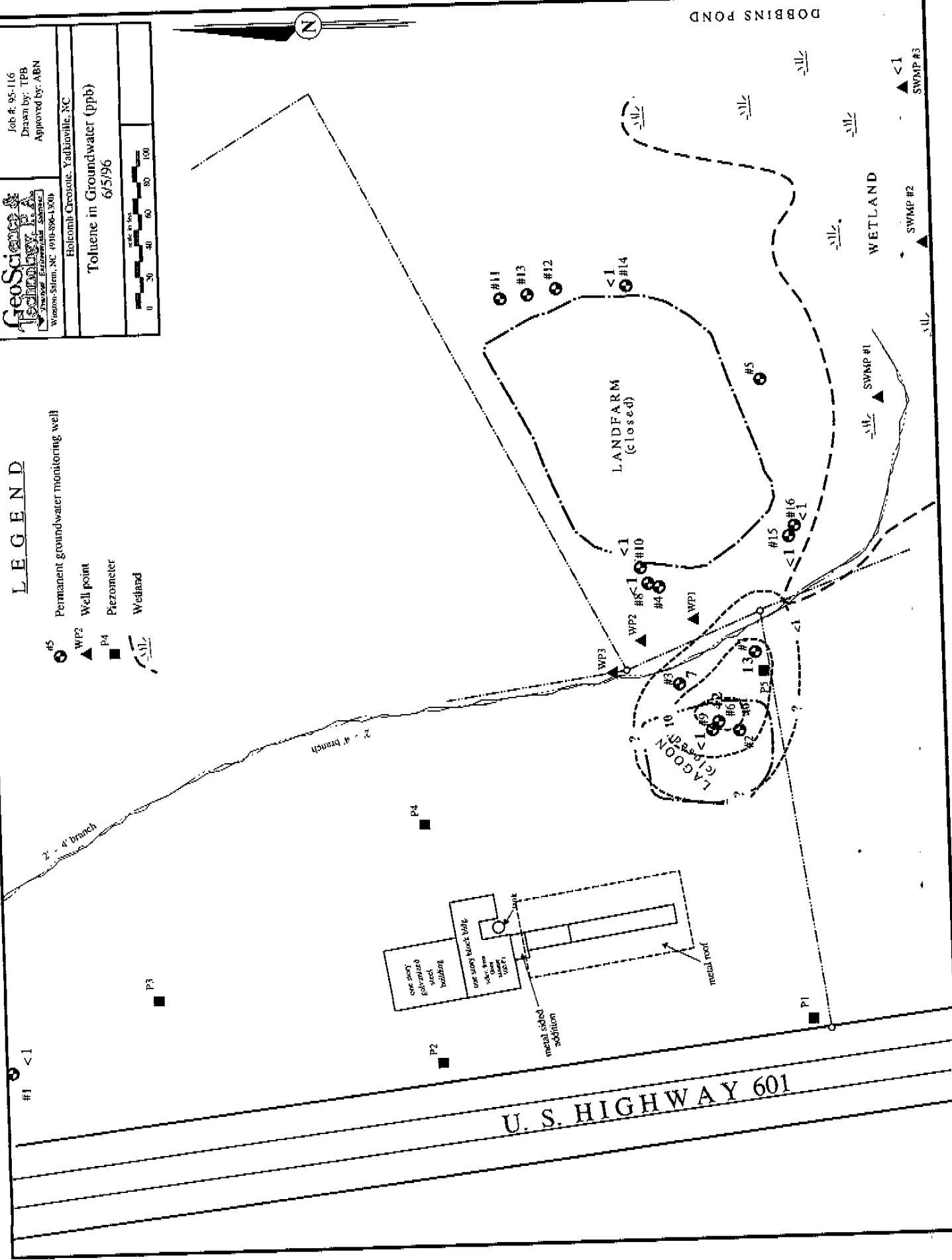
Holcomb Geosonic, Yadkoville, NC

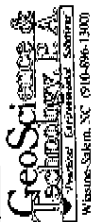
Toluene in Groundwater (ppb)  
6/5/96



# LEGEND

- Permanent groundwater monitoring well
- Well point
- Piezometer
- Wetland





Job #: 95-116  
Drawn by: TPB  
Approved by: ABN

Winston-Salem, NC (910) 896-1300

Holcomb Concrete, Yadkinville, NC

Naphthalene in Groundwater (ppb)  
6/5/96



## LEGEND

Permanent groundwater monitoring well

Well point

Piezometer

Wetland



WP2

P4

Wetland

U. S. HIGHWAY 601

DOBBS POND

WETLAND

SWAMP #2

SWAMP #1

SWAMP #3

SWAMP #4

SWAMP #5

SWAMP #6

SWAMP #7

SWAMP #8

SWAMP #9

SWAMP #10

SWAMP #11

SWAMP #12

SWAMP #13

SWAMP #14

SWAMP #15

SWAMP #16

SWAMP #17

SWAMP #18

SWAMP #19

SWAMP #20



# LEGEND

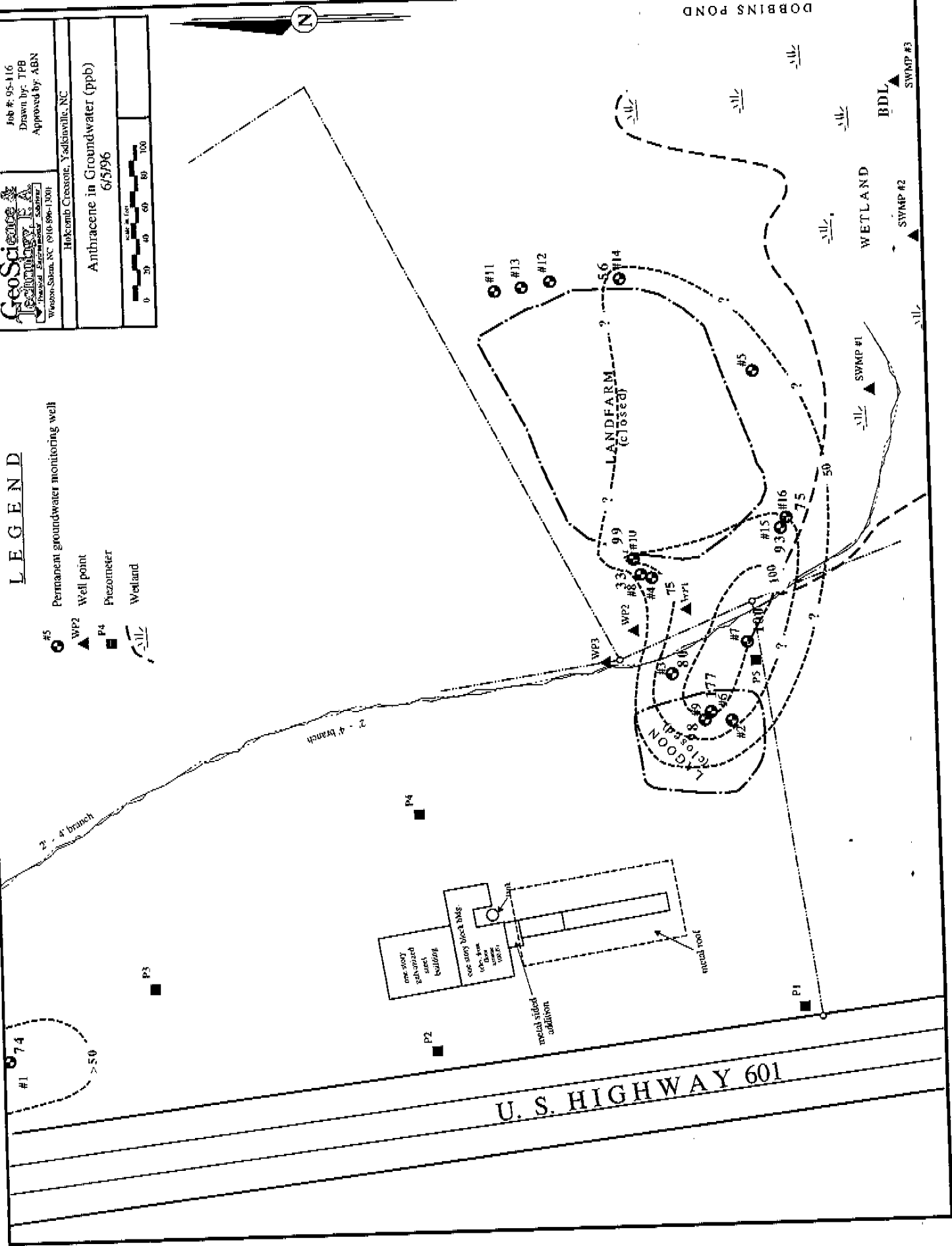
- Permanent groundwater monitoring well
- Well point
- Piezometer
- Wetland

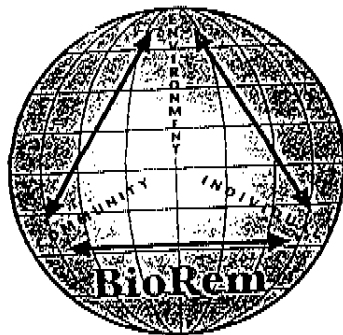
Job #: 95-116  
 Drawn by: TPB  
 Approved by: ABN

**GeoScience & Technology, Inc.**  
 10000 S. 10th St.  
 Winston-Salem, NC 27158-1300

Hokomb Cresson, Yaldeville, NC

Anthracene in Groundwater (ppb)  
 6/5/96





# BIOREMEDIATION RESEARCH, LTD.

ROUTE 2, BOX 180-C  
PINNACLE, NC 27043  
PHONE (910) 325-2318

## CERTIFICATE OF ANALYSIS

NC Cert. # 480

June 7, 1996

Client: GeoScience & Technology, P.A.  
Project: Holcomb Creosote

EPA 602/8020 + Xylenes + MTBE + IPE

Client Sample	Lab Sample	Constituents (ppb)	
MW-1	9600946	Benzene	< 1
		Toluene	< 1
		Ethylbenzene	< 1
		Xylenes	< 1
		Chlorobenzene	< 1
		1,2 Dichlorobenzene	< 1
		1,3 Dichlorobenzene	< 1
		1,4 Dichlorobenzene	< 1
		Methyl(T)butyl Ether	< 1
MW-3	9600947	Isopropyl Ether	< 1
		Benzene	< 1
		Toluene	7
		Ethylbenzene	< 1
		Xylenes	37
		Chlorobenzene	< 1
		1,2 Dichlorobenzene	< 1
		1,3 Dichlorobenzene	< 1
		1,4 Dichlorobenzene	< 1
		Methyl(T)butyl Ether	< 1
		Isopropyl Ether	< 1

MW-6

9600948

Benzene	< 1
Toluene	42
Ethylbenzene	39
Xylenes	261
Chlorobenzene	< 1
1,2 Dichlorobenzene	< 1
1,3 Dichlorobenzene	< 1
1,4 Dichlorobenzene	< 1
Methyl(T)butyl Ether	< 1
Isopropyl Ether	< 1

MW-7

9600949

Benzene	< 1
Toluene	13
Ethylbenzene	21
Xylenes	139
Chlorobenzene	< 1
1,2 Dichlorobenzene	< 1
1,3 Dichlorobenzene	< 1
1,4 Dichlorobenzene	< 1
Methyl(T)butyl Ether	< 1
Isopropyl Ether	< 1

MW-8

9600950

Benzene	< 1
Toluene	< 1
Ethylbenzene	< 1
Xylenes	< 1
Chlorobenzene	< 1
1,2 Dichlorobenzene	< 1
1,3 Dichlorobenzene	< 1
1,4 Dichlorobenzene	< 1
Methyl(T)butyl Ether	< 1
Isopropyl Ether	< 1

MW-9

9600951

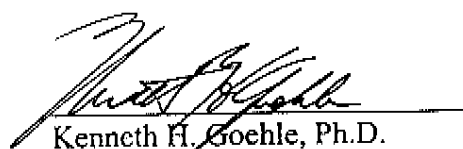
Benzene	< 1
Toluene	< 1
Ethylbenzene	< 1
Xylenes	< 1
Chlorobenzene	< 1
1,2 Dichlorobenzene	< 1
1,3 Dichlorobenzene	< 1
1,4 Dichlorobenzene	< 1
Methyl(T)butyl Ether	< 1
Isopropyl Ether	< 1

MW-10	9600952	Benzene	< 1
		Toluene	< 1
		Ethylbenzene	< 1
		Xylenes	< 1
		Chlorobenzene	< 1
		1,2 Dichlorobenzene	< 1
		1,3 Dichlorobenzene	< 1
		1,4 Dichlorobenzene	< 1
		Methyl(T)butyl Ether	< 1
		Isopropyl Ether	< 1
MW-14	9600953	Benzene	< 1
		Toluene	< 1
		Ethylbenzene	< 1
		Xylenes	< 1
		Chlorobenzene	< 1
		1,2 Dichlorobenzene	< 1
		1,3 Dichlorobenzene	< 1
		1,4 Dichlorobenzene	< 1
		Methyl(T)butyl Ether	< 1
		Isopropyl Ether	< 1
MW-15	9600954	Benzene	< 1
		Toluene	< 1
		Ethylbenzene	< 1
		Xylenes	< 1
		Chlorobenzene	< 1
		1,2 Dichlorobenzene	< 1
		1,3 Dichlorobenzene	< 1
		1,4 Dichlorobenzene	< 1
		Methyl(T)butyl Ether	< 1
		Isopropyl Ether	< 1
MW-16	9600955	Benzene	< 1
		Toluene	< 1
		Ethylbenzene	< 1
		Xylenes	< 1
		Chlorobenzene	< 1
		1,2 Dichlorobenzene	< 1
		1,3 Dichlorobenzene	< 1
		1,4 Dichlorobenzene	< 1
		Methyl(T)butyl Ether	< 1
		Isopropyl Ether	< 1

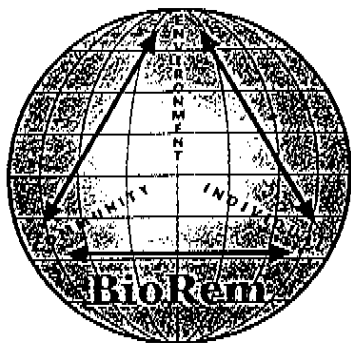
SWMP-3

9600956

Benzene	< 1
Toluene	< 1
Ethylbenzene	< 1
Xylenes	< 1
Chlorobenzene	< 1
1,2 Dichlorobenzene	< 1
1,3 Dichlorobenzene	< 1
1,4 Dichlorobenzene	< 1
Methyl(T)butyl Ether	< 1
Isopropyl Ether	< 1



Kenneth H. Goehle, Ph.D.



# BIOREMEDIATION RESEARCH, LTD.

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PINNACLE, NC 27043

PHONE (910) 325-2318

## CERTIFICATE OF ANALYSIS

NC Cert# 480

June 11, 1996

Client: GeoScience & Technology, P.A.

Project: Holcomb Creosote

EPA 610/8100 Polynuclear Aromatic Hydrocarbons

Client Sample	Lab Sample		Constituents (ppb)	
			MDL	Result
MW-1	9600946	Acenaphthene	1.41	225
		Acenaphthylene	1.17	229
		Anthracene	3.30	74
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	BDL
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	148
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	196
		Phenanthrene	4.02	BDL
		Pyrene	1.63	BDL

MW-3	9600947	Acenaphthene	1.41	216
		Acenaphthylene	1.17	205
		Anthracene	3.30	80
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	55
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	145
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	201
		Phenanthrene	4.02	53
		Pyrene	1.63	62

MW-6	9600948	Acenaphthene	1.41	732
		Acenaphthylene	1.17	207
		Anthracene	3.30	177
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	BDL
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	171
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	174
		Phenanthrene	4.02	BDL
		Pyrene	1.63	228

MW-7	9600949	Acenaphthene	1.41	941
		Acenaphthylene	1.17	BDL
		Anthracene	3.30	100
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	BDL
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	460
		Fluorene	2.36	236
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	205
		Phenanthrene	4.02	264
		Pyrene	1.63	347
MW-8	9600950	Acenaphthene	1.41	281
		Acenaphthylene	1.17	123
		Anthracene	3.30	33
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	BDL
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	71
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	441
		Phenanthrene	4.02	BDL
		Pyrene	1.63	BDL



MW-9	9600951	Acenaphthene	1.41	180
		Acenaphthylene	1.17	259
		Anthracene	3.30	98
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	12
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	BDL
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	46
		Phenanthrene	4.02	BDL
		Pyrene	1.63	59

MW-10	9600952	Acenaphthene	1.41	249
		Acenaphthylene	1.17	255
		Anthracene	3.30	99
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	22
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	97
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	242
		Phenanthrene	4.02	BDL
		Pyrene	1.63	BDL

MW-14	9600953	Acenaphthene	1.41	180
		Accenaphthylene	1.17	177
		Anthracene	3.30	56
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	BDL
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	123
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	189
		Phenanthrene	4.02	BDL
		Pyrene	1.63	BDL
MW-15	9600954	Acenaphthene	1.41	390
		Acenaphthylene	1.17	279
		Anthracene	3.30	93
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	8
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	47
		Fluorene	2.36	158
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	269
		Phenanthrene	4.02	BDL
		Pyrene	1.63	45

MW-16	9600955	Acenaphthene	1.41	243
		Acenaphthylene	1.17	236
		Anthracene	3.30	75
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	5
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	166
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	235
		Phenanthrene	4.02	BDL
		Pyrene	1.63	BDL
SWMP-3	9600956	Acenaphthene	1.41	72
		Acenaphthylene	1.17	99
		Anthracene	3.30	BDL
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	BDL
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	38
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	106
		Phenanthrene	4.02	BDL
		Pyrene	1.63	BDL

  
Kenneth H. Gochle, Ph.D.

# CHAIN OF CUSTODY RECORD

Use ballpoint pen only, press hard

## BIOREMEDIATION RESEARCH, LTD.

1720 Vargrave Street  
Winston-Salem, NC 27107  
Telephone (919) 631-9104 Fax (919) 631-9102

Client Name: GOVERNANCE & TECH  
Project: HOLLUMB CROSBY  
Attention: J. WAT  
Telephone: 846-1300

Please indicate the number of each size of sample container and any preservatives which were used.  
e.g., 2-HNO3 indicates 2 containers w/ nitric acid.

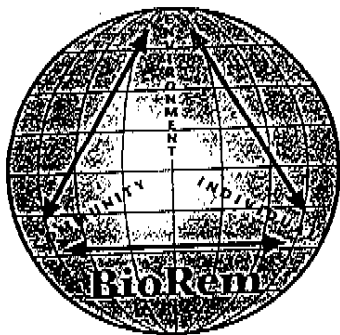
Please indicate the number of each size of sample container and any preservatives which were used. e.g., 2-HNO3 indicates 2 containers w/ nitric acid.											G10 vol		Lab use only			
Sample ID	Yr. 96 Date	Time	Matrix								Suspected Contaminant	Level			Analysis Requested	Lab ID
				40 ml	120 ml	250 ml	500 ml	950 ml	other	0		Low	Med	High		
MW 1	6-4	3:00	H <sub>2</sub> O	2				1			870	-			602 ml. 6010	946
MW 3		2:10		2				1			900		-			947
MW 6		2:15		2				1			935		-			948
MW 7		2:20		2				1			960		-			949
MW 8		2:25		2				1			940		-			950
MW 9		2:30		2				1			960		-			951
MW 10		2:35		2				1			965		-			952
MW 14		2:40		2				1			970		-			953
MW 15		2:45		2				1			890		-			954
MW 16		2:50		2				1			940		-			955
SWMP-3		4:00		2				1			890		-			956

Relinquished by: (Sig.)		Date	Time	Received by: (Sig.)	Date	Time	Remarks:
<u>[Signature]</u>		6/5/96	10:25				
Relinquished by: (Sig.)		Date	Time	Received by: (Sig.)	Date	Time	
<u>[Signature]</u>							
Relinquished by: (Sig.)		Date	Time	Received by: (Sig.)	Date	Time	
<u>[Signature]</u>							

WHITE - ORIGINAL

CANARY - REPORT

PINK - CUSTOMER COPY



# BIOREMEDIATION RESEARCH, LTD.

ROUTE 2, BOX 180-C  
PINNACLE, NC 27043  
PHONE (910) 325-2318

## CERTIFICATE OF ANALYSIS

NC Cert. # 480

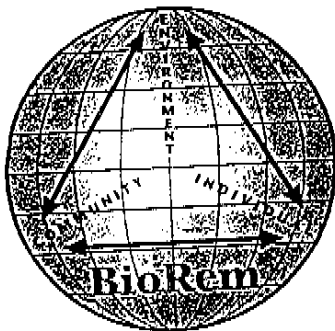
June 13, 1996

Client: GeoScience & Technology, P.A.  
Project: Holcomb Creosote

EPA 602/8020 + Xylenes + MTBE + IPE

Client Sample	Lab Sample	Constituents (ppb)	
MW-1	9600993	Benzene	< 1
		Toluene	< 1
		Ethylbenzene	< 1
		Xylenes	< 1
		Chlorobenzene	< 1
		1,2 Dichlorobenzene	< 1
		1,3 Dichlorobenzene	< 1
		1,4 Dichlorobenzene	< 1
		Methyl(T)butyl Ether	< 1
		Isopropyl Ether	< 1

  
Kenneth H. Goehle, Ph.D.



BIOREMEDIATION RESEARCH, LTD.  
ROUTE 2, BOX 180-C  
PINNACLE, NC 27043  
PHONE (910) 325-2318

## CERTIFICATE OF ANALYSIS

NC Cert# 480

June 13, 1996

Client: GeoScience & Technology, P.A.  
Project: Holcomb Creosote

EPA 610/8100 Polynuclear Aromatic Hydrocarbons

Client Sample	Lab Sample		Constituents (ppb)	
			MDL	Result
MW-1	9600993	Acenaphthene	1.41	11
		Acenaphthylene	1.17	11
		Anthracene	3.30	25
		Benz[a]anthracene	2.61	BDL
		Benzo[b]fluoranthene	2.01	BDL
		Benzo[k]fluoranthene	1.01	BDL
		Benzo[ghi]perylene	0.97	BDL
		Benzo[a]pyrene	1.63	BDL
		Chrysene	2.77	17
		Dibenz[a,h]anthracene	2.04	BDL
		Fluoranthene	1.67	BDL
		Fluorene	2.36	71
		Ideno[1,2,3-cd]pyrene	2.33	BDL
		Naphthalene	1.48	8
		Phenanthrene	4.02	BDL
		Pyrene	1.63	BDL

  
Kenneth H. Goehle, Ph.D.

Page 1 of 1

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Route 2 Box 180-C  
Pinnacle, NC 27043  
Telephone (910) 325-2323

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**Appendix B**  
**Surface Water Quality Data**



Surface Water Quality Data				
Parameter	Sample Location	Date	Concentration	Units
Cadmium	Stream 2	11/9/81	<5.0	ppb
Chromium	Stream 2	11/9/81	50.0	ppb
Lead	Stream 2	11/9/81	10.0	ppb
Phenol	Stream 2	11/9/81	26.0	ppb
	Stream 2	5/26/83	40.0	ppb
	Stream 1	9/9/83	10.0	ppb
	Stream 3	9/9/83	90.0	ppb
	Pond 1	9/9/83	7.0	ppb
	Stream 1	1/20/84	94.0	ppb
	Stream 2	1/20/84	23.0	ppb
	Stream 3	1/20/84	156.0	ppb
	Stream 1	3/12/84	7.0	ppb
	Stream 3	3/12/84	82.0	ppb
	Pond 1	3/12/84	20.0	ppb
	Stream 1	7/1/86	<100.0	ppb
	Stream 2	7/1/86	<25.0	ppb
	Stream 3	7/1/86	<250.0	ppb
	Pond 3	7/1/86	<25.0	ppb
	Stream 1	8/26/86	<50.0	ppb
	Stream 2	8/26/86	<50.0	ppb
	Stream 2A	8/26/86	<50.0	ppb
	Stream 3	8/26/86	<50.0	ppb
	Stream 3A	8/26/86	<50.0	ppb
	Pond 1	8/26/86	<50.0	ppb
	Pond 2	8/26/86	<50.0	ppb
	Pond 4	8/26/86	<50.0	ppb
	Pond 5	8/26/86	<50.0	ppb
	Stream 1	5/6/87	<50.0	ppb
	Stream 2	5/6/87	<50.0	ppb
	Stream 3	5/6/87	<50.0	ppb
	Pond 1	5/6/87	<50.0	ppb
	Pond 2	5/6/87	<50.0	ppb
	Stream 1	5/22/87	<50.0	ppb
	Stream 2	5/22/87	<50.0	ppb
	Stream 3	5/22/87	<50.0	ppb
	Pond 1	5/22/87	<50.0	ppb
	Pond 2	5/22/87	<50.0	ppb
	Stream 1	7/22/87	25.0	ppb
	Stream 2	7/22/87	28.0	ppb
	Stream 3	7/22/87	86.0	ppb
	Pond 1	7/22/87	32.0	ppb
	Pond 2	7/22/87	25.0	ppb
Pentachlorophenol	Stream 1	7/1/86	<100.0	ppb
	Stream 2	7/1/86	<25.0	ppb
	Stream 3	7/1/86	<250.0	ppb
	Pond 3	7/1/86	<25.0	ppb
	Stream 1	8/26/86	<50.0	ppb

	Stream 2	8/26/86	<50.0	ppb
	Stream 2A	8/26/86	<50.0	ppb
	Stream 3	8/26/86	<50.0	ppb
	Stream 3A	8/26/86	<50.0	ppb
	Pond 1	8/26/86	<50.0	ppb
	Pond 2	8/26/86	<50.0	
	Pond 4	8/26/86	<50.0	ppb
	Pond 5	8/26/86	<50.0	
	Stream 1	5/6/87	<50.0	ppb
	Stream 2	5/6/87	<50.0	ppb
	Stream 3	5/6/87	<50.0	ppb
	Pond 1	5/6/87	<50.0	ppb
	Pond 2	5/6/87	<50.0	ppb
	Stream 1	5/22/87	<50.0	ppb
	Stream 2	5/22/87	<50.0	ppb
	Stream 3	5/22/87	<50.0	ppb
	Pond 1	5/22/87	<50.0	ppb
	Pond 2	5/22/87	<50.0	ppb
2,4-Dinitrophenol	Stream 1	8/26/86	<500.0	ppb
	Stream 2	8/26/86	<500.0	ppb
	Stream 3	8/26/86	<500.0	ppb
	Pond 3	8/26/86	<500.0	ppb
	Stream 1	8/26/86	<500.0	ppb
	Stream 2	8/26/86	<500.0	ppb
	Stream 2A	8/26/86	<500.0	ppb
	Stream 3	8/26/86	<500.0	ppb
	Stream 3A	8/26/86	<500.0	ppb
	Pond 1	8/26/86	<500.0	ppb
	Pond 2	8/26/86	<500.0	ppb
	Pond 4	8/26/86	<500.0	ppb
	Pond 5	8/26/86	<500.0	ppb
	Stream 1	5/6/87	<500.0	ppb
	Stream 2	5/6/87	<500.0	ppb
	Stream 3	5/6/87	<500.0	ppb
	Pond 1	5/6/87	<500.0	ppb
	Pond 2	5/6/87	<500.0	ppb
	Stream 1	5/22/87	<500.0	ppb
	Stream 2	5/22/87	<500.0	ppb
	Stream 3	5/22/87	<500.0	ppb
	Pond 1	5/22/87	<500.0	ppb
	Pond 2	5/22/87	<500.0	ppb
2,4-Dimethylphenol	Stream 1	7/1/86	<100.0	ppb
	Stream 2	7/1/86	<25.0	ppb
	Stream 3	7/1/86	<250.0	ppb
	Pond 3	7/1/86	<25.0	ppb
	Stream 1	8/26/86	<50.0	ppb
	Stream 2	8/26/86	<50.0	ppb
	Stream 2A	8/26/86	<50.0	ppb
	Stream 3	8/26/86	<50.0	ppb

	Stream 3A	8/26/86	<50.0	ppb
	Pond 1	8/26/86	<50.0	ppb
	Pond 2	8/26/86	<50.0	ppb
	Pond 4	8/26/86	<50.0	ppb
	Pond 5	8/26/86	<50.0	ppb
	Stream 1	5/6/87	<50.0	ppb
	Stream 2	5/6/87	<50.0	ppb
	Stream 3	5/6/87	<50.0	ppb
	Pond 1	5/6/87	<50.0	ppb
	Pond 2	5/6/87	<50.0	ppb
	Stream 1	5/22/87	<50.0	ppb
	Stream 2	5/22/87	<50.0	ppb
	Stream 3	5/22/87	<50.0	ppb
	Pond 1	5/22/87	<50.0	ppb
	Pond 2	5/22/87	<50.0	ppb
2-Chlorophenol	Stream 1	7/1/86	<100.0	ppb
	Stream 2	7/1/86	<25.0	ppb
	Stream 3	7/1/86	<250.0	ppb
	Pond 3	7/1/86	<25.0	ppb
	Stream 1	8/26/86	<50.0	ppb
	Stream 2	8/26/86	<50.0	ppb
	Stream 2A	8/26/86	<50.0	ppb
	Stream 3	8/26/86	<50.0	ppb
	Stream 3A	8/26/86	<50.0	ppb
	Pond 1	8/26/86	<50.0	ppb
	Pond 2	8/26/86	<50.0	ppb
	Pond 4	8/26/86	<50.0	ppb
	Pond 5	8/26/86	<50.0	ppb
	Stream 1	5/6/87	<50.0	ppb
	Stream 2	5/6/87	<50.0	ppb
	Stream 3	5/6/87	<50.0	ppb
	Pond 1	5/6/87	<50.0	ppb
	Pond 2	5/6/87	<50.0	ppb
	Stream 1	5/22/87	<50.0	ppb
	Stream 2	5/22/87	<50.0	ppb
	Stream 3	5/22/87	<50.0	ppb
	Pond 1	5/22/87	<50.0	ppb
	Pond 2	5/22/87	<50.0	ppb
Tetrachlorophenols	Stream 1	7/1/86	<100.0	ppb
	Stream 2	7/1/86	<25.0	ppb
	Stream 3	7/1/86	<250.0	ppb
	Pond 3	7/1/86	<25.0	ppb
	Stream 1	8/26/86	<500.0	ppb
	Stream 2	8/26/86	<500.0	ppb
	Stream 2A	8/26/86		
	Stream 3	8/26/86	<100.0	ppb
	Stream 3A	8/26/86	<25.0	ppb
	Pond 1	8/26/86	<50.0	ppb
	Pond 2	8/26/86	<50.0	ppb

	Pond 4	8/26/86	<50.0	ppb
	Pond 5	8/26/86	<50.0	ppb
	Stream 1	5/6/87	<50.0	ppb
	Stream 2	5/6/87	<50.0	ppb
	Stream 3	5/6/87	<50.0	ppb
	Pond 1	5/6/87	<50.0	ppb
	Pond 2	5/6/87	<50.0	ppb
	Stream 1	5/22/87	<50.0	ppb
	Stream 2	5/22/87	<50.0	ppb
	Stream 3	5/22/87	<50.0	ppb
	Pond 1	5/22/87	<50.0	ppb
	Pond 2	5/22/87	<50.0	ppb
Trichlorophenols	Stream 1	7/1/86	<100.0	ppb
	Stream 2	7/1/86	<25.0	ppb
	Stream 3	7/1/86	<250.0	ppb
	Pond 3	7/1/86	<25.0	ppb
	Stream 1	8/26/86	<50.0	ppb
	Stream 2	8/26/86	<50.0	ppb
	Stream 2A	8/26/86	<50.0	ppb
	Stream 3	8/26/86	<50.0	ppb
	Stream 3A	8/26/86	<50.0	ppb
	Pond 1	8/26/86	<50.0	ppb
	Pond 2	8/26/86	<50.0	ppb
	Pond 4	8/26/86	<50.0	ppb
	Pond 5	8/26/86	<50.0	ppb
	Stream 1	5/6/87	<50.0	ppb
	Stream 2	5/6/87	<50.0	ppb
	Stream 3	5/6/87	<50.0	ppb
	Pond 1	5/6/87	<50.0	ppb
	Pond 2	5/6/87	<50.0	ppb
	Stream 1	5/22/87	<50.0	ppb
	Stream 2	5/22/87	<50.0	ppb
	Stream 3	5/22/87	<50.0	ppb
	Pond 1	5/22/87	<50.0	ppb
	Pond 2	5/22/87	<50.0	ppb
Naphthalene	Stream 1	7/1/86	<50.0	ppb
	Stream 2	7/1/86	<10.0	ppb
	Stream 3	7/1/86	<100.0	ppb
	Pond 3	7/1/86	<10.0	ppb
	Stream 1	8/26/86	<50.0	ppb
	Stream 2	8/26/86	<50.0	ppb
	Stream 2A	8/26/86	<50.0	ppb
	Stream 3	8/26/86	<20.0	
	Stream 3A	8/26/86	<20.0	ppb
	Pond 1	8/26/86	<20.0	ppb
	Pond 2	8/26/86	<20.0	ppb
	Pond 4	8/26/86	<20.0	ppb
	Pond 5	8/26/86	<20.0	ppb
	Stream 1	5/6/87	<20.0	ppb

	Stream 2	5/6/87	<20.0	ppb
	Stream 3	5/6/87	50.0	ppb
	Pond 1	5/6/87	<20.0	ppb
	Pond 2	5/6/87	<20.0	ppb
	Stream 1	5/22/87	<20.0	ppb
	Stream 2	5/22/87	<20.0	ppb
	Stream 3	5/22/87	300.0	ppb
	Pond 1	5/22/87	<20.0	ppb
	Pond 2	5/22/87	<20.0	ppb
	Stream 1	7/22/87	<10.0	ppb
	Stream 2	7/22/87	8.0	ppb
	Stream 3	7/22/87	170.0	ppb
	Pond 1	7/22/87	<10.0	ppb
	Pond 2	7/22/87	<10.0	ppb
Indeno (1,2,3-cd) pyrene	Stream 1	7/1/86	<100.0	ppb
	Stream 2	7/1/86	<25.0	ppb
	Stream 3	7/1/86	<250.0	ppb
	Pond 3	7/1/86	<25.0	ppb
	Stream 1	8/26/86	<50.0	ppb
	Stream 2	8/26/86	<50.0	ppb
	Stream 2A	8/26/86	<50.0	ppb
	Stream 3	8/26/86	<50.0	ppb
	Stream 3A	8/26/86	<50.0	ppb
	Pond 1	8/26/86	<50.0	ppb
	Pond 2	8/26/86	<50.0	ppb
	Pond 4	8/26/86	<50.0	ppb
	Pond 5	8/26/86	<50.0	ppb
	Stream 1	5/6/87	<50.0	ppb
	Stream 2	5/6/87	<50.0	ppb
	Stream 3	5/6/87	<50.0	ppb
	Pond 1	5/6/87	<50.0	ppb
	Pond 2	5/6/87	<50.0	ppb
	Stream 1	5/22/87	<50.0	ppb
	Stream 2	5/22/87	<50.0	ppb
	Stream 3	5/22/87	<50.0	ppb
	Pond 1	5/22/87	<50.0	ppb
	Pond 2	5/22/87	<50.0	ppb
Fluoranthene	Stream 1	7/1/86	<50.0	ppb
	Stream 2	7/1/86	<10.0	ppb
	Stream 3	7/1/86	<100.0	ppb
	Pond 3	7/1/86	<10.0	ppb
	Stream 1	8/26/86	<20.0	ppb
	Stream 2	8/26/86	<20.0	ppb
	Stream 2A	8/26/86	<20.0	ppb
	Stream 3	8/26/86	<20.0	ppb
	Stream 3A	8/26/86	<20.0	ppb
	Pond 1	8/26/86	<20.0	ppb
	Pond 2	8/26/86	<20.0	ppb
	Pond 4	8/26/86	<20.0	ppb

	Pond 5	8/26/86	<20.0	ppb
	Stream 1	5/6/87	<20.0	ppb
	Stream 2	5/6/87	<20.0	ppb
	Stream 3	5/6/87	<20.0	ppb
	Pond 1	5/6/87	<20.0	ppb
	Pond 2	5/6/87	<20.0	ppb
	Stream 1	5/22/87	<20.0	ppb
	Stream 2	5/22/87	<20.0	ppb
	Stream 3	5/22/87	45.0	ppb
	Pond 1	5/22/87	<20.0	ppb
	Pond 2	5/22/87	<20.0	ppb
Dibenzo (a, h)- Anthracene	Stream 1	7/1/86	<50.0	ppb
	Stream 2	7/1/86	<10.0	ppb
	Stream 3	7/1/86	<100.0	ppb
	Pond 3	7/1/86	<10.0	ppb
	Stream 1	8/26/86	<20.0	ppb
	Stream 2	8/26/86	<20.0	ppb
	Stream 2A	8/26/86	<20.0	ppb
	Stream 3	8/26/86	<20.0	ppb
	Stream 3A	8/26/86	<20.0	ppb
	Pond 1	8/26/86	<20.0	ppb
	Pond 2	8/26/86	<20.0	ppb
	Pond 4	8/26/86	<20.0	ppb
	Pond 5	8/26/86	<20.0	ppb
	Stream 1	5/6/87	<20.0	ppb
	Stream 2	5/6/87	<20.0	ppb
	Stream 3	5/6/87	<20.0	ppb
	Pond 1	5/6/87	<20.0	ppb
	Pond 2	5/6/87	<20.0	ppb
	Stream 1	5/22/87	<20.0	ppb
	Stream 2	5/22/87	<20.0	ppb
	Stream 3	5/22/87	<20.0	ppb
	Pond 1	5/22/87	<20.0	ppb
	Pond 2	5/22/87	<20.0	ppb
Chrysene	Stream 1	7/1/86	<50.0	ppb
	Stream 2	7/1/86	<10.0	ppb
	Stream 3	7/1/86	<100.0	ppb
	Pond 3	7/1/86	<10.0	ppb
	Stream 1	8/26/86	<50.0	ppb
	Stream 2	8/26/86	<50.0	ppb
	Stream 2A	8/26/86	<20.0	ppb
	Stream 3	8/26/86	<20.0	ppb
	Stream 3A	8/26/86	<20.0	ppb
	Pond 1	8/26/86	<20.0	ppb
	Pond 2	8/26/86	<20.0	ppb
	Pond 4	8/26/86	<20.0	ppb
	Pond 5	8/26/86	<20.0	ppb
	Stream 1	5/6/87	<20.0	ppb
	Stream 2	5/6/87	<20.0	ppb

	Stream 3	5/6/87	<20.0	ppb
	Pond 1	5/6/87	<20.0	ppb
	Pond 2	5/6/87	<20.0	ppb
	Stream 1	5/22/87	<20.0	ppb
	Stream 2	5/22/87	<20.0	ppb
	Stream 3	5/22/87	<20.0	ppb
	Pond 1	5/22/87	<20.0	ppb
	Pond 2	5/22/87	<20.0	ppb
Benzo (b) - Fluoranthene	Stream 1	7/1/86	<20.0	ppb
	Stream 2	7/1/86	<20.0	ppb
	Stream 3	7/1/86	<20.0	ppb
	Pond 3	7/1/86	<20.0	ppb
	Stream 1	8/26/86	<20.0	ppb
	Stream 2	8/26/86	<20.0	ppb
	Stream 2A	8/26/86	<20.0	
	Stream 3	8/26/86	<20.0	ppb
	Stream 3A	8/26/86	<20.0	ppb
	Pond 1	8/26/86	<20.0	ppb
	Pond 2	8/26/86	<20.0	ppb
	Pond 4	8/26/86	<20.0	ppb
	Pond 5	8/26/86	<20.0	ppb
	Stream 1	5/6/87	<20.0	ppb
	Stream 2	5/6/87	<20.0	ppb
	Stream 3	5/6/87	<20.0	ppb
	Pond 1	5/6/87	<20.0	ppb
	Pond 2	5/6/87	<20.0	ppb
	Stream 1	5/22/87	<20.0	ppb
	Stream 2	5/22/87	<20.0	ppb
	Stream 3	5/22/87	<20.0	ppb
	Pond 1	5/22/87	<20.0	ppb
	Pond 2	5/22/87	<20.0	ppb
Benzo (a) - pyrene	Stream 1	7/1/86	<50.0	ppb
	Stream 2	7/1/86	<10.0	ppb
	Stream 3	7/1/86	<100.0	ppb
	Pond 3	7/1/86	<10.0	ppb
	Stream 1	8/26/86	<20.0	ppb
	Stream 2	8/26/86	<20.0	ppb
	Stream 2A	8/26/86	<20.0	ppb
	Stream 3	8/26/86	<20.0	ppb
	Stream 3A	8/26/86	<20.0	ppb
	Pond 1	8/26/86	<20.0	ppb
	Pond 2	8/26/86	<20.0	ppb
	Pond 4	8/26/86	<20.0	ppb
	Pond 5	8/26/86	<20.0	ppb
	Stream 1	5/6/87	<20.0	ppb
	Stream 2	5/6/87	<20.0	ppb
	Stream 3	5/6/87	<20.0	ppb
	Pond 1	5/6/87	<20.0	ppb
	Pond 2	5/6/87	<20.0	ppb

	Stream 1	5/22/87	<20.0	ppb
	Stream 2	5/22/87	<20.0	ppb
	Stream 3	5/22/87	<20.0	ppb
	Pond 1	5/22/87	<20.0	ppb
	Pond 2	5/22/87	<20.0	ppb
Benzo (a) - Anthracene	Stream 1	7/1/86	<50.0	ppb
	Stream 2	7/1/86	<10.0	ppb
	Stream 3	7/1/86	<100.0	ppb
	Pond 3	7/1/86	<10.0	ppb
	Stream 1	8/26/86	<20.0	ppb
	Stream 2	8/26/86	<20.0	ppb
	Stream 2A	8/26/86	<20.0	ppb
	Stream 3	8/26/86	<20.0	ppb
	Stream 3A	8/26/86	<20.0	ppb
	Pond 1	8/26/86	<20.0	ppb
	Pond 2	8/26/86	<20.0	ppb
	Pond 4	8/26/86	<20.0	ppb
	Pond 5	8/26/86	<20.0	ppb
	Stream 1	5/6/87	<20.0	ppb
	Stream 2	5/6/87	<20.0	ppb
	Stream 3	5/6/87	<20.0	ppb
	Pond 1	5/6/87	<20.0	ppb
	Pond 2	5/6/87	<20.0	ppb
	Stream 1	5/22/87	<20.0	ppb
	Stream 2	5/22/87	<20.0	ppb
	Stream 3	5/22/87	<20.0	ppb
	Pond 1	5/22/87	<20.0	ppb
	Pond 2	5/22/87	<20.0	ppb
Acenaphthalene	Stream 1	7/1/86	<50.0	ppb
	Stream 2	7/1/86	<10.0	ppb
	Stream 3	7/1/86	<100.0	ppb
	Pond 3	7/1/86	<10.0	ppb
	Stream 1	8/26/86	<20.0	ppb
	Stream 2	8/26/86	<20.0	ppb
	Stream 2A	8/26/86	<20.0	ppb
	Stream 3	8/26/86	<20.0	ppb
	Stream 3A	8/26/86	<20.0	ppb
	Pond 1	8/26/86	<20.0	ppb
	Pond 2	8/26/86	<20.0	ppb
	Pond 4	8/26/86	<20.0	ppb
	Pond 5	8/26/86	<20.0	ppb
	Stream 1	5/6/87	<20.0	ppb
	Stream 2	5/6/87	<20.0	ppb
	Stream 3	5/6/87	<20.0	ppb
	Pond 1	5/6/87	<20.0	ppb
	Pond 2	5/6/87	<20.0	ppb
	Stream 1	5/22/87	<20.0	ppb
	Stream 2	5/22/87	<20.0	ppb
	Stream 3	5/22/87	<20.0	ppb



	Pond 1	5/22/87	<20.0	ppb
	Pond 2	5/22/87	<20.0	ppb
p-Chloro-m-Cresol	Stream 1	5/6/87	<50.0	ppb
	Stream 2	5/6/87	<50.0	ppb
	Stream 3	5/6/87	<50.0	ppb
	Pond 1	5/6/87	<50.0	ppb
	Pond 2	5/6/87	<50.0	ppb
	Stream 1	5/22/87	<50.0	ppb
	Stream 2	5/22/87	<50.0	ppb
	Stream 3	5/22/87	<50.0	ppb
	Pond 1	5/22/87	<50.0	ppb
	Pond 2	5/22/87	<50.0	ppb
Creosote	Stream 1	5/6/87	<50.0	ppb
	Stream 2	5/6/87	<50.0	ppb
	Stream 3	5/6/87	<50.0	ppb
	Pond 1	5/6/87	<50.0	ppb
	Pond 2	5/6/87	<50.0	ppb
	Stream 1	5/22/87	<50.0	ppb
	Stream 2	5/22/87	<50.0	ppb
	Stream 3	5/22/87	<50.0	ppb
	Pond 1	5/22/87	<50.0	ppb
	Pond 2	5/22/87	<50.0	ppb
2-Methyl-Naphthalene	Stream 3	5/22/87	190.0	ppb
Anthracene	Stream 3	5/22/87	36.0	ppb
Acenaphthene	Stream 3	5/22/87	250.0	ppb
Fluorene	Stream 3	5/22/87	100.0	ppb
Toluene	Stream 1	5/6/87	<10.0	ppb
	Stream 2	5/6/87	<10.0	ppb
	Stream 3	5/6/87	12.0	ppb
	Pond 1	5/6/87	<10.0	ppb
	Pond 2	5/6/87	<10.0	ppb
	Stream 1	5/22/87	<10.0	ppb
	Stream 2	5/22/87	<10.0	ppb
	Stream 3	5/22/87	<10.0	ppb
	Pond 1	5/22/87	<10.0	ppb
	Pond 2	5/22/87	<10.0	ppb
Total Organic Carbon	Stream 1	7/22/87	2.6	ppm
	Stream 2	7/22/87	4.2	ppm
	Stream 3	7/22/87	25.0	ppm
	Pond 2	7/22/87	3.8	ppm
pH	Stream 2	11/9/81	6.2	
	Stream 1	8/26/86	7.05	
	Stream 2	8/26/86	7.05	
	Stream 2A	8/26/86	7.05	
	Stream 3	8/26/86	7.15	
	Stream 3A	8/26/86	7.15	
	Pond 1	8/26/86	7.10	
	Pond 2	8/26/86	7.15	
	Pond 4	8/26/86	7.15	

	Pond 5	8/26/86	7.15	
	Stream 1	5/6/87	6.2	
	Stream 2	5/6/87	6.4	
	Stream 3	5/6/87	6.2	
	Pond 1	5/6/87	6.2	
	Pond 2	5/6/87	6.2	
	Stream 1	5/22/87	6.0	
	Stream 2	5/22/87	5.95	
	Stream 3	5/22/87	6.55	
	Pond 1	5/22/87	6.45	
	Pond 2	5/22/87	6.30	
Specific Conductance	Stream 1	5/6/87	109.0	
	Stream 2	5/6/87	84.6	Umho/sq cm
	Stream 3	5/6/87	117.0	Umho/sq cm
	Pond 1	5/6/87	41.6	Umho/sq cm
	Pond 2	5/6/87	53.4	Umho/sq cm
	Stream 1	5/22/87	111.0	Umho/sq cm
	Stream 2	5/22/87	96.0	Umho/sq cm
	Stream 3	5/22/87	225.0	Umho/sq cm
	Pond 1	5/22/87	52.0	Umho/sq cm
	Pond 2	5/22/87	49.0	Umho/sq cm
	Stream 1	7/22/87	87.0	Umho/sq cm
	Stream 2	7/22/87	89.0	Umho/sq cm
	Stream 3	7/22/87	134.0	Umho/sq cm
	Pond 1	7/22/87	54.0	Umho/sq cm
	Pond 2	7/22/87	58.0	Umho/sq cm

Composite Stormwater Analyses	
Parameter	Results
Inorganic Analysis (all data in ppm)	
<u>Individual Parameters</u>	
Biochemical Oxygen Demand, 05 Day	<3.0
Chemical Oxygen Demand (Method 410.4)	ND
Nitrogen, Kjeldahl	0.87
Nitrogen, Nitrate	0.74
Nitrogen, Nitrite	0.004
Oils and Greases	413.1
Phosphorus, Total	ND
Solids, Total Suspended	3.0
Specific Conductivity	98
pH	6.10
Organic Analysis (all data in ppb)	
<i>GCMS for Volatile Organics-8240</i>	
Chloromethane	ND
Bromomethane	ND
Vinyl Chloride	ND
Chloroethane	ND
Methylene chloride	17
Acetone	ND
Carbon Disulfide	ND
1,1-Dichloroethylene	ND
1,1-Dichloroethane	ND
Total 1,2-dichloroethylene	ND
Chloroform	ND
1,2-Dichloroethane	ND
2-Butanone (MEK)	ND
1,1,1-Trichloroethane	ND
Carbon tetrachloride	ND
Vinyl acetate	ND
Bromodichloromethane	ND
1,1,2,2-Tetrachloroethane	ND
1,2-Dichloropropane	ND
Trans-1,3-dichloropropene	ND
Trichloroethylene	ND
Dibromochloromethane	ND
1,1,2-Trichloroethane	ND
Benzene	ND
Cis-1,3-dichloropropene	ND
2-Chloroethylvinyl ether	ND
Bromoform	ND
2-Hexanone	ND
4-Methyl-2-pentanone (MIBK)	ND
Tetrachloroethylene	ND

Toluene	ND
Chlorobenzene	ND
Ethyl Benzene	ND
Styrene	ND
Xylenes, (total)	ND
<i>Semivolatile Organics- 625AB</i>	
<i>Date Analyzed: 9/17/92; Date Extracted: 9/16/92</i>	
4-Chloro-3-methylphenol	ND
2-Chlorophenol	ND
2,4-Dichlorophenol	ND
2,4-Dimethylphenol	ND
2,4-Dinitrophenol	ND
2-Methyl-4,6-dinitrophenol	ND
2-Nitrophenol	ND
4-Nitrophenol	ND
Pentachlorophenol	ND
Phenol	ND
2,4,6-Trichlorophenol	ND
Acenaphthene	ND
Acenaphthylene	ND
Anthracene	ND
Benzo(a)anthracene	ND
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Benzo(g,h,i)perylene	ND
Bis(2-chloroethoxy)methane	ND
Bis(2-chloroethyl)ether	ND
Bis(2-chloroisopropyl) ether	ND
Bis(2-ethylhexyl)phthalate	ND
2-Chloronaphthalene	ND
4-Chlorophenyl phenyl ether	ND
Chrysene	ND
Dibenzo(a,h)anthracene	ND
1,2-Dichlorobenzene	ND
1,3-Dichlorobenzene	ND
1,4-Dichlorobenzene	ND
3,3 Dichlorobenzidine	ND
Diethyl phthalate	ND
Dimethyl phthalate	ND
Di-n-butyl phthalate	ND
2,4-Dinitrotoluene	ND
2,6-Dinitrotoluene	ND
Di-n-octylphthalate	ND
Flouranthene	ND
Flourene	ND
Hexachlorobenzene	ND
Hexachlorobutadiene	ND
Hexachloroethane	ND

Indeno(1,2,3-cd)pyrene	ND
Isophorone	ND
Naphthalene	ND
Nitrobenzene	ND
N-Nitrosodi-n-propylamine	ND
N-Nitrosodiphenylamine	ND
Phenanthrene	ND
Pyrene	ND
1,2,4-Trichlorobenzene	ND
Hexachlorocyclopentadiene	ND
N-Nitrosodi-n-methylamine	ND
<i>GCMs for Semivolatile Organics-8270</i>	
<i>Date Analyzed: 9/17/92; Date Extracted: 9/16/92</i>	
Phenol	ND
bis(2-Chloroethyl) ether	ND
2-Chlorophenol	ND
1,3-Dichlorobenzene	ND
1,4-Dichlorobenzene	ND
Benzyl, alcohol	ND
1,2-Dichlorobenzene	ND
2-Methylphenol (o-Cresol)	ND
bis(2-Chloroisopropyl) ether	ND
4- Methylphenol	ND
n-Nitrosodi-n-propylamine	ND
Hexachloroethane	ND
Nitrobenzene	ND
Isophorone	ND
2-Nitrophenol	ND
2,4-Dimethylphenol	ND
Benzoic acid	ND
bis(2-chloroethoxy)Methane	ND
2,4-Dichlorophenol	ND
1,2,4-Trichlorobenzene	ND
Naphthalene	ND
4-Chloroaniline	ND
Hexachlorobutadiene	ND
4-Chloro-3-methylphenol	ND
2-Methylnaphthalene	ND
Hexachlorocyclopentadiene	ND
2,4,6-Trichlorophenol	ND
2,4,5-Trichlorophenol	ND
2-Chloronaphthalene	ND
2-Nitroaniline	ND
Dimethyl phthalate	ND
Acenaphthylene	ND
3-Nitroaniline	ND
Acenaphthene	ND
2,4-Dinitrophenol	ND
4-Nitrophenol	ND

Dibenzofuran	ND
2,4-Dinitrotoluene	ND
2,6-Dinitrotoluene	ND
Diethyl phthalate	ND
4-Chlorophenyl phenyl ether	ND
Fluorene	ND
4-Nitroaniline	ND
2-Methyl-4,6-dinitrophenol	ND
N-Nitrosodiphenylamine	ND
4-Bromophenol phenyl ether	ND
Hexachlorobenzene	ND
Pentachlorophenol	ND
Phenanthrene	ND
Anthracene	ND
Di-n-butyl phthalate	ND
Flouranthene	ND
Pyrene	ND
Benzyl butyl phthalate	ND
3,3-Dichlorobenzidine	ND
Benzo(a)anthracene	ND
Bis(2-ethylhexyl)phthalate	ND
Chrysene	ND
Di-n-octylphthalate	ND
Benzo(b)fluoranthene	ND
Benzo(a)pyrene	ND
Indeno(1,2,3-cd)pyrene	ND
Dibenzo(a,h)anthracene	ND
Benzo(g,h,i)perylene	ND

First Flush Stormwater Quality Data	
Parameter	Results
Inorganic Analysis (all data in ppm)	
Individual Parameters	
Biochemical Oxygen Demand, 05 Day	<3.0
Chemical Oxygen Demand (Method 410.4)	ND
Nitrogen, Kjeldahl	0.87
Nitrogen, Nitrate	0.74
Nitrogen, Nitrite	0.004
Oils and Greases	413.1
Phosphorus, Total	ND
Solids, Total Suspended	3.0
Specific Conductivity	98
pH	6.10
Organic Analysis (all data in ppb)	
GCMs for Volatile Organics-8240 Date Analyzed: 9/15/92	
Chloromethane	ND
Bromomethane	ND
Vinyl Chloride	ND
Chloroethane	ND
Methylene chloride	17
Acetone	ND
Carbon Disulfide	ND
1,1-Dichloroethylene	ND
1,1-Dichloroethane	ND
Total 1,2-dichloroethylen	ND
Chloroform	ND
1,2-Dichloroethane	ND
2-Butanone (MEK)	ND
1,1,1-Trichloroethane	ND
Carbon tetrachloride	ND
Vinyl acetate	ND
Bromodichloromethane	ND
1,1,2,2-Tetrachloroethane	ND
1,2-Dichloropropane	ND
Trans-1,3-dichloropropene	ND
Trichloroethylene	ND
Dibromochloromethane	ND
1,1,2-Trichloroethane	ND
Benzene	ND
Cis-1,3-dichloropropene	ND
2-Chloroethylvinyl ether	ND
Bromoform	ND
2-Hexanone	ND
4-Methyl-2pentanone (MIBK)	ND

Tetrachloroethylene	ND
Toluene	ND
Chlorobenzene	ND
Ethyl Benzene	ND
Styrene	ND
Xylenes, (total)	ND
<i>Semivolatile Organics- 625AB</i>	
<i>Date Analyzed: 9/17/95; Date Extracted: 9/16/92</i>	
Date Analyzed	9/17/92
Date Extracted	9/16/92
4-Chloro-3-methylphenol	ND
2-Chlorophenol	ND
2,4-Dichlorophenol	ND
2,4-Dimethylphenol	ND
2,4-Dinitrophenol	ND
2-Methyl-4,6-dinitrophenol	ND
2-Nitrophenol	ND
4-Nitrophenol	ND
Pentachlorophenol	ND
Phenol	ND
2,4,6-Trichlorophenol	ND
Acenaphthene	ND
Acenaphthylene	ND
Anthracene	ND
Benzo(a)anthracene	ND
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Benzo(g,h,i)perylene	ND
Bis(2-chloroethoxy)methane	ND
Bis(2-chloroethyl)ether	ND
Bis(2-chloroisopropyl) ether	ND
Bis(2-ethylhexyl)phthalate	ND
2-Chloronaphthalene	ND
4-Chlorophenyl phenyl ether	ND
Chrysene	ND
Dibenzo(a,h)anthracene	ND
1,2-Dichlorobenzene	ND
1,3-Dichlorobenzene	ND
1,4-Dichlorobenzene	ND
3,3 Dichlorobenzidine	ND
Diethyl phthalate	ND
Dimethyl phthalate	ND
Di-n-butyl phthalate	ND
2,4-Dinitrotoluene	ND
2,6-Dinitrotoluene	ND
Di-n-octylphthalate	ND
Flouranthene	ND
Flourene	ND



Hexachlorobenzene	ND
Hexachlorobutadiene	ND
Hexachloroethane	ND
Indeno(1,2,3-cd)pyrene	ND
Isophorone	ND
Naphthalene	ND
Nitrobenzene	ND
N-Nitrosodi-n-propylamine	ND
N-Nitrosodiphenylamine	ND
Phenanthrene	ND
Pyrene	ND
1,2,4-Trichlorobenzene	ND
Hexachlorocyclopentadiene	ND
N-Nitrosodi-n-methylamine	ND
<i>GCMs for Semivolatile Organics-8270</i>	
<i>Date Analyzed: 9/17/92; Date Extracted: 9/16/92</i>	
Phenol	ND
bis(2-Chloroethyl) ether	ND
2-Chlorophenol	ND
1,3-Dichlorobenzene	ND
1,4-Dichlorobenzene	ND
Benzyl, alcohol	ND
1,2-Dichlorobenzene	ND
2-Methylphenol (o-Cresol)	ND
bis(2-Chloroisopropyl) ether	ND
4- Methylphenol	ND
n-Nitrosodi-n-propylamine	ND
Hexachloroethane	ND
Nitrobenzene	ND
Isophorone	ND
2-Nitrophenol	ND
2,4-Dimethylphenol	ND
Benzoic acid	ND
bis(2-chloroethoxy)Methane	ND
2,4-Dichlorophenol	ND
1,2,4-Trichlorobenzene	ND
Naphthalene	ND
4-Chloroaniline	ND
Hexachlorobutadiene	ND
4-Chloro-3-methylphenol	ND
2-Methylnaphthalene	ND
Hexachlorocyclopentadiene	ND
2,4,6-Trichlorophenol	ND
2,4,5-Trichlorophenol	ND
2-Chloronaphthalene	ND
2-Nitroaniline	ND
Dimethyl phthalate	ND
Acenaphthylene	ND
3-Nitroaniline	ND

Acenaphthene	ND
2,4-Dinitrophenol	ND
4-Nitrophenol	ND
Dibenzofuran	ND
2,4-Dinitrotoluene	ND
2,6-Dinitrotoluene	ND
Diethyl phthalate	ND
4-Chlorophenyl phenyl ether	ND
Fluorene	ND
4-Nitroaniline	ND
2-Methyl-4,6-dinitrophenol	ND
N-Nitrosodiphenylamine	ND
4-Bromophenol phenyl ether	ND
Hexachlorobenzene	ND
Pentachlorophenol	ND
Phenanthrene	ND
Anthracene	ND
Di-n-butyl phthalate	ND
Flouranthene	ND
Pyrene	ND
Benzyl butyl phthalate	ND
3,3-Dichlorobenzidine	ND
Benzo(a)anthracene	ND
Bis(2-ethylhexyl)phthalate	ND
Chrysene	ND
Di-n-octylphthalate	ND
Benzo(b)fluoranthene	ND
Benzo(a)pyrene	ND
Indeno(1,2,3-cd)pyrene	ND
Dibenzo(a,h)anthracene	ND
Benzo(g,h,i)perylene	ND

**APPENDIX C**  
**Biofeasibility Study Data**



**BIOREMEDIATION RESEARCH, LTD.**

ROUTE 2, BOX 180-C

PINNACLE, NC 27043

PHONE (910) 325-2318

**Study of the Bioremediation Potential**

**of a**

**Creosote Site**

**Prepared for**

**Holcomb Creosote**

**and**

**GeoScience & Technology, P.A.**

**June 1996**

This study was designed to answer the following:

- 1] Are there microbes present within the soil column at the contaminated site that have developed resistance to, and are at the same time able to metabolize, the creosote contaminant?
- 2] Can these microbes be purified and characterized on artificial media?
- 3] Are there sufficient nutrients present at the site to support passive remediation, or are nutrient additions and/or air sparging necessary to support growth?

The study was begun by accepting a 5 gallon glass carboy of groundwater and 9 soil cores from the areas of contamination at Holcomb Creosote.

The water was cooled, allowed to settle, filtered, and sterilized by autoclaving to prevent microbial growth and preserve the nutrients and trace elements present in the groundwater.

The soil cores were entered as lab samples and numbered in the following fashion.

Table I: Strain/Sample Number Crossed to Core Sample.

868	GP6-14
869	GP6-22
870	GP6-24
871	GPP-8
872	GPP-10
873	GPP-22
874	GP16-14
875	GP16-22
876	GP16-24

Each core was split and approximately 1 gram of soil was removed aseptically and placed in a flask containing 50 milliliters of Basic Media (BM), and 0.2 milliliters of creosote obtained from Holcomb Creosote. The Basic Media consisted of:

Ammonium Sulfate	500 mg
Magnesium Sulfate	100 mg
Ferric Chloride	0.5 mg
Manganous Sulfate	10 mg
1 M Phosphate Buffer pH 7.2	25 ml
Tap Water (Trace Elements)	100 ml
Deionized Water	875 ml

The flasks were shaken on an orbital shaker at 150 RPM for 4 days in the presence of creosote to allow the resistant strains that metabolize creosote constituents to express themselves and grow. The flasks were shaken at 25°C for 4 days and checked for growth. After 4 days each flask was streaked onto a nutrient agar (NA) and a tryptic soy agar (TSA) plate and incubated at 25°C.

Table II: Growth Results from Original Inoculations.

+ Some colonies present;  
 ++ Moderate growth with some merging of colonies;  
 +++ Heavy growth

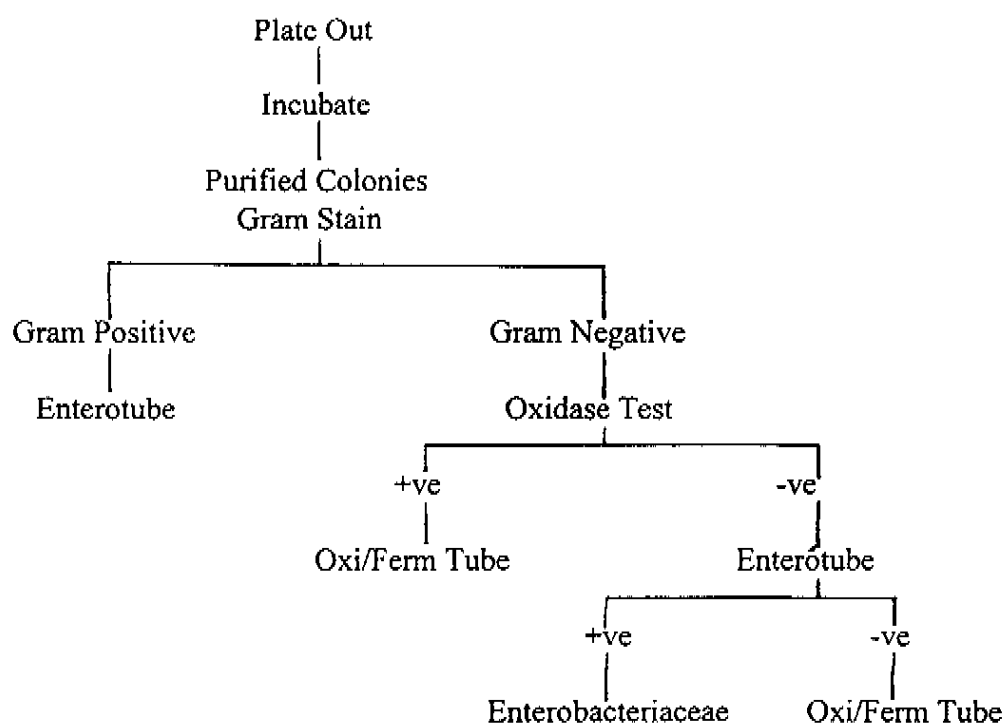
Strain	NA	TSA
868	+++	+++
869	++	+++
870	++	++
871	+	++
872	++	++
873	No growth	No growth
874	+++	+++
875	+++	+++
876	+++	+++

Samples from individual, representative colonies were transferred to new plates for growth and identification, while the remaining growth was suspended in sterile BM and transferred to new flasks of sterile BM + 0.2 ml creosote. These flasks were shaken and allowed to grow for several days in order to obtain pure cultures metabolizing creosote in artificial media.

These flasks supplied the stock cultures utilized for the final growth study comparing groundwater, tapwater + 2L nutrients, and BM.

The colonies from the second set of plates were subjected to an identification scheme from Roche Diagnostic Systems of Hoffmann La Roche, Inc., Gram stains were done using BBL gram stain solutions and were verified with Fisher Gram Check slides.

The identification scheme was as follows:



Results of the identification exercise were as follows:

Table III: Identification of Remediating Strains.

868	<i>Enterobacter sp.</i>
869	<i>Pseudomonas sp.</i> + <i>Micrococcus sp.</i>
870	<i>Bacillus sp.</i>
871	<i>Acinetobacter sp.</i>
872	<i>Enterobacter sp.</i>
873	No Growth
874	<i>Serratia sp.</i>
875	<i>Enterobacter sp.</i>
876	<i>Enterobacter sp.</i>

Soil samples from each core were subjected to chemical analysis for pH and nutrients and are summarized as follows:

Table IV: Soil pH/NPK (Agricultural Methods)

Sample	pH	Ammonia N	Nitrate N	Phosphorus	Potassium(Potash)
868	5.11	< 0.1 ppm	< 0.02 ppm	< 1.0 ppm	< 0.1 ppm
869	5.87	< 0.1	0.03	< 1.0	0.3
870	5.91	< 0.1	< 0.02	< 1.0	< 0.1
871	5.41	< 0.1	< 0.02	< 1.0	< 0.1
872	5.93	< 0.1	< 0.02	1.1	0.4
873	4.68	< 0.1	< 0.02	< 1.0	< 0.1
874	6.21	< 0.1	0.05	1.5	0.8
875	5.82	< 0.1	< 0.02	< 1.0	< 0.1
876	5.77	< 0.1	< 0.02	< 1.0	< 0.1

An earlier set of samples collected from each monitoring well into BOD bottles were analyzed for dissolved oxygen utilizing the modified Winkler iodometric method which resulted in the following levels:(Also reported separately 6/4/1996)

Table V: Oxygen Levels in Monitoring Wells.

MW-1	6.6 ppm
MW-2	< 0.05
MW-3	< 0.05
MW-4	4.3
MW-5	3.4
MW-6	< 0.05
MW-7	< 0.05
MW-8	4.9
MW-9	< 0.05
MW-10	0.7
MW-11	6.2
MW-12	5.9
MW-14	4.9
MW-15	0.3
MW-16	3.4

For the final portion of the study the remediating strains purified earlier were tested for growth with sterile groundwater, sterile tap water + 2L nutrients, and BM. The tapwater was prepared by adding potassium nitrate to 10 mg/L nitrate, and sodium sulfate to 250 mg/L sulfate as prescribed in the North Carolina 2L standards for groundwater.



Growing cultures, in BM + creosote, of each strain were filtered through a 0.45 micron membrane and resuspended in sterile 0.9 % NaCl. Ten milliliters were then transferred with a sterile pipette into each of three flasks containing;

50 ml sterile Holcomb groundwater + 0.2 ml creosote (GW)

50 ml sterile tapwater + 2L nutrients + 0.2 ml creosote (2L)

50 ml sterile BM + 0.2 ml creosote (BM)

These flasks were shaken at 150 rpm on an orbital shaker at 25°C. Samples were removed daily with a sterile pasture pipette, placed in an optical glass cuvette and read for optical density in a spectrophotometer using visible light at a 450 millimicron wavelength. Readings were taken at the same time on 6 successive days and recorded.

Media	Strain	Optical Density on Each Day					
		I	II	III	IV	V	VI
GW	868	.133	.130	.129	.147	.151	.163
	869	.239	.235	.237	.243	.240	.251
	870	.126	.124	.122	.151	.155	.161
	871	.106	.103	.104	.115	.130	.152
	872	.115	.119	.125	.127	.142	.167
	874	.162	.156	.159	.179	.181	.201
	875	.238	.235	.240	.242	.259	.272
	876	.170	.165	.163	.172	.179	.181
2L	868	.160	.157	.158	.168	.179	.189
	869	.228	.226	.224	.227	.231	.252
	870	.110	.113	.117	.135	.141	.173
	871	.105	.101	.103	.107	.117	.131
	872	.129	.123	.127	.129	.141	.163
	874	.138	.136	.139	.142	.152	.167
	875	.240	.221	.222	.226	.236	.242
	876	.159	.152	.153	.158	.166	.173
BM	868	.182	.176	.178	.193	.207	.247
	869	.231	.225	.227	.230	.251	.301
	870	.138	.133	.134	.150	.173	.202
	871	.108	.099	.095	.108	.123	.174
	872	.150	.145	.147	.146	.167	.193
	874	.182	.178	.179	.207	.244	.283
	875	.252	.246	.249	.250	.278	.307
	876	.179	.174	.175	.176	.199	.243
		Lag Time			Difference for Calculations		

Because of leaching of nutrients from the microbial cells during filtration there was a lag time after resuspension until growth began, therefore the optical density differences were calculated utilizing readings from day III to day VI. These are summarized as follows:

Table VI: Average Increase in OD Units/Day; Day III-----> Day VI.

Strain	GW	2L	BM
868	.0113	.0103	.0230
869	.0047	.0093	.0247
870	.0130	.0187	.0227
871	.0160	.0093	.0263
872	.0140	.0120	.0153
874	.0140	.0093	.0347
875	.0107	.0067	.0193
876	.0060	.0067	.0227

The results of these calculations were also summarized in the attached figure.

Results of this study demonstrate that in 8 of 9 soil cores from the site there is at least one strain which is able to tolerate all of the creosote constituents and metabolizes some portion of the creosote constituents.

Since these strains were purified directly from the contaminated cores it follows that there must be sufficient nutrients present to support growth at some level. The methodology used for the NPK testing only reports levels of free nutrients, while the microbes have mechanisms for chemically removing bound nutrients.

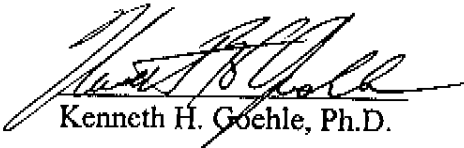
The pH seems to be slightly acidic, but only low enough to interfere with growth in one core, (873), which is the only core that did not demonstrate the presence of remediating microbes.

Although dissolved oxygen was at or near saturation levels in the test flasks and therefore was not limiting, there seems to be enough dissolved oxygen to support remediation in all of the wells except those from the lagoon area (2,3,6,7, and 9). These wells will most likely require sparging to add oxygen so that remediation may occur.

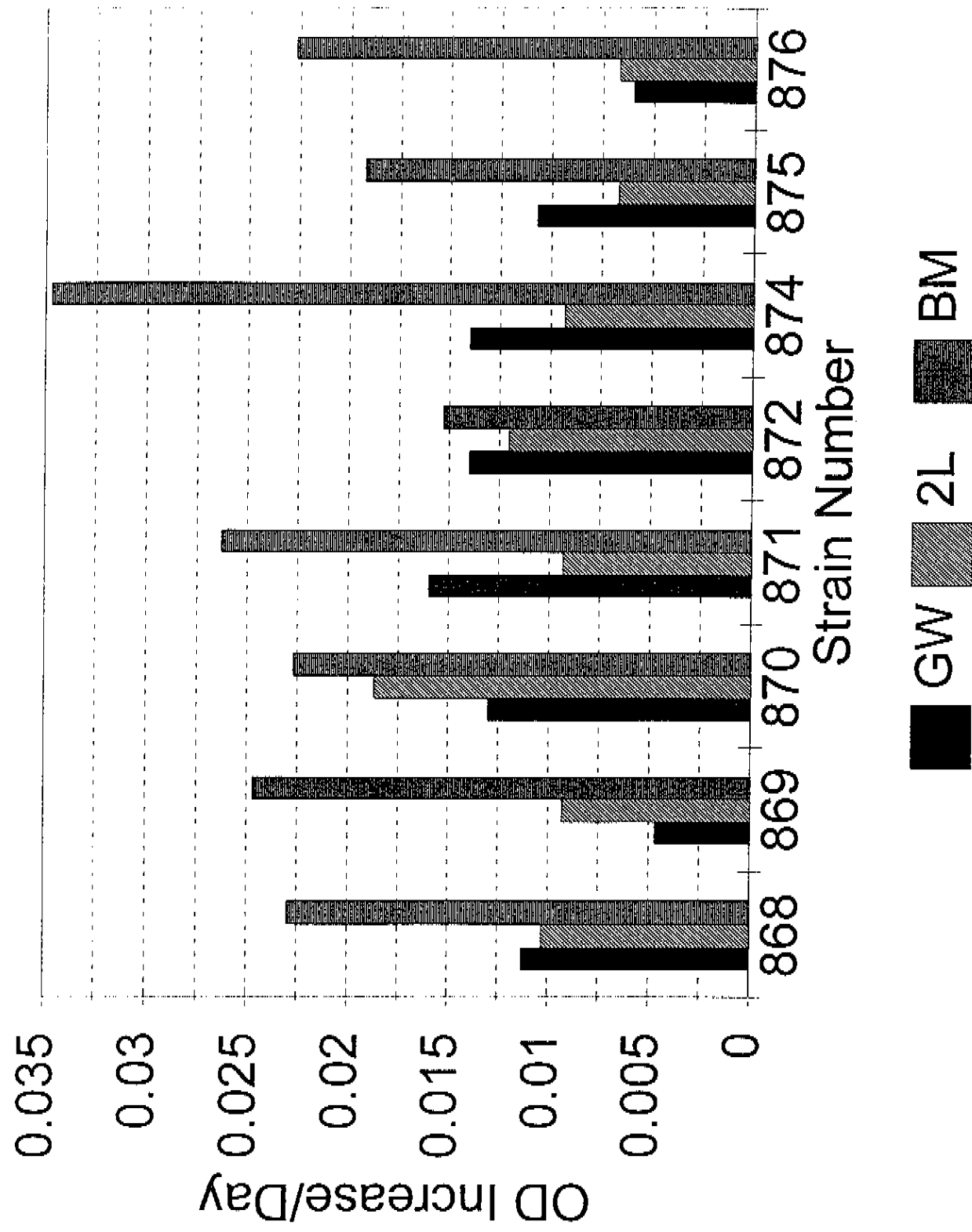
The water tests were most telling, in that all of the purified microbe strains demonstrated growth in each of the media mixtures. As expected, the best rates of growth were found in BM flasks where nutrients were non-limiting. It is interesting to note, however, that in 5 of the 8 strains the growth was better on the sterilized groundwater than on the tapwater + 2L nutrients. This may have been due to the groundwater containing very low levels of some trace elements absent in the tap water and required for growth. This would occur because the strains of bacteria evolved within an environment containing this particular groundwater and require the particular mix of nutrients found therein.

It can be concluded from the results of this study that:

- 1) Strains of bacteria have evolved within the contaminated soil profile that are capable of tolerating significant levels of creosote contamination, and are capable of metabolizing some portion of the mixture of compounds contained in the creosote.
- 2) These microbes are common fastidious organisms that can be cultured and identified by standard microbiological methodologies.
- 3) There are sufficient nutrients present to support the passive remediation of the creosote contaminants over some period of time, and that, with sparging of some wells, the site is probably capable of significant bioremediation.



Kenneth H. Goehle, Ph.D.



## Page 1 of 1

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 Pinnacle, NC 27043  
 Telephone (910) 325-2318

Client Name: Geosa  
 Project: Holcomb  
 Attention: Barr  
 Telephone: 1

Please indicate the number of each size of sample container and any preservatives which were used.  
 e.g., 2-HNO3 indicates 2 containers w/ nitric acid.

Sample ID	Date	Time	Matrix	Please indicate the number of each size of sample container and any preservatives which were used.					Suspected Contaminant	Level			Analysis Requested	Lab use only Lab ID	
				40 ml	120 ml	250 ml	500 ml	950 ml		other	0	Low			Med
GP6-14	5/18	11:24	Soil												868
GP6-22		11:30													869
GP6-24		11:45													870
GP6-8		12:10													871
GP6-10		12:20													872
GP6-22		12:40													873
GP6-14	11:24	9:36													874
GP6-22	11:30	10:24													875
GP6-24		1:30													876
Relinquished by: (Sig.)	Date	Time	Collector	Received by: (Sig.)					Date	Time	Remarks:				
Relinquished by: (Sig.)	Date	Time		Received by: (Sig.)					Date	Time					
Relinquished by: (Sig.)	Date	Time		Received by: (Sig.)					Date	Time					

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