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# UNION BLEACHERY SITE

## REMEDIAL INVESTIGATION/FEASIBILITY STUDY
## REMEDIAL INVESTIGATION REPORT
## GREENVILLE, SOUTH CAROLINA

July 25, 1991

Prepared for:
American Fast Print, Ltd.

# AMERICAN FAST PRINT LIMITED



REMEDIAL INVESTIGATION/FEASIBILITY STUDY
REMEDIAL INVESTIGATION REPORT

UNION BLEACHERY SITE
GREENVILLE, SOUTH CAROLINA

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718 Lowndes Hill Road
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Project No. 7551-000
July 25, 1991

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# 1 PRELIMINARY INVESTIGATION

## 1.1 INTRODUCTION AND PURPOSE

American Fast Print Limited (AFP) authorized Rogers & Callcott, Engineers, Inc. (R&C) to perform a Preliminary Investigation at the Union Bleachery site located at 3335 Buncombe Road, Greenville, South Carolina, in 1987. In 1989, GeoTrans, Inc. (GeoTrans) was authorized to assist R&C in completing the Preliminary Investigation. AFP authorized GeoTrans and R&C to perform a Remedial Investigation (RI). All work for this RI was completed during the period August 1990 to June 1991. All RI activities were based on regulations and procedures for implementing response actions set forth in the National Oil and Hazardous Substance Contingency Plan (NCP) as amended.

The Preliminary Investigation that began in 1987 produced an Interim Assessment Report (GeoTrans, 1989). Because the conceptual understanding of several areas at the site was poor, further Preliminary Investigation was undertaken as an interim scoping task prior to developing the work plan. These data were used to develop the Remedial Investigation/Feasibility Study Work Plan (GeoTrans, 1990a). Based on initial stages of the Remedial Investigation and in light of the complexity of the site, it was determined that additional data were required to determine the extent of contamination. Therefore, Work Plan addenda to the RI were developed (GeoTrans, 1990b, 1991a).

The objectives of the Remedial Investigation were to:

- Determine the nature and extent of contamination; and
- Identify areas that represent sources of contamination.

A field effort was initiated to address these objectives, and included: the installation of monitor wells and soil borings, collection of sludge, surface soil, split-spoon, and groundwater samples, and performance of a Rapid Bioassessment.

This Remedial Investigation Report provides a summary of Union Bleachery site data that are available and describes the fate and transport of the contaminants found to date. This information includes data from prior site investigations, which began in 1981, and from the conductance of the Union Bleachery site Remedial Investigation (RI), which commenced in the summer of 1990.

This report provides site characterization information that will be referenced for evaluating the development and screening of remedial alternatives. The Baseline Risk Assessment will be issued as a separate report or included with the Feasibility Study. This report is divided into four chapters. Chapter 1 provides background information and presents data collected as part of the Preliminary Investigation (pre-RI data). At the end of Chapter 1, operable units are defined, which are groupings of discrete areas or media that help expedite field investigation and remedial actions. Chapter 2 describes the field investigations performed at each operable unit at the Union Bleachery site. Chapter 3 presents the physical and chemical results of the RI field investigations. In general, this only includes the data collected between August 1990 to June 1991. Finally, contaminant fate and transport for each operable unit are discussed in Chapter 4.

## 1.2 DESCRIPTION OF THE UNION BLEACHERY SITE

### 1.2.1 Background/History

The Union Bleachery site is located in Greenville County, South Carolina, approximately two and one-half (2.5) miles northwest of the City of Greenville as shown in Figure 1. The plant was originally constructed in 1903 and expanded on several occasions. It contains approximately four hundred thousand (400,000) square feet; the first floor contains the main production area, the second floor contains the dye and chemical mixing areas and inspection and grading areas for completed material. The Basement area was constructed as a collection area for wastewaters.

The plant was constructed as a textile bleaching and finishing operation by the Arrington family. The facility was sold to the Aspinook Corporation in 1947 and then to Cone Mills Corporation (Cone)

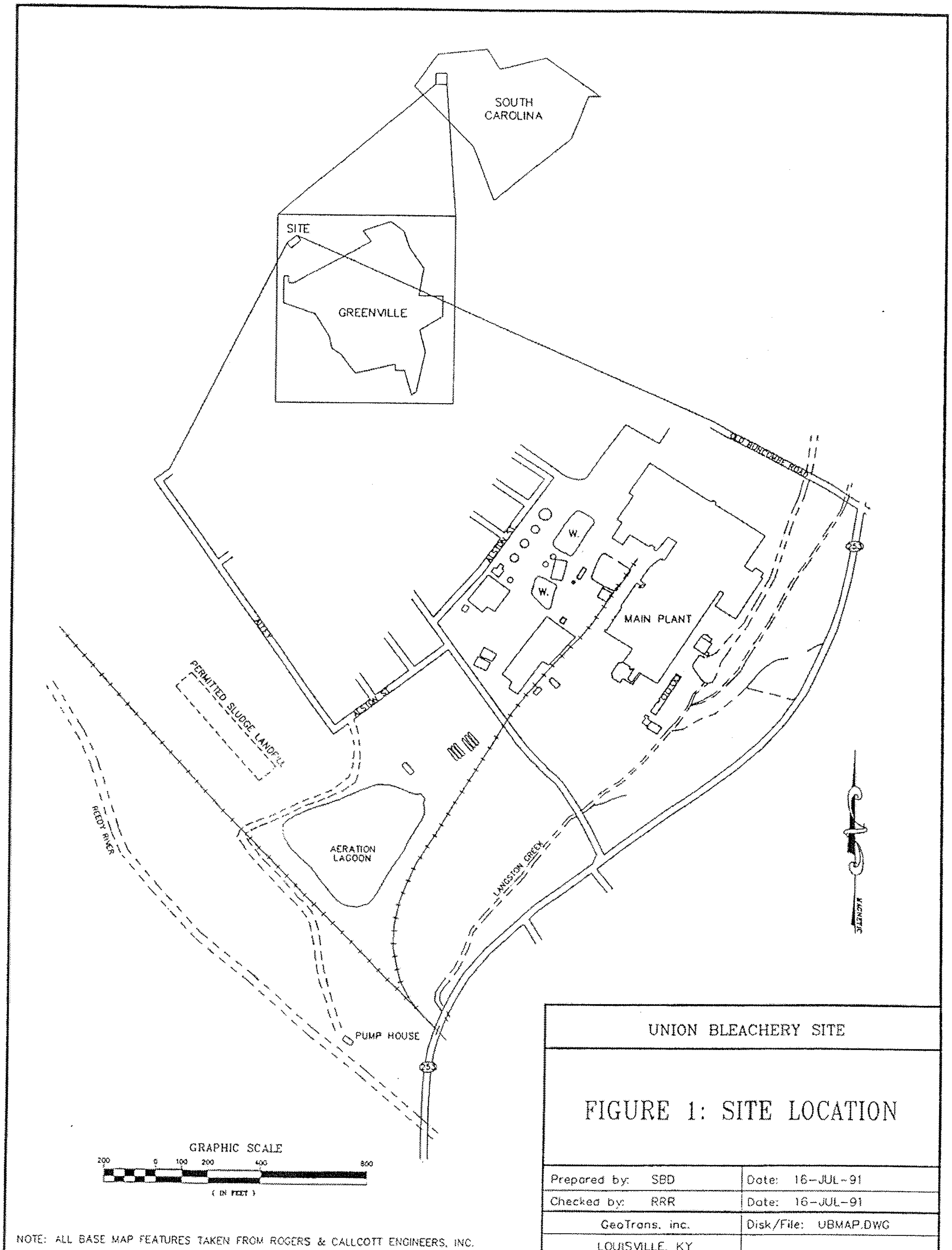


FIGURE 1: SITE LOCATION

in 1952. Cone owned and operated the facility for thirty-two (32) years. It prepared grey goods and dyed these materials as well as corduroy, denims and cotton-synthetic blends. American Fast Print (AFP) purchased the facility in May of 1984 and currently owns and operates the facility as U.S. Finishing.

Preparation of grey goods was accomplished originally by batch-type boil out and kiering processes but these were later replaced by continuous bleaching and mercerizing operations. Dyeing was originally accomplished by batch-type jiggs. The number of jiggs were reduced as they were replaced by continuous dye ranges. Some jigg dying continued for small lots through the early 1980s. Three dye ranges were present in 1952 when Cone purchased the property. These were expanded to six continuous ranges in the early 1970s plus a pigment range was added in approximately 1976. In approximately 1979 or 1980 the number of dye ranges was decreased from six to four. In the 1960s mechanical, thermal and chemical finishing operations were also added.

Because of the variety of goods processed at this plant, various types of dyes, including vats, sulphurs, reactives, dispersivies and naphthals were used. Large quantities of sodium dichromate were used as the oxidizing agent for sulphur dyes and vat-type dyes which, for many years, represented the majority of the dyes used by Union Bleachery. Zinc, copper and dyes containing other metals were also used in the dyeing and finishing process. Cone ceased to use sodium dichromate and zinc as oxidizing agents in the late 1970s. As industry practices changed in response to environmental requirements, the presence of metals in dyes was reduced to small amounts by the late 1970s. AFP reports it has never used sodium dichromate as an oxidizing agent. AFP reports it has not discharged dyes or chemicals containing metals except in trace amounts. Historically, both the dye waste and the oxidizing materials were wasted into the Basement area. Most of the wastewaters were discharged into the Basement onto bare ground and in other areas into sumps and then migrated via a series of ditches to a main ditch that then flowed directly into Langston Creek. Before the 1980s, the pipes and ditches in the Basement area would become plugged on a regular basis because of lint and cloth scraps that would be discharged with the wastewater. Water would collect to depths of 1-5 feet on a weekly basis. Work crews would be dispatched to clean the stoppages to allow this wastewater to continue its flow to Langston Creek. Langston Creek itself also flooded on a periodic basis and immersed portions of the Basement area. Chemicals were stored in the Basement until a flood in 1974 inundated the Basement and flooded many of these chemical storage areas.

Surface water runoff from the west side of the plant created during rainfall events flowed through the Basement and then discharged through the ditch to Langston Creek. The stormwater continued to flow through the Basement area, but was discharged into the Aeration Lagoon after it was constructed in 1965. In 1989, AFP diverted the stormwater from the Basement and piped it to the drainage system connected to the Aeration Lagoon.

In connection with AFP's acquisition of the Union Bleachery site in 1984, AFP obtained representations and undertakings by Cone as to the environmental condition of the Facility. Cone acknowledged full responsibility for the cleanup and restoration of the aquifer near Langston Creek and clean up and removal of sludge and chemical substances. Cone failed to identify any environmental problems at the site other than chromium in the groundwater near Langston Creek.

Why didn't AFP perform a pre-buy assessment of the site?

1.2.2 Physical Setting/Environment

1.2.2.1 Topography/General Information

The Union Bleachery site encompasses approximately 259 acres and is located approximately 2.5 miles northwest of Greenville, South Carolina. The approximate center of the site lies at latitude 34° 53' 02" north and longitude 82° 25' 37" west.

As shown in Figure 1, the site is bounded on the north by Old Buncombe Road and on the east by Highway 253. The site is L-shaped and bounded on the west by a residential area originally constructed to house Union Bleachery employees and other residential areas. The site is bounded on the south by the Reedy River. Langston Creek flows from the north to south through the property and then joins the Reedy River.

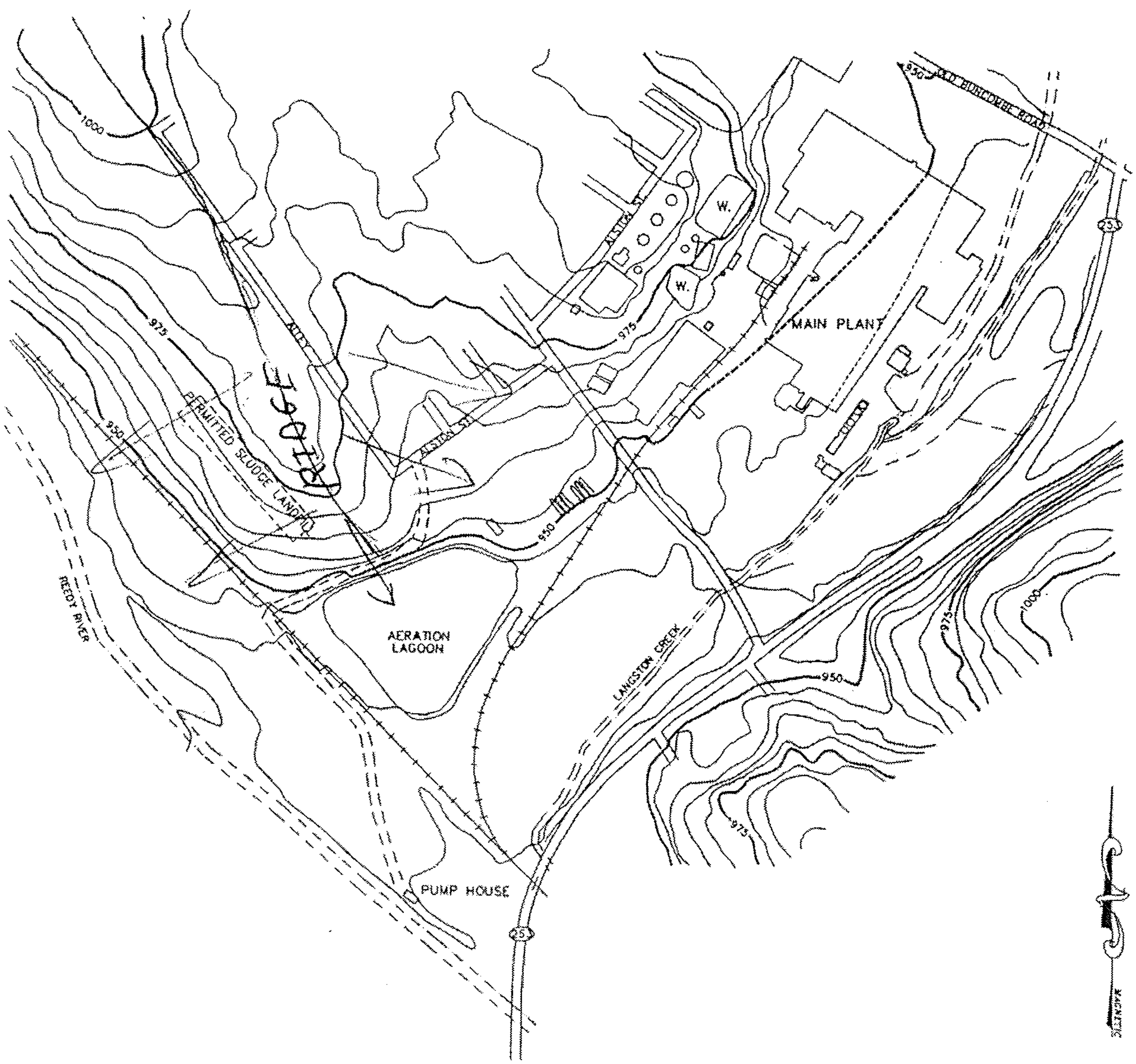
Figure 2 illustrates the topography of the site. In the area of the main plant, the property slopes from west to east towards Langston Creek. There is approximately a 40-foot elevation change from the western boundary of the plant over the approximate 800 linear feet to the creek. At the Aeration Lagoon, the property slopes generally in a southeast direction toward the confluence of Langston Creek and the Reedy River. To the northwest of the Aeration Lagoon, a topographic divide occurs. The land slopes to the southeast with a 30-foot elevation change over approximately 400 linear feet. Along the ridge which borders the edge of the closest residential area, the slope changes to a southwest direction. A 40-foot elevation change occurs over the approximate 800 feet of land surface from the edge of this residential area to the Reedy River.

1.2.2.2 Geology

The Union Bleachery site is located within the Piedmont geologic province. Bedrock in this province is characterized by high-grade metamorphic and igneous rock. Drilling logs indicate that the granite gneiss bedrock is overlain by weathered bedrock (saprolite) and poorly sorted alluvium (Figure 3). In some places, the alluvium is overlain by as much as 8 feet of fill (S&ME, 1985).

The alluvium thickens easterly from the main mill site to the floodplain of Langston Creek. The alluvium varies from 17-20 feet thick to being absent west of the main mill and can be characterized as a mixture of reddish brown to brown sandy clayey silt and gray to dark-gray very micaceous silt.

For the thirteen wells present in 1985 a fairly consistent saprolite thickness of 10-20 feet had been encountered. The lithology of the saprolite varies with the depth of weathering. The lower saprolite (LS) is characterized as a hard to very hard micaceous fine to coarse sandy silt. At some locations this silt contains abundant quartz fragments. Upper portions of the saprolite consist of very




GRAPHIC SCALE

200 0 100 200 400 800

( IN FEET )

CONTOUR INTERVAL = 5 FEET

NOTE: ALL BASE MAP FEATURES TAKEN FROM ROGERS & CALLCOTT ENGINEERS, INC.

| | |
|---|---|
| UNION BLEACHERY SITE | |
| FIGURE 2: SITE TOPOGRAPHY | |
| Prepared by: SBD | Date: 16-JUL-91 |
| Checked by: RRR | Date: 16-JUL-91 |
| GeoTrans, inc. | Disk/File: UBMAP.DWG |
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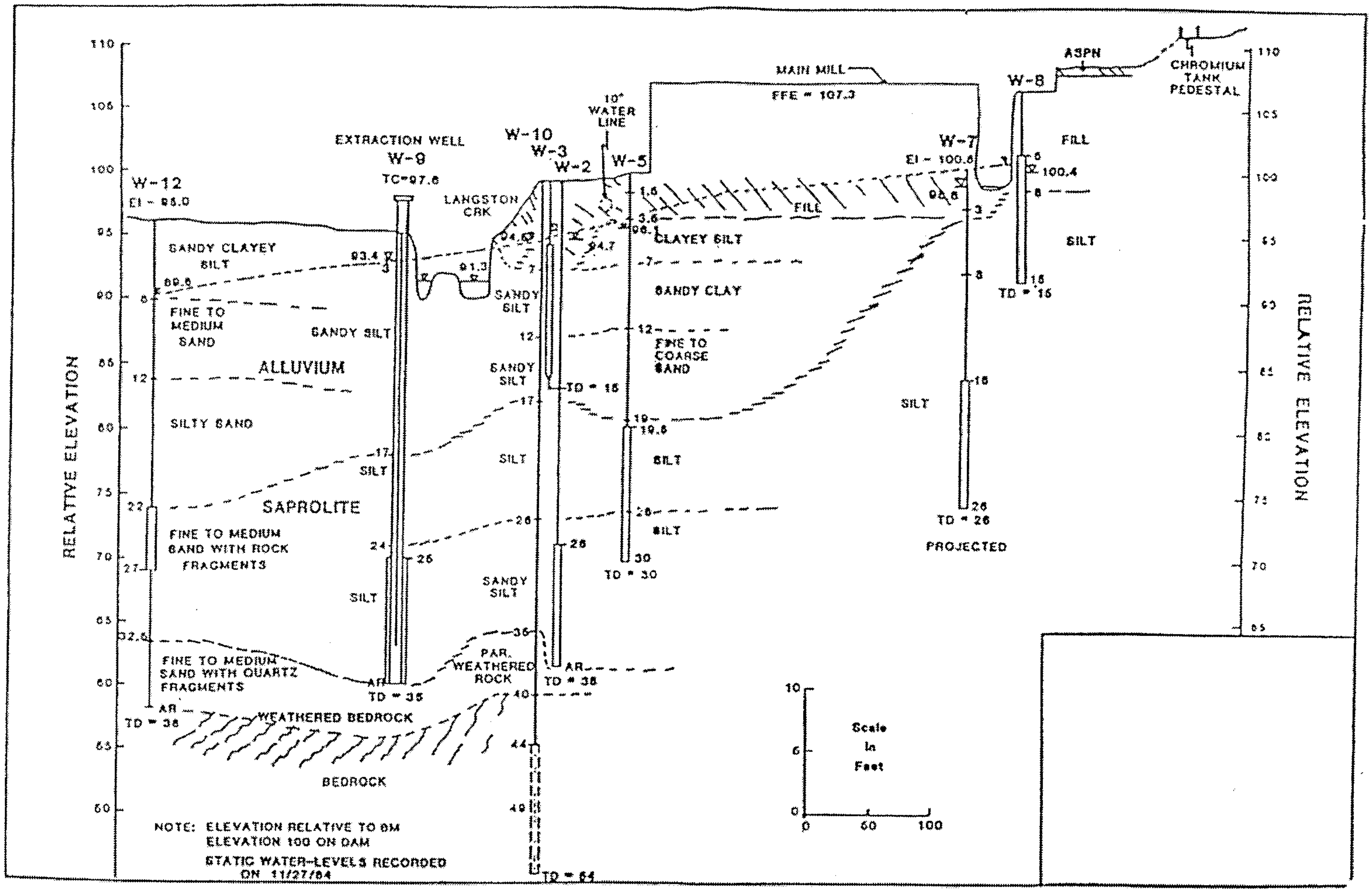



Figure 3: Hydrogeologic cross-section of the Union Bleachery site (from S&ME, 1985).

loose to loose, very silty fine to medium sand, which is texturally similar to the overlying alluvium.

The bedrock beneath the site consists of gray granite gneiss. Cores from the upper 10-15 feet of the bedrock indicate that the gneiss is fractured and weathered.

1.2.2.3 Hydrogeology

Groundwater at the Union Bleachery site is classified under the South Carolina Pollution Control Act as Class GB. That is, the groundwater system in this area contains a sufficient quantity of groundwater to supply a public water system and contains water with fewer than 10,000 milligrams per liter (mg/l) total dissolved solids (TDS). For Class GB waters, the state primary drinking water standards apply.

Groundwater at the Union Bleachery site is recharged from topographically higher elevations and locally by direct infiltration of rainfall. Based on water levels in wells at the Union Bleachery site, groundwater generally flows downward to lower units or laterally toward either Langston Creek or Reedy River. Upward flow occurs at and near Langston Creek. Groundwater in the alluvium is under water-table conditions (unconfined). Groundwater in lower units is generally in a confined state, that is, water levels in wells within these units rise higher than the top of the unit.

Law Engineering Testing Company (LAW) (1982) reported estimated hydraulic conductivities of $2 \times 10^{-3}$ cm/sec for the saprolite and $8 \times 10^{-4}$ cm/sec for the alluvial soils at the site. These measurements were based on single hole permeability tests. LAW also noted that W-9, which is located adjacent to Langston Creek, was artesian when it was first installed.

An aquifer test was performed by S&ME Consultants (1985). The objectives of this test were to:

- Determine hydraulic parameters of the saprolite,
- Evaluate the specific capacity and relative hydraulic efficiency of the extraction well, and

- Use the data developed in estimating the radius of influence of the extraction well.

From this pump test S&ME Consultants, among other things, concluded that:

- The saprolite is an anisotropic semiconfined low permeability unit with an average hydraulic conductivity of 10 ft/day ($3.5 \times 10^{-3}$ cm/sec). Hydraulic conductivity, however, varies widely throughout the site. The storage coefficient is estimated to be 0.01.
- The bedrock aquifer is in hydraulic connection with the saprolite.
- There is a relatively poor hydraulic connection between the saprolite and the alluvium.

1.2.2.4 Ecology

No plant or animal species as defined and protected by the Endangered Species Act of 1973 as amended, 16 U.S.C. 1531 et seq., have been found on or near the Union Bleachery property. The majority of the property is either maintained for industrial use or is maintained as open grassed areas. The Reedy River Floodplain has not been used since its use as a solid waste landfill reportedly as late as the 1970s. This area is densely vegetated by indigenous grasses, shrubs and scrub trees. Indigenous birds and small game animals inhabit this area.

Langston Creek is a small tributary to the Reedy River and drains a watershed approximately four square miles in size. It flows in a southerly direction through the property and then discharges into the Reedy River. The main branch of the creek was dammed in 1903 when Union Bleachery was originally constructed to provide a source of process water.

A stream study conducted by South Carolina Department of Health and Environmental Control (SC DHEC) in 1981 revealed a high concentration of hexavalent chromium in Langston Creek. Cone conducted a macroinvertebrate assessment of the creek in 1985. The macroinvertebrate population was reduced by 75% from an upstream sampling station to a sampling station impacted by chromium-contaminated groundwater from the Union Bleachery site and the number of species was reduced by 35% between these two stations. The results of this study show that the chromium remediation conducted by Cone from 1982 through 1985 had not yet been effective in protecting the water quality in Langston Creek. Bream and Hornyhead fish taken and analyzed by Cone in 1985 revealed chromium concentrations in their organs and intestines.

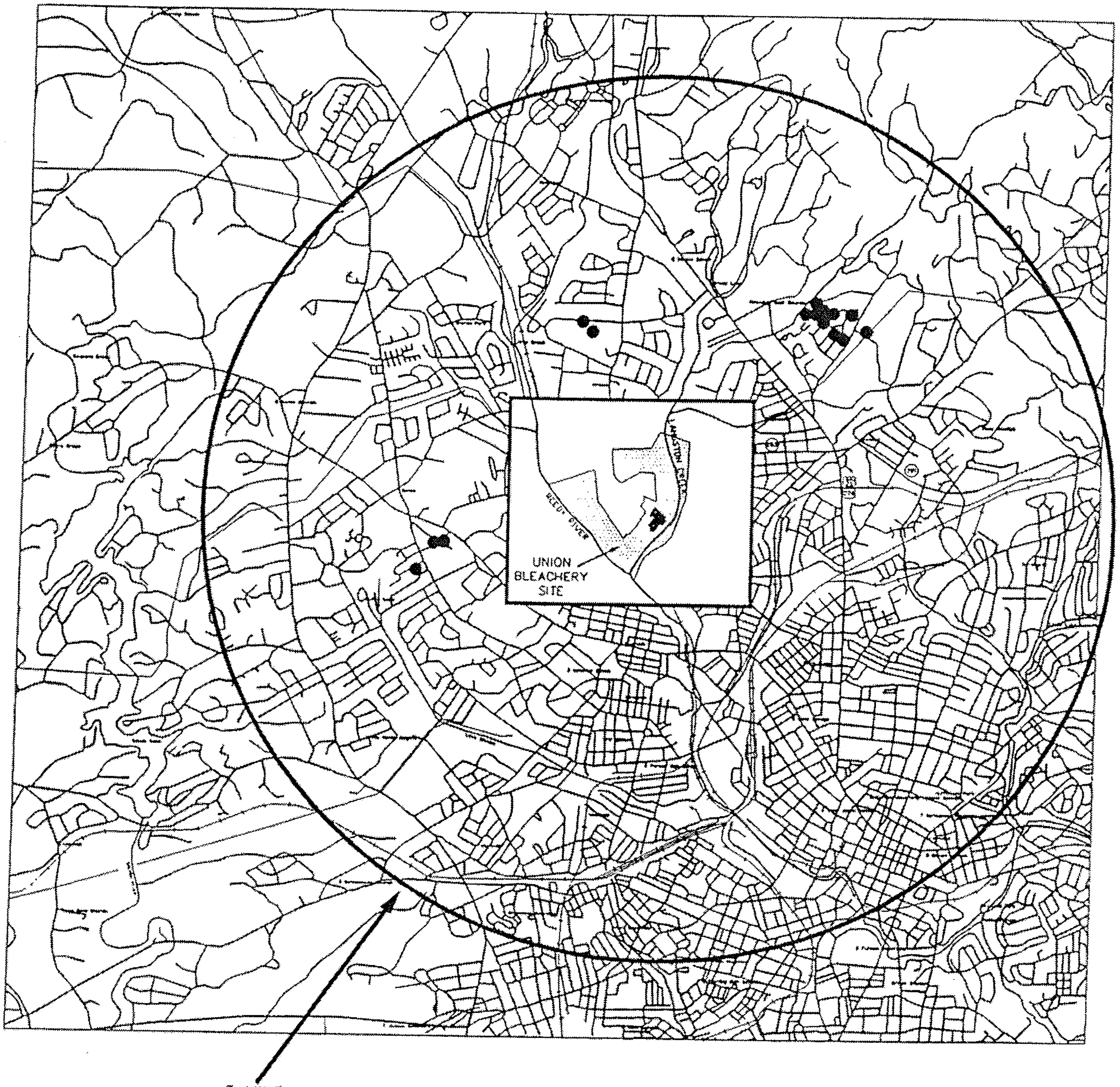
Union Bleachery is located near the headwaters of the Reedy River which drains a watershed area of approximately twelve square miles before its confluence with Langston Creek. The water quality in the Reedy River has been historically categorized as poor. This was primarily due to raw wastewater discharges into the river by Union Bleachery and other textile mills until the 1950s. In 1955 the predecessor agency to SC DHEC issued administrative orders to various industrial dischargers, including Union Bleachery, requiring them to modify their discharges. Prior to this investigation, no stream study had been conducted of this portion of the Reedy River to assess the quantity and quality of aquatic life. The stream survey conducted in 1981 by SC DHEC did not find detectable chromium in the Reedy River.

1.2.2.5 Groundwater Usage

On August 2, 1989, Rogers & Callcott performed a search of the South Carolina Water Resources Commission database. Based on this review, only fifteen water wells were identified within a 3-mile radius as shown in Figure 4. None of the identified wells are located downgradient of the groundwater at the Union Bleachery site.

1.2.3 Historical Characterization of Wastes On-site and Extent of Contamination (Including Preliminary Investigation)

1.2.3.1 Langston Creek Floodplain




3 MILE
RADIUS

● APPROXIMATE LOCATION OF WATER WELL BASED ON SOUTH CAROLINA WATER RESOURCES COMMISSION DATA BASE

GRAPHIC SCALE

2000 0 1000 2000 4000 8000

( IN FEET )

NORTH

NOTE: ALL BASE MAP FEATURES TAKEN FROM ROGERS & CALLCOTT ENGINEERS, INC.

| | |
|---|---|
| UNION BLEACHERY SITE | |
| FIGURE 4: WATER WELLS WITHIN 3-MILE RADIUS OF UNION BLEACHERY SITE | |
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| Checked by: RRR | Date: 16-JUL-91 |
| GeoTrans, inc. | Disk/File: UB3MILE.DWG |
| LOUISVILLE, KY | |

1.2.3.1.1 Chromium Contamination

In 1981, chromium contamination was found in Langston Creek. Based on a study of Langston Creek and the Reedy River, the SC DHEC determined that Union Bleachery was the source of the chromium contamination in Langston Creek. SC DHEC directed Cone to begin an investigation to determine the source and extent of this contamination. Cone retained LAW in late 1981 to begin this investigation. LAW performed a resistivity study in the Langston Creek Floodplain and installed eleven monitor wells. Table 1 provides specifications for these wells and other wells drilled during the Preliminary Investigation. LAW recommended that two extraction wells be installed near the dam on Langston Creek. Cone, through negotiations with SC DHEC, agreed to convert one monitor well, W-9, into an extraction well in the area of greatest groundwater contamination. Chromium was also found at significant concentrations in the bedrock at well W-10. LAW concluded that the chromium contamination had migrated under Langston Creek in a confined aquifer and possibly surfaced through leaks in the confining layer on the opposite side of Langston Creek.

LAW's report states that its investigation was premised on the assumption that the source of chromium contamination resulted from a leak in the chromium tank supply line. The 13,500 gallon chromium storage tank was used to supply hexavalent chromium to the dye ranges for dye oxidation from approximately the early 1960's through 1975. The tank was removed in 1981. Cone incorrectly reported that the underground delivery lines were also removed. Cone postulated that the reported chromium contamination reached Langston Creek by following an underground water line that ran beneath the plant. No data were obtained to support this pathway. Figure 5 shows the location of the chromium tank, the chromium supply line to the dye area (as incorrectly reported by Cone) and the 10-inch water line under the building. Additionally, S&ME later reported that Cone stated that no other likely sources of chromium contamination existed.

Soil & Material Engineering, Inc. (S&ME) replaced LAW in late 1982 and continued the investigation of chromium contamination. S&ME

Table 1. Well specifications and borehole stratigraphy pre-November 1990 wells, Langston Creek.

| Well No. | TOC elevation (ft w.r.t. Langston Dam) | Depth of Sandpack[1] | Zone Monitored | Media Monitored | Well Diameter (inches) | Well Material | Max Discharge Rate (gpm) |
|---|---|---|---|---|---|---|---|
| W-1 | 99.1 | 3.0-27.0 | Alluvial | Sand/Silt | 2 | PVC | NA |
| W-2 | 101.8 | 17.0-38.0 | Saprolite | Silt | 2 | PVC | 2.5 |
| W-3 | 102.0 | 3.0-15.0 | Alluvial | Silt | 2 | PVC | NA |
| W-4 | 101.1 | 17.0-30.5 | Saprolite | Silt | 2 | PVC | NA |
| W-5 | 102.4 | 13.3-30.0 | Alluvial | Sand/Silt | 2 | PVC | NA |
| W-6 | 103.5 | 11.3-30.0 | Saprolite/Alluvial | Sand/Silt | 2 | PVC | NA |
| W-7 | 103.8 | 11.4-26.0 | Saprolite | Silt | 2 | PVC | NA |
| W-8 | 109.7 | 4.0-15.0 | Saprolite/Fill | Silt | 2 | PVC | NA |
| W-9 | 97.6 | 13.0-35.0 | Saprolite/Alluvial | Silt | 2 | PVC | 6.6 |
| W-10 | 100.6 | 44.0-54.0 | Bedrock | Gneiss | 3 | Openhole | 0.5 |
| W-11 | 102.1 | 36.0-48.8 | Bedrock | Gneiss | 3 | Openhole | NA |
| W-12 | 98.3 | NA | Saprolite | Sand | 3 | PVC | NA |
| W-13 | 102.9 | 37.0-51.0 | Bedrock | Gneiss | 4 | Openhole | 15-20 |
| W-14 | 102.2 | 6.0-20.0 | Alluvial | Sand/Silt | 4 | PVC | 0.5 |
| W-15 | 98.5 | 5.0-16.5 | Alluvial | Sand/Silt | 2 | PVC | NA |
| W-16 | 97.7 | 23.5-50.0 | Bedrock | Gneiss | 4 | Openhole | NA |
| W-17 | 98.2 | 8.5-34.0 | Alluvial/Saprolite/ Bedrock | Sand/Silt/Gneiss | 6 | SS/PVC | 3.0 |
| RMT-1 | 132.2[2] | 12.0-32.0 | Saprolite | Sand | 2 | PVC | NA |
| RMT-2 | 122.2[2] | 22.4-30.5 | Saprolite | Sand | 2 | PVC | NA |
| RMT2A | 121.9[2] | 48.9-58.5 | Saprolite | Sand | 2 | PVC | NA |
| RMT-4 | 94.8[2] | 3.0-15.0 | Alluvial/Saprolite | Clay/Silt/Sand | 2 | PVC | NA |
| RMT-5 | 94.3[2] | 1.5-13.5 | Alluvial | Clay/Sand | 2 | PVC | NA |
| RMT-5 | 94.3[2] | 1.5-13.5 | Alluvial | Clay/Sand | 2 | PVC | NA |
| RMT-5A | 93.9[2] | 20.5-30.0 | Saprolite | Sand | 2 | PVC | NA |
| RMT-5B | 94.3[2] | 39.0-46.5 | Bedrock | Gneiss | 2 | PVC | NA |

NA = Not available

[1]ft below ground surface

[2]land surface elevation

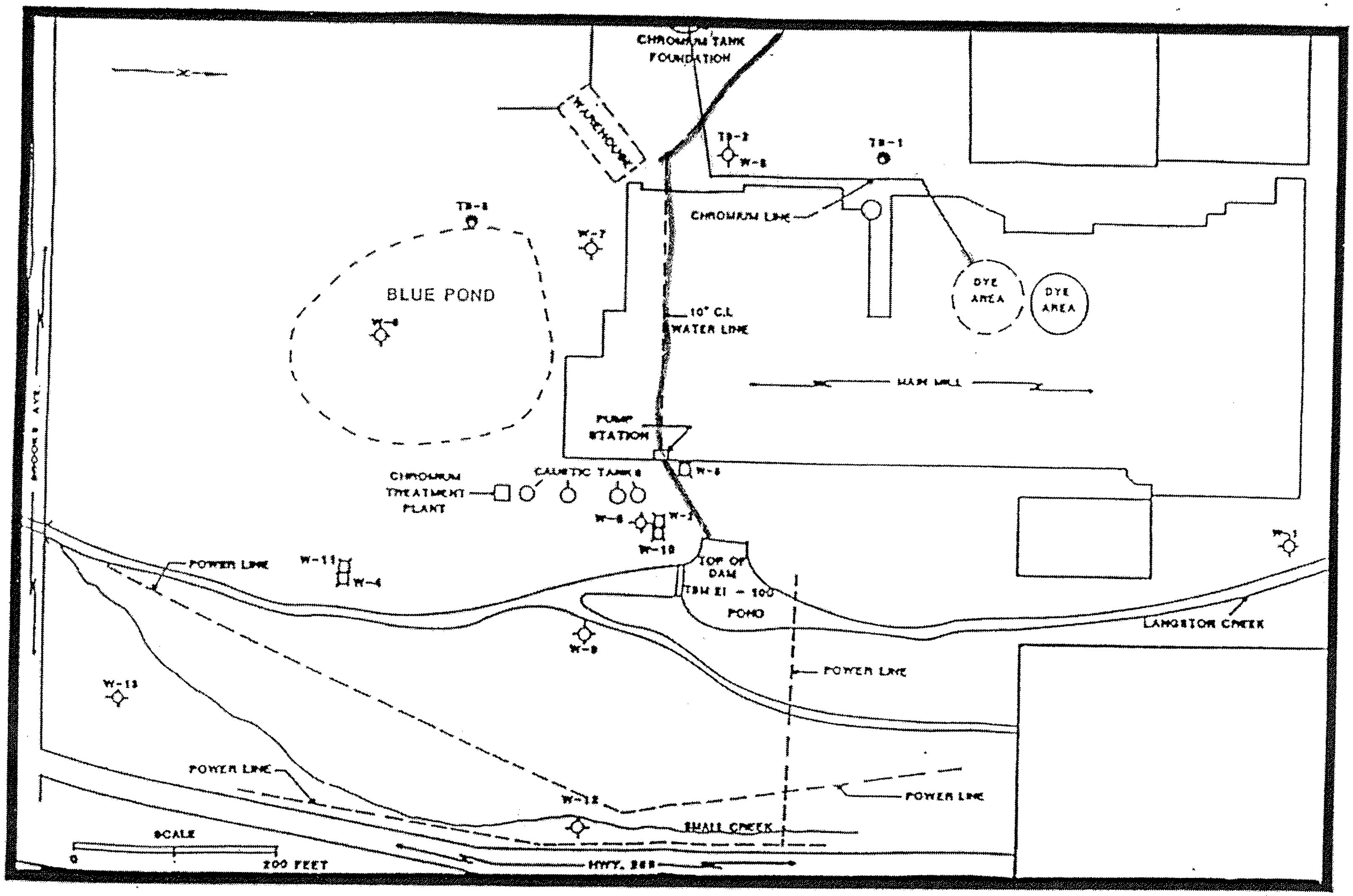



Figure 5: Location of the chromium tank, the chromium supply line to the dye area; and the ten-inch waterline (modified from S&ME, 1985).

installed six additional monitor wells and performed resistivity studies in 1985 and 1987. From these studies, it appeared the contaminant plume was decreasing in size. These geophysical results are uncertain due to interferences, such as the caustic plume. The chromium concentration in W-9 had decreased from approximately 3,000 mg/l in 1982 to approximately 110 mg/l in 1990. The chromium concentrations in W-2 and W-10 decreased from approximately 150 mg/l to 55 mg/l and 27 mg/l, respectively, while W-15 on the other hand has increased from 2 mg/l when it was first installed in 1987 to 44 mg/l in April 1991. Well W-15 is located at the eastern property boundary and the increase in chromium concentration implies that a portion of the plume is migrating off-site.

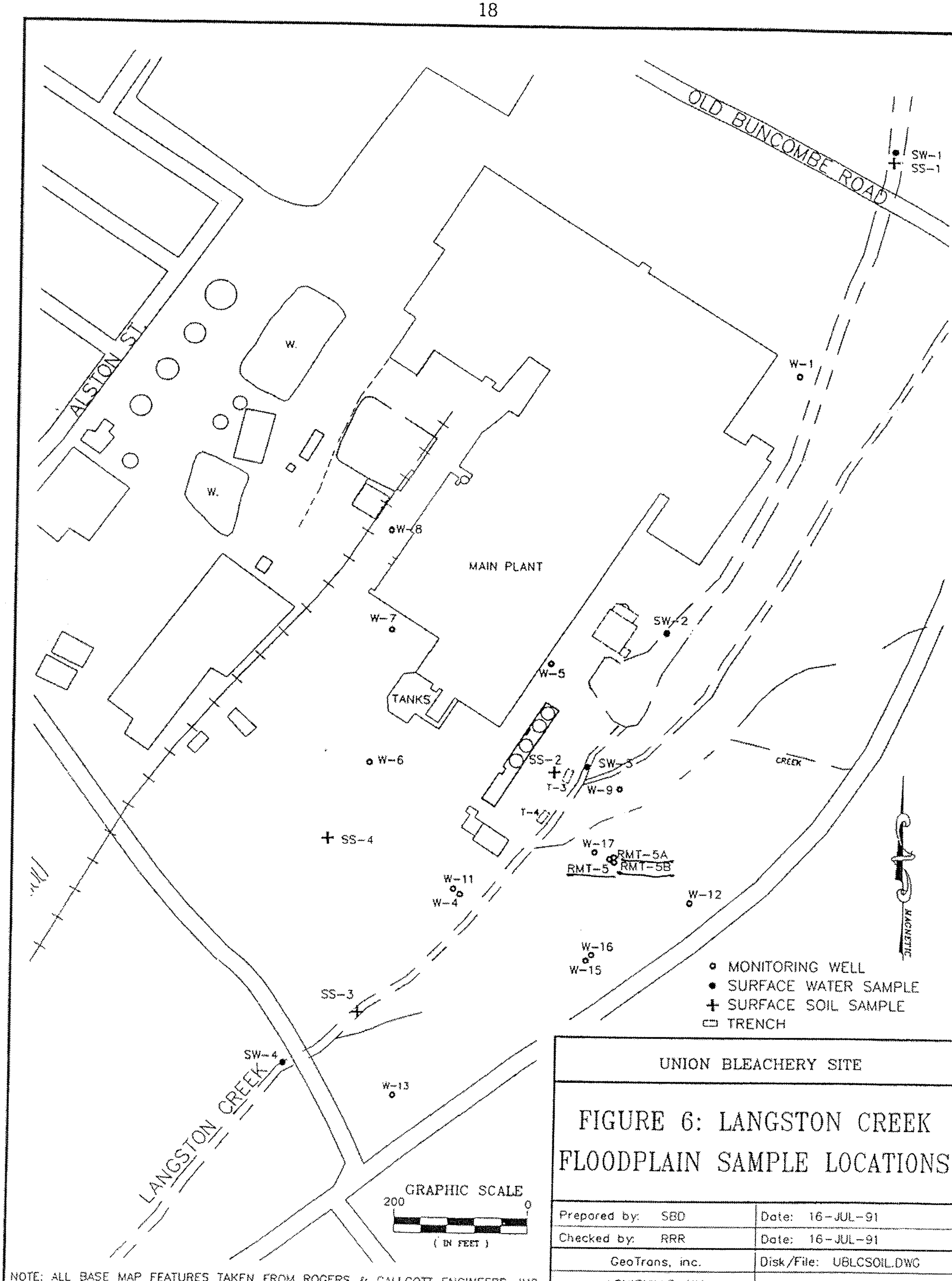
In 1984, Cone signed an Administrative Consent Order with the South Carolina Department of Health and Environmental Control (SC DHEC) to remediate the groundwater contamination beneath the site until SC DHEC determines that background levels have been met. In response to this Consent Order, Cone has only addressed the chromium contamination in a portion of the area adjacent to the Langston Creek. Cone continued pumping contaminated groundwater from W-9 and operating the chromium remediation facility to remove and precipitate the chromium contamination from the groundwater. Monthly reports of well analyses, Langston Creek water quality and chromium remediation facility activities were submitted to SC DHEC.

In 1987 high levels of chromium contamination were again detected in Langston Creek, and SC DHEC directed Cone to begin pumping wells W-2 and W-10 in addition to W-9 to better protect the surface water quality in Langston Creek. Pumping from W-2 and W-10 ceased until April 1990 when these wells were again placed into operation as extraction wells. A more complete discussion of the current pump-and-treat system is provided in the interim assessment (GeoTrans, 1989) and in an aquifer test design report (GeoTrans, 1991b).

Sampling performed by R&C during 1987 through May of 1990, as part of the Preliminary Investigation, shows that the surface water quality of Langston Creek is still adversely affected by the groundwater contamination. Random samples taken in Langston Creek during 1989 and 1990 often exceeded the maximum contaminant level (MCL) for chromium. Sampling by R&C also revealed additional contaminants in many of the wells located in the Langston Creek Floodplain not previously discovered by LAW or S&ME. Metals detected in addition to chromium were arsenic, barium, and lead. Organic contaminants including phenol, volatile organics and acid and base neutral extractables were detected. Additionally, high pH and specific conductance were discovered in Wells W-3 and W-14, and separate phase petroleum products were found in Well W-8. The presence of contaminants other than chromium suggested that the contamination in the Langston Creek Floodplain groundwater did not originate solely from a pure hexavalent chromium source. Further investigation was required to determine the source of chromium contamination as well as the other contaminants. Potential sources include wastewater discharges prior to the mid 1970's from the dye and preparation areas into the Basement, and the chromium tank and line.

In the spring of 1990, three additional wells were installed by RMT in the Langston Creek Floodplain. In addition, both RMT and R&C collected surface soil samples along with surface water samples from Langston Creek. The locations of these sample sites are shown in Figure 6. Four additional soil samples were collected (SS-1, SS-2, SS-3, and SS-4). As shown in Figure 6, SS-1 is an upgradient sample that had a chromium concentration of 25 mg/kg (RMT 4/25/90 sample). SS-2 is located closer to the main plant and had a chromium concentration of 62 mg/kg (RMT 4/24/90 sample). Further down Langston Creek, Sample SS-3 had a chromium concentration of 110 mg/kg (RMT 4/25/90 sample). Finally, SS-4, located between the main plant and the Aeration Lagoon, had a chromium concentration of 8 mg/kg (RMT 4/24/90 sample). Although SS-2 and SS-3 had concentrations greater than the "background" concentration at SS-1, all concentrations are below the proposed RCRA soil action level of 400 mg/kg for chromium (Federal Register, 55(145), July 27, 1990).

The three new wells drilled in the Langston Creek Floodplain by RMT included: RMT-5 screened in the alluvium, RMT-5A screened in the saprolite, and RMT-5B screened in the bedrock. Groundwater samples




UNION BLEACHERY SITE

FIGURE 6: LANGSTON CREEK FLOODPLAIN SAMPLE LOCATIONS

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NOTE: ALL BASE MAP FEATURES TAKEN FROM ROGERS & CALLCOTT ENGINEERS, INC.

split by RMT and R&C were collected from the entire well network on March 6, 1990, and June 20-21, 1990. The chemical analyses are given in Appendix A.

Data from these RMT wells supports the conceptualization of a shallow aquifer in the alluvium separated from a bedrock/lower saprolite aquifer by the upper saprolite, which acts as a confining bed. Reviewing the chromium data in the new RMT wells, chromium occurs in the alluvial and bedrock wells, but not the saprolite well. This suggests multiple plumes, with at least one plume in the alluvium. It also should be noted that the chromium concentrations are higher in the bedrock well (5B) than in the alluvial well (5). The spatial variability in hydraulic conductivity in the Langston Creek aquifer system causes the plume(s) to be complex and difficult to characterize.

To evaluate the variation in concentration with time, chromium values are provided for July for the years 1987 through 1990 in Table 2. For 1990 both Cone and R&C laboratory results are given for comparison. The trend for 1987 through 1989 is stable or decreasing chromium concentrations (except for W-15 and W-16). Except for W-15, all values in 1990 are equal to or greater than those obtained in 1989 (Cone data).

This increase in chromium concentrations, especially near the main plant may be due partly to the pumping at W-2 and W-10, which began in April 1990. This pumping may be recovering some of the contaminated groundwater that extends under the main plant. This is particularly interesting in the case of W-10, a bedrock well. Appendix B provides plots of chromium versus time for the original 17-well network. The concentration at W-10 has more than doubled from 40 mg/l on April 27, 1990, to 98 mg/l on August 8, 1990. Increases at W-16, a bedrock well, appear to be due to the migration of the chromium plume in that region that is not being captured by the existing recovery system, possibly resulting in off-site contamination.

Table 2. Groundwater chromium data (mg/l) for July 1987 through 1990. Data from Cone unless indicated otherwise.

| WELL | DATE 07/16/87 | 07/13/88 | 07/21/89 | 07/11/90 | 07/11/90* |
|---|---|---|---|---|---|
| W- 1 | <0.06 | <0.05 | <0.04 | 0.09 | 0.08 |
| W- 2 | 130.00 | 57.00 | 29.00 | 87.00 | 50.00 |
| W- 3 | 0.58 | <0.05 | <0.04 | 0.07 | 0.14 |
| W- 4 | <0.06 | <0.05 | <0.04 | 0.25 | 0.04 |
| W- 5 | <0.06 | <0.05 | <0.04 | 0.09 | 0.10 |
| W- 6 | <0.06 | <0.05 | <0.04 | <0.04 | 0.07 |
| W- 7 | <0.06 | 1.07 | 0.04 | 0.87 | 0.63 |
| W- 8 | <0.06 | <0.05 | <0.04 | <0.04 | <0.02 |
| W- 9 | 233.00 | 228.00 | 88.00 | 169.00 | 128.00 |
| W-10 | 60.00 | 30.00 | 23.00 | 92.00 | 79.00 |
| W-11 | <0.06 | <0.05 | <0.04 | 0.05 | 0.02 |
| W-12 | <0.06 | 0.73 | 0.22 | -- | -- |
| W-13 | <0.06 | <0.05 | <0.04 | <0.04 | <0.02 |
| W-14 | <0.06 | <0.05 | <0.04 | 0.06 | 0.04 |
| W-15 | | 7.47 | 20.75 | 7.60 | 13.00 |
| W-16 | | <0.05 | 0.16 | 1.13 | 1.50 |
| W-17 | | <0.05 | <0.04 | 0.15 | 0.18 |

*R&C

Although W-9 has been recovering chromium from the alluvium/saprolite material, its impact on the bedrock aquifer could not be determined until completion of the RI. As previously indicated, the significance of the saprolite as a confining bed is demonstrated by well cluster 5, 5A, and 5B, which are completed in the alluvium, saprolite, and bedrock, respectively. Sampling results by R&C from a sample taken on June 20, 1990, from 5, 5A, and 5B showed chromium concentrations of 7.1 mg/l for the alluvium, <0.02 mg/l for the saprolite, and 18.00 mg/l for the bedrock.

One purpose of a pump-and-treat system is to protect surface water in Langston Creek. According to a letter from Mr. Paul F. Wise (SC DHEC) to Mr. Arthur J. Toompas (Cone) dated August 20, 1987, "The criterion utilized for water quality in Langston Creek should be 50 µg/l [0.05 mg/l] or background (whichever is less stringent)." Using Cone's data for 1989 this criterion was reached or exceeded in May, July, August, September, October, November, and December. The maximum value for that year was measured on August 12, 1989, above the floodgates, and was 0.98 mg/l for chromium.

To evaluate the variation in concentration in Langston Creek with time, Table 3 is provided. For this table, chromium values in Langston Creek for July are provided since the date of the SC DHEC letter. As may be seen, the criterion has been exceeded in all the years shown (1987-1990). Thus, although the pump-and-treat system, e.g., Well W-9, has been operating for nearly eight years, it has not consistently reduced chromium concentrations in Langston Creek to below 0.05 mg/l.

1.2.3.1.2 Caustic Contamination

A caustic plume also is present in the Langston Creek Floodplain. Wells W-3 and W-14 were drilled downgradient of several caustic tanks. They are both alluvium wells, with W-3 being 15 feet deep and W-14 being 20 feet deep. The chemistry of these wells is different than that associated with other wells in the Langston Creek Floodplain. As shown in Table 4, the water from these wells exhibits high pH and specific conductance. The water is also characterized by the presence

Table 3. Chromium values (mg/l) measured in Langston Creek for July 1987, 1988, 1989, and 1990. Data from Cone unless indicated otherwise.

| Date | Buncombe Rd. | Above Floodgates | Below Floodgates |
|---|---|---|---|
| | | 1987 | |
| July 1 | <0.06 | <0.06 | <0.06 |
| July 9 | <0.06 | <0.06 | 0.11 |
| July 16 | <0.06 | <0.06 | 0.29 |
| July 24 | <0.06 | <0.06 | 0.43 |
| July 28 | <0.06 | <0.06 | 0.59 |
| | | 1988 | |
| July 4 | 0.14 | 0.18 | 0.22 |
| July 13 | <0.05 | <0.05 | <0.05 |
| July 19 | <0.05 | <0.05 | <0.05 |
| July 26 | <0.05 | <0.05 | <0.05 |
| | | 1989 | |
| July 21 | <0.04 | 0.44 | 0.48 |
| July 28 | <0.04 | <0.04 | <0.04 |
| | | 1990 | |
| July 4 | 0.27 | 0.29 | 0.19 |
| July 6[1] | <0.02 | <0.02 | 0.14 |
| July 11 | <0.04 | 0.22 | 0.49 |
| July 19 | -- | 0.37 | -- |
| July 20[1] | <0.02 | <0.02 | 0.19 |
| July 25 | 0.21 | 0.08 | 0.89 |
| July 27[1] | <0.02 | 0.15 | <0.02 |

[1]R&C

GeoTrans, inc.

Table 4. Sampling results of R&C from W-3 and W-14 in mg/l unless otherwise noted.

| | | W-3 | | W-14 | |
|---|---|---|---|---|---|
| Parameter | MCL | Oct 1987 | Mar 6, 1990 | Oct 1987 | Mar 6,1990 |
| pH, units | | 10.2 | 12.0 | 9.7 | 9.7 |
| specific conductance, (umhos/cm) | | 14,000 | 17,000 | 8,200 | 6,700 |
| Phenols, µg/l | 20,000* | 101 | -- | 25 | -- |
| Arsenic, µg/l | 50 | 11 | 242 | 24 | 13 |
| Barium | 1 | <0.1 | 0.02 | <0.01 | 0.02 |
| Cadmium | .01 | <0.01 | <0.01 | <0.01 | 0.01 |
| Chromium | .05 | <0.05 | 0.07 | <0.05 | 0.05 |
| Nickel | .7 | 0.36 | -- | 0.14 | -- |
| Silver | .05 | 0.03 | -- | 0.02 | -- |
| Lead, µg/l | 50 | <10 | 38 | <10 | 23 |

*RCRA Proposed Action Levels, Fed. Register, Vol. 55, NO. 145.

Should also analyze for Na.

GeoTrans, inc.

of the metals arsenic, nickel and silver, as well as various organic solvents. Note that the pH of Wells W-3 and W-14 exceed the U.S. EPA Secondary Maximum Contaminant Level (SMCL) for pH, which is 6.5-8.5.

Based on a letter to Mr. Jim Kahle (LAW) from Arthur J. Toompas (Cone) dated April 29, 1982, "Sodium hydroxide appears to have been a contaminant in Well #3." In a memorandum from Mr. Richard W. Oldham (SC DHEC, Groundwater Protection Division) to Mr. Paul Wise (SC DHEC, Water Quality Assessment and Enforcement Division) dated May 2, 1988, the following is stated:

> "Routinely submitted monitor results have indicated high pH in these monitor wells [wells W-3, W-10, W-12, and W-14]. The cause of this high pH in well W-12 may be caused by grout contamination. The high pH in wells W-3, W-10 and W-14 may be caused by spills or leaks from the adjacent and upgradient caustic tanks/lines(?). If the high pH is determined to be caused by grout contamination the monitor well(s) should be replaced. If a caustic plume is present, the horizontal and vertical extent should be determined."

Cone has never determined the extent of the "caustic plume." R&C dug two trenches downgradient of the four tanks near Langston Creek. Trench #3 was approximately 50 feet downgradient of W-3; Trench #4 was further southwest. A sample taken on June 26, 1989, from Trench #3 had a pH of 8.0, a chromium concentration of 0.14 mg/l, and an arsenic concentration of 23 μg/l. Because of the slightly elevated pH and the arsenic content, this trench appears to represent the leading edge of the "caustic plume."

1.2.3.1.3 Blue Pond

The Blue Pond was located in the Langston Creek Floodplain southwest of W-6 and is incorrectly located on Figure 5 based on historical air photographs. It was operated by Cone as a storage area for logs used in dye and finishing machinery as cloth rollers. Copper sulfate was added to the pond as a preservative and maintained at a sufficient concentration to cause the water to appear blue in color. Backwash water from Cone's water treatment plant also was discharged into the pond. This backwash water contained sediment, aluminum hydroxide sludge and sulfates. Cone ceased the use of this pond more than twenty years ago and filled it to the surrounding ground level. This area was then used by Cone as a holding and drying area for dye sludge removed from the Basement during July 4th plant shutdowns.

1.2.3.2 Basement Contamination

Throughout its operation, Cone discharged waste dye into the Basement under the dye areas. Dye ranges four through six and the jiggs discharged into a concrete lined Basement sump area. Dye ranges one and two discharged directly onto soil in the Basement. Since 1982, all waste was piped to sumps and trenches. Wastewater from the dye range oxidation chemical boxes also flowed directly into the Basement.

Hexavalent chromium combined with acetic acid were used until 1975 as the oxidation chemicals for a large part of the dyeing processes. Approximately 10% of the chromium added to the washboxes for oxidation would be absorbed onto the cloth. The remaining 90% would be discharged into the Basement. According to a study conducted by Cone, until the late 1950s approximately one-half of the hexavalent chromium applied to the dyed material was not consumed in the oxidation process and was discharged into the Basement in hexavalent form. A chromium recovery unit was installed in the late 1950s to reduce the amount of excess hexavalent wasted. Documented chromium usage by Cone is shown in Table 5.

Because of the periodic stoppage of the drainage pipes and ditches, the flooding in the Basement would provide significant hydrostatic pressure to cause infiltration of these chromium and dye wastewaters into the soil under the plant. During the 1970's, Cone became concerned about structural failure in the building due to corrosion caused by continuous wastewater discharge into the Basement. Piedmont Engineers reported a water bearing soil underneath the Basement concrete in 1982 when structural testing and renovation was performed. No water quality samples were obtained at that time. R&C performed a boring, HP-5, and collected a shallow groundwater sample

Table 5. Documented Sodium Dichromate Usage by Cone.

| Year | Sodium Dichromate Used (Pounds) |
|---|---|
| 1903-1957 | data not available |
| 5/57-5/58 | 397,100 |
| 1958-1968 | data not available |
| 1969 | 680,695 |
| 1970 | 670,906 |
| 1971 | 956,155 |
| 1972 | 893,249 |
| 1973 | 486,281 |
| 1974 | 571,395 |
| 1975 | 248,026 |

under the old dye ranges one and two in 1989. This groundwater contained arsenic, barium, chromium and mercury at concentrations higher than the respective MCL's for these metals.

Cone removed contaminated dye sludge from the Basement area during the annual July 4th plant shutdowns. In 1981, 1983, and 1984 Cone analyzed the dye sludge that was removed and found significant concentrations of heavy metals (Table 6). Cone sent the dye sludge to GSX Pinewood as hazardous waste. In AFP's investigation to determine the source of the chromium contamination in the Langston Creek Floodplain, samples were taken by R&C in 1988 in the Basement. AFP discovered that all of the dye sludge had not been removed by Cone. Again, high concentrations of heavy metals were found in the dye sludge left by Cone. The results from these analyses are given in Table 6.

The metals found in the dye sludge correspond with the contaminants found in some of the wells in the Langston Creek Floodplain, the Wastewater Treatment Lagoon, Permitted Sludge Landfill, and the Reedy River Floodplain. The resistivity data collected by LAW in 1982 indicates that the chromium contamination may extend well under the building.

The high concentrations of chromium and other heavy metals indicates that the chromium contamination in the Basement is pervasive and is evidence that substantial amounts of metal-containing dyes were used by Cone. AFP represents that it has never used chromium or zinc as an oxidizing agent. AFP has not had any flooding in the basement, has diverted the influx of surface water from entering the basement, and has substantially decreased the volume of process water used.

1.2.3.3 Aeration Lagoon

The Aeration Lagoon was constructed in 1965 as an equalization basin prior to discharge of the wastewater into the Greenville Sewer System. Prior to this time, most of Union Bleachery's industrial wastewater flowed, untreated, directly into the Reedy River via Langston Creek. Stormwater from the area west of the main building flowed through the Basement to ditches and the Aeration Lagoon. The

Table 6. Metal Concentrations in Basement Dye Sludge.

| Contaminant* | 1981 | 1983 | 1984 | 1988 |
|---|---|---|---|---|
| Arsenic | <20 | - | - | 3.6 |
| Barium | - | - | - | 192 |
| Cadmium | 4.5 | 15 | - | 1 |
| Chromium | 9,850 | 40,250 | 2,800 | 7,596 |
| Copper | 1,065 | 2,400 | - | 394 |
| Iron | 63,250 | - | - | 28,846 |
| Lead | 118 | 1,290 | - | 28.8 |
| Mercury (ug/kg) | 43.6 | - | - | 480 |
| Nickel | 95 | 41 | - | 73 |
| Zinc | 4,075 | 4,650 | - | 904 |

*mg/kg unless otherwise noted
(-) indicates that the sample was not analyzed for this contaminant.

stormwater flushed much of the dye sludge from underneath the building, and this was transported into the Aeration Lagoon. Additionally, during July 4th shutdowns, some of the accumulated dye sludge was washed down the ditches to the lift station and into the lagoon by cleaning crews using fire hoses. A permit was obtained from the SC DHEC to dredge the lagoon in 1974 and deposit the sludge in an unsecured landfill northwest of the lagoon on the Union Bleachery site.

The use of chromium by Cone as an oxidizing chemical was discontinued in 1975. Even though the lagoon was dredged during 1975 sludge ~~contaminated by~~ containing heavy metals remains in the lagoon because the contaminated dye sludge continued to be washed into the lagoon by stormwater runoff events. Wastewater samples collected by Cone in 1982 revealed metal contamination (see Table 7). According to a Cone Inter-Company Correspondence to Tom Alspaugh and Arthur Toompas from Lew Cadwallader dated December 1, 1982, "An average silt profile across the lagoon appears to be about one inch--although sludge depth is greater in two places."

Cone temporarily started pumping well W-10 on December 2, 1983, (letter to Andy Yasinsac (SC DHEC) from T.A. Alspaugh dated December 7, 1983). According to Cone Inter-Company Correspondence to Lew Cadwallader from Arthur J. Toompas dated December 15, 1983, "Mr. Yasinsac agreed to allow us to continue to pump well W-10 directly to the lagoon for another two weeks." On 11/2/83, well W-10 had 151 mg/l chromium; on 11/8/83, well W-10 had 166 mg/l chromium. Cone temporarily started pumping well W-2 on January 4, 1984, with water being discharged to the Wastewater Lagoon (letter to Andy Yasinsac (SC DHEC) from Arthur J. Toompas dated January 4, 1984). According to a Cone Note to Lew Cadwallader from Stan Gross dated 3/15/84, a series of measurements shows that the chromium in the Lagoon reached a high of 1.23 mg/l on 1/24/84.

why?

Beginning in 1988, additional studies were performed on the Aeration Lagoon; Table 8 summarizes these studies. A sludge sample and water sample were taken from the Aeration Lagoon on March 16, 1988. The chromium results were 3,200 mg/kg and 0.24 mg/l,

Table 7. 1982 Aeration Lagoon sample.

| Parameter | Wastewater (mg/l) |
|---|---|
| Arsenic | 0.0023 |
| Barium | ND |
| Cadmium | ND |
| Chromium | 380 |
| Copper | 0.10 |
| Lead | ND |
| Mercury | ND |
| Nickel | 0.23 |
| Selenium | 0.012 |
| Silver | <0.00014 |
| Zinc | 0.09 |

ND = not detected

Table 8. Summary of Aeration Lagoon data.

| Date | Method/Media | Company |
|---|---|---|
| 3/16/88 | Grab Sample/Lagoon Wastewater (unfiltered) | R&C |
| 3/16/88 | Grab Sample/Lagoon Sludge (composition) | R&C |
| 4/26/89 | Hydropunch HP-3/Groundwater (unfiltered) | R&C |
| 4/26/89 | Hydropunch HP-4/Groundwater (unfiltered) | R&C |
| 4/24/90 | Grab Sample (SL-2)/Lagoon Sludge (composition/TCLP) | R&C<br>RMT |
| 6/19/90 | Well RMT-4/Groundwater (filtered) | RMT |
| 6/20/90 | Well RMT-4/Groundwater (filtered) | R&C |
| 9/18/90 | Well RMT-4/Groundwater (unfiltered) | R&C |

R&C = Rogers & Callcott

respectively. Another sludge Sample (SL-2) was collected on April 24, 1990. This time, the chromium concentration was 1,750 mg/kg. TCLP was run on this sample, resulting in a chromium concentration of 0.12 mg/l. RMT conducted analyses on the same sample showing a chromium concentration of 1,900 mg/kg and a chromium TCLP result of 0.07 mg/l. Appendix A provides complete chemical analysis.

In 1989, two hydropunches (see for example Edge and Cordry, 1989) were installed down gradient of the lagoon and groundwater sampled. The chromium results exceeded the MCL with HP-3 containing 0.06 mg/l and HP-4 containing 0.07 mg/l. RMT constructed Monitor Well RMT-4 near the lagoon in the proximity of Hydropunch HP-4. Groundwater samples were collected on June 19-20, 1990, and September 18, 1990. Results from these samples are compared to analysis from HP-4 in Table 9. In spite of the difference in dates and sampling methods, the results are similar. For the filtered samples, less chromium is present. This is probably due to the presence of particulate matter in the unfiltered sample that contained sorbed chromium. Figure 7 illustrates the locations of samples taken in and around the Aeration Lagoon.

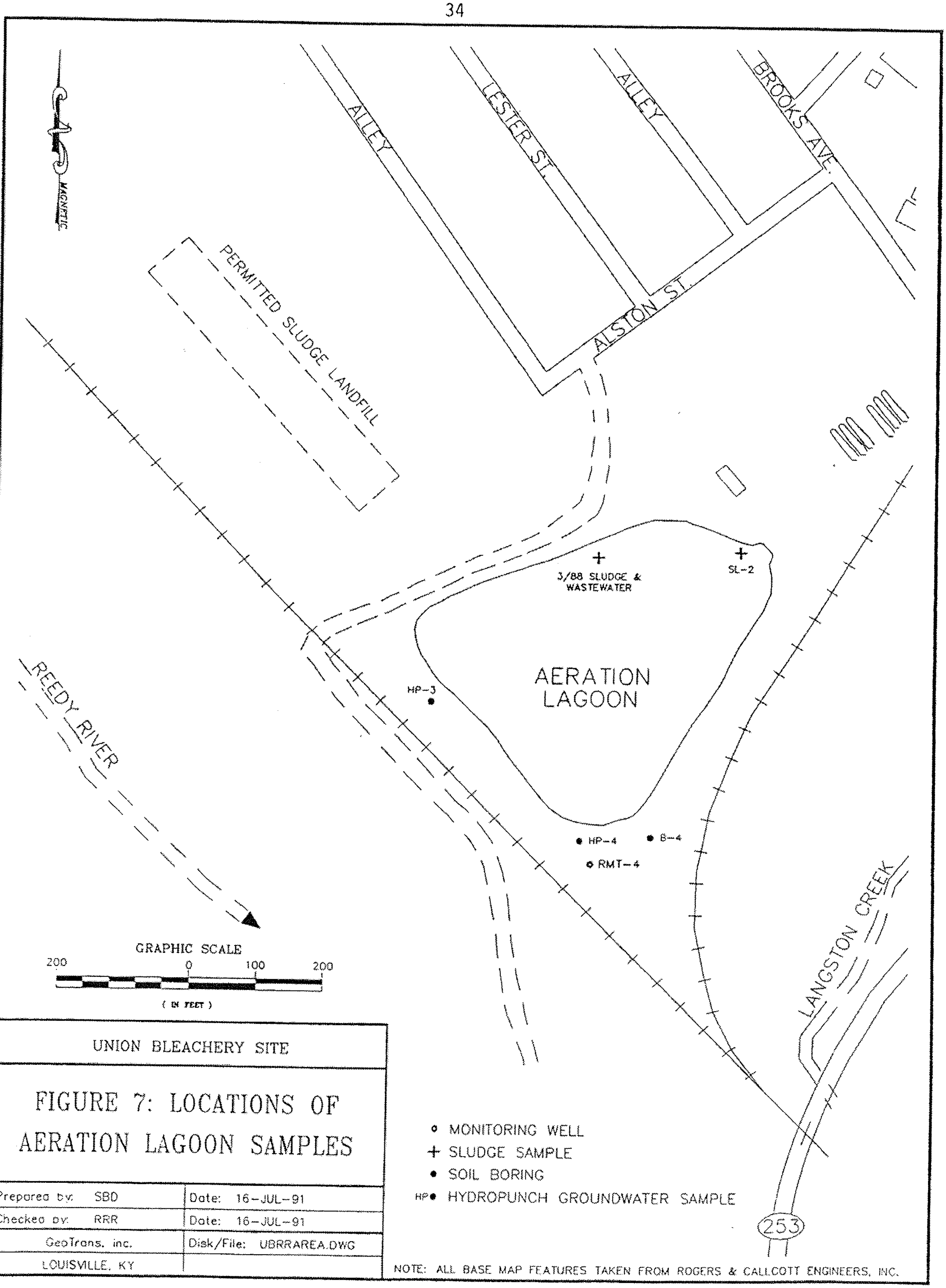
#### 1.2.3.4 Permitted Sludge Landfill

Cone applied for a permit to dredge the Wastewater Treatment Lagoon in 1974 and began the actual dredging operation in 1975. Originally, Cone proposed to dispose of the dried sludge in a sanitary landfill, but later requested SC DHEC approve burial of the sludge on the Union Bleachery property. The permit issued by SC DHEC in 1975 to allow Cone to landfill this sludge appears to have been granted based on incomplete and erroneous information. Sample analyses and calculations prepared by Cone in 1984 show that as much as 250,000 pounds of chromium were placed in the Sludge Landfill. Cone also obtained soil samples from this landfill in 1984 prior to the sale to AFP. Cones soil analysis revealed chromium concentrations up to 17,000 mg/kg. A summary of data collected to date is shown in Table 10. Figure 8 shows the location of the sampling points.

Table 9. Groundwater samples taken near the Aeration Lagoon in mg/l. R&C data unless otherwise noted.

| | | RMT-4 | | |
|---|---|---|---|---|
| Parameter | HP-4[1] | Filtered[2] | Unfiltered[3] | RMT[4] |
| Arsenic | 0.014 | <0.01 | <0.01 | <0.003 |
| Barium | 0.20 | 0.08 | 0.21 | 0.07 |
| Chromium | 0.07 | <0.02 | 0.04 | 0.003 |
| Lead | <0.1 | <0.005 | 0.046 | <0.003 |
| Mercury | <0.001 | <0.001 | <0.001 | <0.0002 |
| Silver | <0.01 | <0.01 | 0.03 | <0.001 |

[1]Sample collected April 26, 1989 - unfiltered
[2]Sample collected June 20, 1990
[3]Sample collected September 18, 1990
[4]Sample collected June 19, 1990 - filtered




UNION BLEACHERY SITE

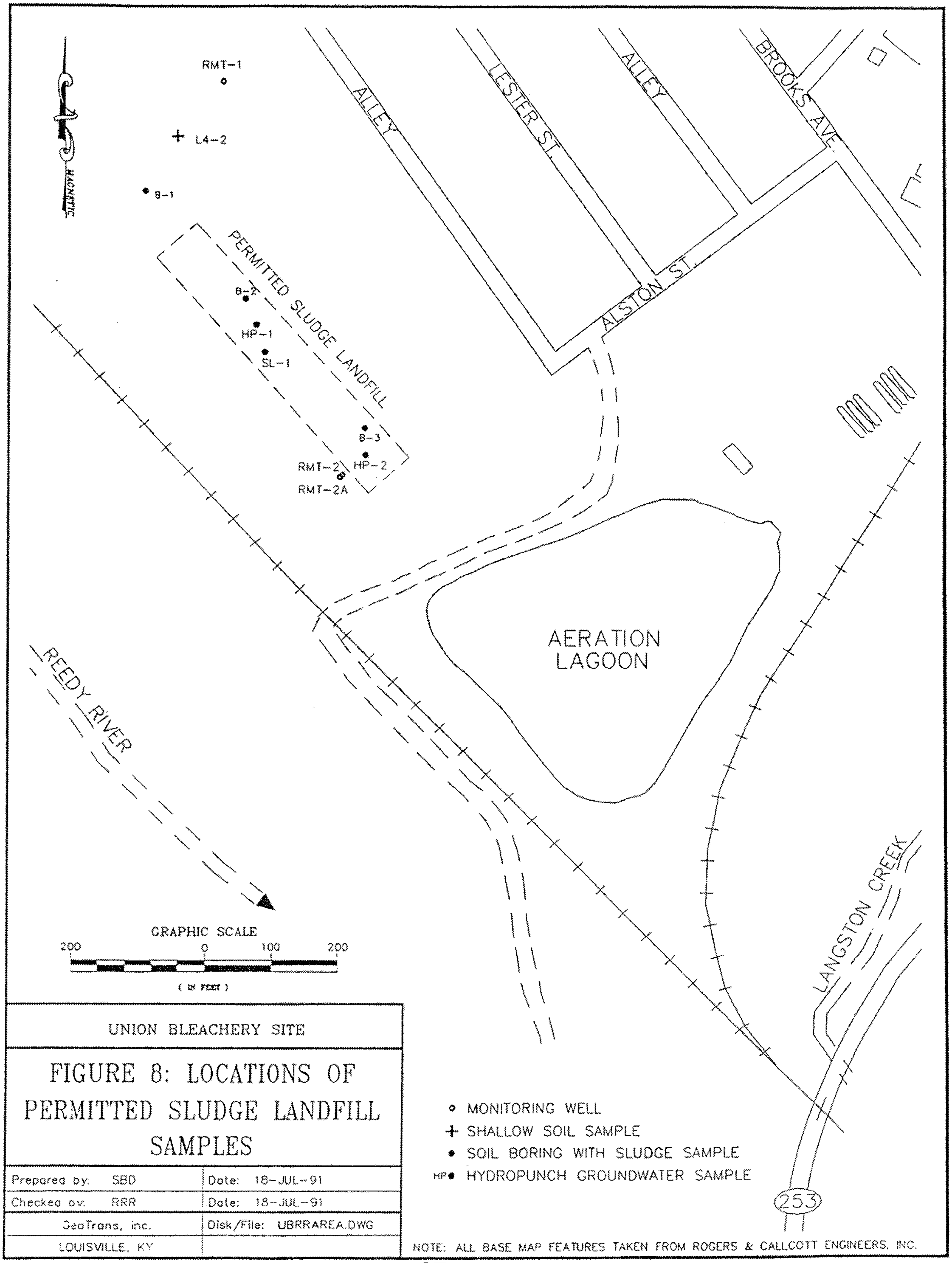
FIGURE 7: LOCATIONS OF AERATION LAGOON SAMPLES

| | |
|---|---|
| Prepared by: SBD | Date: 16-JUL-91 |
| Checked by: RRR | Date: 16-JUL-91 |
| GeoTrans, inc. | Disk/File: UBRRAREA.DWG |
| LOUISVILLE, KY | |

Table 10. Summary of Sludge Landfill data.

| Date | Method/Media | Company |
|---|---|---|
| 1/21/88 | Borings B-1, B-2, & B-3/Soil | R&C |
| 3/17/88 | Grab L4-2/Soil | R&C |
| 4/24/89 & 4/25/89 | Hydropunch HP-1 & HP-2/Sludge & Groundwater | R&C |
| 5/08/90 | Grab Sample B-1E/Sludge (Composition/TCLP) | RMT |
| 5/09/90 | Grab Sample SL-1/Sludge (Composition/TCLP) | R&C |
| 6/19/90 | Wells RMT-1, RMT-2 & RMT-2A/Groundwater (filtered) | R&C RMT |
| 9/18/90 | Wells RMT-1, RMT-2 & RMT-2A/Groundwater (unfiltered) | R&C |

R&C = Rogers & Callcott




UNION BLEACHERY SITE

FIGURE 8: LOCATIONS OF PERMITTED SLUDGE LANDFILL SAMPLES

| | |
|---|---|
| Prepared by: SBD | Date: 18-JUL-91 |
| Checked by: RRR | Date: 18-JUL-91 |
| GeoTrans, inc. | Disk/File: UBRRAREA.DWG |
| LOUISVILLE, KY | |

In 1989, R&C obtained soil samples from the Sludge Landfill and water samples by means of a hydropunch beneath the landfill. The hydropunches were planned to be installed down gradient of the landfill. Because of the inaccurate Cone drawings used to locate the hydropunches, both penetrated the landfill. The hydropunch results, shown in Table 11, reveal high concentrations of chromium and other metals in the soil and a chromium concentration in the groundwater beneath the landfill that exceeds the MCL for chromium.

RMT drilled two wells slightly downgradient of the location of Hydropunch HP-2. RMT-2 is an upper (shallow) saprolite well, whereas RMT-2A is a lower saprolite (auger refusal) well. R&C sampled the wells on June 19, 1990, and September 18, 1990. For the first sampling, the chemical analysis was performed on filtered water; the second used unfiltered water. Although the samples were taken on different dates, which can produce chemical variations, the main reason for chemical differences between the two dates is probably due to filtering versus nonfiltering. RMT also sampled the wells on June 19, 1990. Results from R&C are shown in Table 12. A comparison of R&C and RMT results is provided in Appendix A.

As may be noted, filtering appears to have reduced concentrations of all parameters. This indicates that many of the metals are attached to fine particles. For example, given the iron content in the unfiltered sample, chromium is most likely sorbed to iron hydroxide. Puls and Barcelona (1989) point out that "Metal contaminants may move through fractured and porous media not only as dissolved species, but also as precipitated phases, polymeric species or adsorbed to inorganic or organic particles of colloidal dimensions." They further state "that use of a 0.45 micron filter was not useful, appropriate or reproducible in providing information on metals mobility in groundwater systems, nor was it appropriate for determination of truly 'dissolved' constituents in groundwater."

It should also be noted that drinking water wells are not generally filtered. From the drinking water perspective, MCL's should be applied to unfiltered water. Note that MCL's for cadmium and chromium are exceeded in the unfiltered sample from the alluvium well.

are the wells yielding turbid samples?

Table 11. Sludge Landfill analyses.

| Parameter | Cone 1984 | Sludge HP-1 | Sludge HP-2 | Groundwater HP-1 | Groundwater HP-2 |
|---|---|---|---|---|---|
| Arsenic | | 2.7 | 2.6 | 0.029 | 0.024 |
| Barium | | 221 | 34 | 0.8 | 1.4 |
| Chromium | 17,000 | 38,460 | 5,860 | 2.6 | 0.48 |
| Lead | | 48 | 8.6 | <0.01 | 0.2 |
| Mercury | | <0.1 | 0.14 | <0.002 | <0.004 |

Soil results in mg/kg and water samples in mg/l

penetrated the landfill

This data is speculative because the Hydropunches penetrated the landfill.

Table 12. Groundwater sampling results (R&C) from downgradient of the sludge burial area. Results in mg/l unless otherwise noted.

| | RMT-2[1] | | RMT-2A[2] | |
|---|---|---|---|---|
| Parameter | Filtered[3] | Unfiltered[4] | Filtered[3] | Unfiltered[4] |
| Barium | 0.07 | 1.00 | 0.04 | 0.27 |
| Cadmium | <0.01 | 0.02 | <0.01 | 0.01 |
| Chromium | <0.02 | 0.06 | <0.02 | 0.03 |
| Lead, ug/l | <5.00 | <5.00 | <5.00 | 23.00 |
| Silver | <0.01 | <0.01 | <0.01 | 0.14 |
| Copper | <0.01 | 0.06 | <0.01 | 0.03 |
| Iron | 0.03 | 80.00 | <0.02 | 44.00 |
| Manganese | 0.81 | 3.30 | 0.23 | 0.56 |
| Magnesium | 1.70 | 7.60 | 2.40 | 7.60 |
| Calcium | -- | 3.50 | -- | 7.90 |
| Sodium | -- | 7.40 | -- | 6.60 |
| Potassium | -- | 13.00 | -- | 13.00 |
| pH, units | 4.9 | 4.8 | 6.4 | 6.4 |
| Eh, mV | -- | 342 | -- | 306 |

[1]Upper saprolite well
[2]Lower saprolite well
[3]Sample taken June 19, 1990
[4]Sample taken September 18, 1990

RMT performed the Toxicity Characteristic Leachate Procedure (TCLP) on a sludge sample from the sludge burial area. TCLP is a laboratory procedure to determine the leachability of a solid. If it exceeds regulatory values for specified chemicals, the solid is classified as a hazardous waste. It replaces the EP toxicity test. As may be seen in Table 13, which shows data from several locations, the TCLP value for chromium from the landfill sludge is 2.8 mg/l. This is below the regulatory limit but significant considering the possible 250,000 pounds of chromium contained in the landfill (Edwards, December 30, 1974) and sandy soil within which the landfill is situated (Froehling & Robertson, February 26, 1975 letter to A.C. Edwards from M.H. Woodward). A comparison of RMT and R&C results are included in Appendix A. Figure 8 shows the locations of samples taken in and around the Sludge Landfill.

1.2.3.5 Reedy River Floodplain

The Reedy River Floodplain was used by Cone as a solid waste landfill through the late 1960s. Historical aerial photographs and interviews with former Union Bleachery employees revealed that large portions of the Reedy River Floodplain, between the railroad tracks and the Reedy River, were used as an open dump for solid waste disposal. Coal ash from the boiler operations is one of the major constituents of the waste deposited in this area. Construction debris, including asbestos and general paper waste from offices and production floor waste, also were deposited throughout this area. Dye sludge that had collected underneath the dye ranges in the Basement of the plant and which was cleaned out during the July 4th shutdowns was deposited for many years in this area. Local residents also used this area as a waste dump for general household trash.

During the Preliminary Investigation, several groundwater, surface water, and soil sampling studies were performed and are outlined chronologically in Table 14, with sample locations shown in Figure 9. An EM31 ground conductivity survey was performed in February and March 1988. This type of geophysical survey records electrical conductivity of subsurface materials. These readings may

Table 13. RMT's results from the TCLP in mg/l.

| Parameter | Regulatory Level | Landfill Sludge SL-1 | Lagoon Sludge SL-2 | Dye Range Sludge SL-3 | Dye Range Sludge SL-4 |
|---|---|---|---|---|---|
| Arsenic | 5.00 | <0.003 | <0.01 | <0.01 | <0.003 |
| Barium | 100.00 | 0.72 | 0.59 | <0.01 | 1.3 |
| Cadmium | 1.00 | 0.008 | <0.01 | <0.01 | <0.005 |
| Chromium | 5.00 | 2.80 | 0.12 | 0.24 | 0.04 |
| Copper | -- | <0.02 | <0.01 | 0.63 | 1.1 |
| Iron | -- | 0.8 | 38.00 | 0.29 | <0.1 |
| Lead | 5.00 | <0.1 | <0.02 | 0.15 | <0.1 |
| Magnesium | -- | 13.00 | 12.00 | 13.00 | 11.0 |
| Manganese | -- | 1.1 | 4.00 | 0.63 | 0.55 |
| Mercury | 0.20 | <0.0002 | <0.002 | <0.002 | <0.0002 |
| Selenium | 1.00 | <0.003 | <0.01 | <0.01 | <0.003 |
| Silver | 5.00 | <0.01 | <0.01 | <0.01 | <10.00 |
| Zinc | -- | 8.5 | 0.24 | 1.0 | 1.3 |

Table 14. Chronology of Reedy River Floodplain sampling.

| | |
|---|---|
| 2/88-3/88 | R&C performed an EM31 ground conductivity survey. Survey lines were spaced 200 feet (+ or -) apart.<br><br>R&C took six shallow soil Samples (L1-8.5, L15-3.5, L14-2, L13-3.75, L12-2, and L12-4) for analysis of arsenic, barium, chromium, lead, mercury, selenium, silver, zinc, cyanide, phenol, VOAs, acid extractables, and base neutral extractables. |
| 6/89 | R&C sampled soils and waters from two trenches (Trenches #1 and #2) and surface waters and debris in the Reedy River Floodplain. The trench samples were analyzed for pH, chromium, arsenic, barium, lead, mercury, silver, and PCB. |
| 1/90-2/90 | R&C performed a second EM31 ground conductivity survey using anecdotal information from previous employees, aerial photos, and the previous EM31 to better locate potential waste disposal sites. |
| 2/90 | R&C sampled soils and waters from two trenches (Trenches #5 and #6) and from surface debris materials. Trench waters were analyzed for chromium, volatile solids, arsenic, barium, cadmium, lead, and mercury. Trench soils were analyzed for chromium, volatile solids, arsenic, barium, cadmium, lead, mercury, BTU/lbs, % ash, and total solids. Surface debris material and waters were sampled for pH, chromium, arsenic, barium, lead, and mercury. Tiles and insulation samples were analyzed for asbestos content. |
| 4/90 | RMT sampled soils at SS-5 located west of the approximate location of the sludge burial area. This sample was analyzed by R&C for chromium, arsenic, barium, cadmium, copper, iron, lead, magnesium, manganese, mercury, selenium, silver, and zinc. |

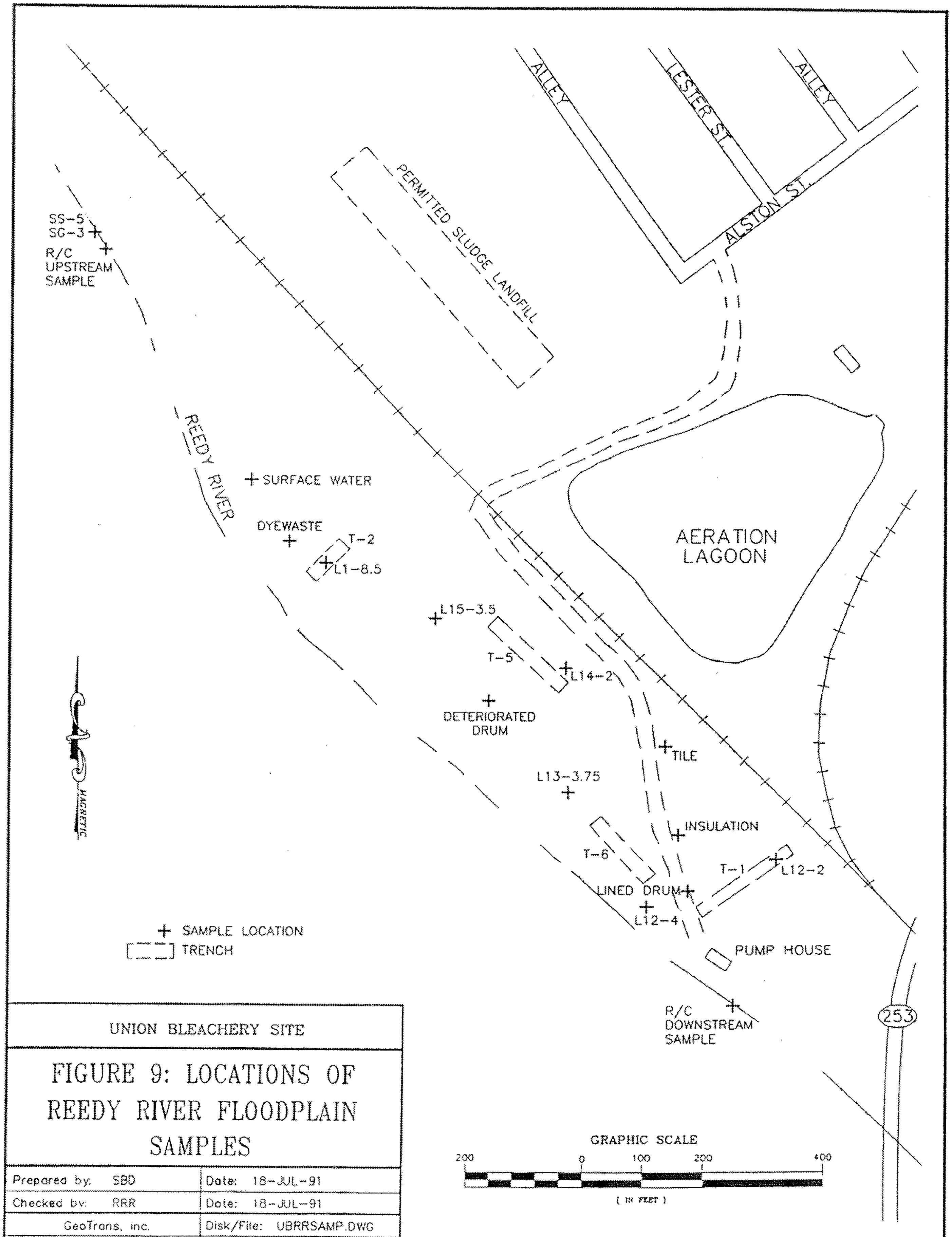



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FIGURE 9: LOCATIONS OF REEDY RIVER FLOODPLAIN SAMPLES

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be related to buried metal objects or conductive contaminant plumes. To the extent possible, high ground conductivity trends along with soil analyses were utilized to locate potential trench sites for further studies.

Soil analyses performed by R&C in February and March 1988 show evidence of elevated metal concentrations in the Reedy River Floodplain. The metals found were the same metals as found in the dye sludge from earlier operations. The elevated metal concentrations are noted when compared with a background soil location B-1, located upstream from the Reedy River Floodplain soil samples. Although elevated above background levels (B-1), none of the samples exceed proposed RCRA action levels for soils, however, a Cone sample result in 1984 prior to the sale did exceed the RCRA action level for chromium.

Based on the EM31 survey, trenches #1 and #2 were completed in June 1989. Trench #1 was located approximately 200 feet northwest of the Reedy River pump house. Various materials were detected including coal, soils, roofing materials, water, and orange silt. Soil samples had pH values ranging from 6.0 to 8.9 and chromium values from 16 to 156 mg/kg. A water and sediment grab sample from the same trench had a pH of 3.1 and a chromium level of 456 mg/kg. This exceeds the proposed RCRA action level of 400 mg/kg (Federal Register, Vol. 55, No. 145, Friday, July 27, 1990). A water grab sample taken from the same trench yielded a pH of 3.1 with a chromium level of less than 0.05 mg/l, the drinking water standard. A pH of 3.1 exceeds the bounds of a secondary MCL for pH.

Trench #2 was located 850 feet upstream from Trench #1. All samples (soil and water) yielded results within the proposed RCRA action level standards and were at levels near background levels in soil Sample B-1.

In January and February 1990 R&C performed a more detailed EM31 ground conductivity survey using knowledge gained from previous employee interviews, aerial photos, and the previous EM31 survey.

Because of the presence of disposed materials on the floodplain, surface samples of potentially contaminating materials were sampled in

February. The results of these samples show proposed RCRA action levels were exceeded in a surface water sample taken northwest of Trench #2. Levels indicated that mercury had exceeded drinking water standards (3.3 μg/l versus 2 μg/l). Samples of tiles indicated a 40% asbestos content. Results of these surface samples and the EM31 survey were used to select trench excavation locations.

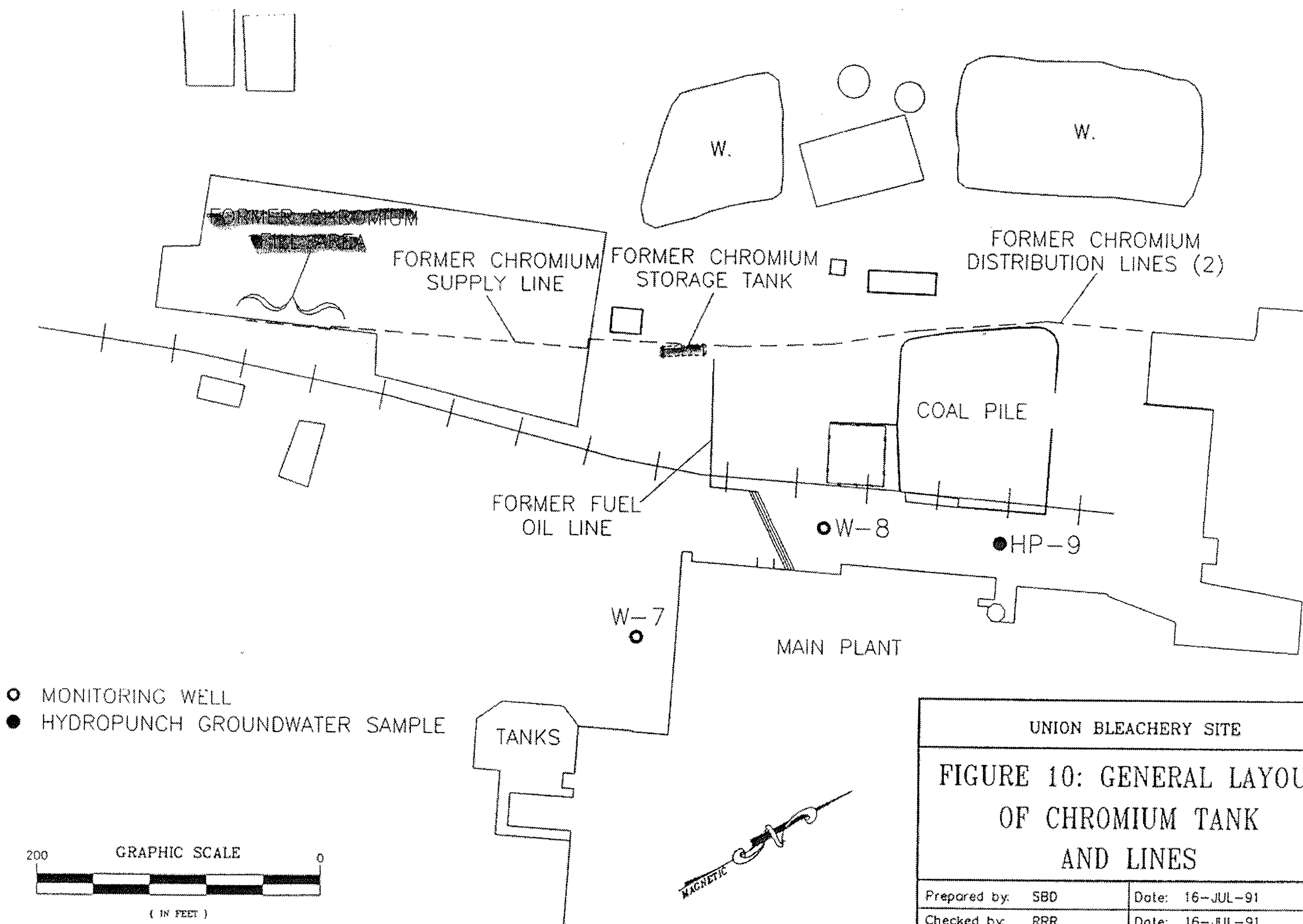
In February 1990 R&C excavated two additional trenches (Trenches #5 and #6) in the Reedy River Floodplain. Grab samples of waters in both these trenches exceeded drinking water standards for lead and chromium levels (0.05 mg/l). Trench #6, located near the Reedy River pump house, had levels of 0.35 and 0.08 mg/l for chromium and lead, respectively. Trench #5 had levels of 0.06 and 0.09 mg/l for chromium and lead, respectively. RCRA action levels are exceeded in Trench 6 for lead and Trench 5 for chromium and lead.

RMT selected soil sample location SS-5, upgradient from all other soil locations along the Reedy River. Analysis of this sample by R&C yielded results similar to background levels as detected in B-1, located up the hill from SS-5 off the floodplain.

Based on the results of the Preliminary Investigation of the Reedy River Floodplain, it appears that the landfilled materials placed on the floodplain have caused environmental damage. Because RCRA action levels have been exceeded at several locations, the floodplain presents a potential liability for present and future landowners.

1.2.3.6 Chromium Tank and Lines

Beginning in 1960, sodium dichromate was delivered to the Union Bleachery dye houses via railroad tanker cars. These railroad cars followed a railroad spur lying northwest of the Union Bleachery Plant (Figure 10). Sodium dichromate was then pumped through a two-inch diameter supply line to the 13,500 gallon chromium holding tank. As shown in Figure 10, this line traveled outside along a southeastern wall of a warehouse. At the line's entry point into the warehouse, a pump was used to pump the chromium uphill towards the chromium holding tank. This line exited the warehouse and proceeded a short distance




| | |
|---|---|
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| FIGURE 10: GENERAL LAYOUT OF CHROMIUM TANK AND LINES | |
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underground to the chromium holding tank. Chromium then was pumped from the tank and transferred to the dye house via a delivery line. Previous reports incorrectly indicated that the alignment of the chromium delivery line was oriented from the chromium tank directly to the dye house as shown in Figure 5. The line, formerly believed to be the chromium deliver line, was determined to be a former fuel line and not the chromium delivery line. Prior to its use as a chromium tank, the 13,500 gallon tank had been used as a fuel oil storage tank.

Letters and reports by both LAW and S&ME indicate that neither consultant was requested by Cone to investigate and determine the source nor did either conduct such an investigation upon its own initiative. In July 1990, an investigation was begun by AFP to determine if pipeline stub outs near the location of the former chromium tank were chromium lines.

The chromium line and tank have been suspected as the source of the chromium contamination in the Langston Creek groundwater system, even though chromium usage was discontinued in 1975. According to a letter to Mr. Arthur Toompas (Cone) from Stephen Hooper and James Kahle (LAW) dated July 15, 1982:

– in addition to basement sludge.

> "The most likely source of chromium in the groundwater was a break in the line between the old chromium storage tank and the dyeing area. The exact source of the chromium may never be known."

In July 1990, a contractor was engaged by AFP to pressurize both the old and new chromium delivery lines. The newer of the two lines (stainless steel) held, whereas the older line (carbon steel) failed to hold pressure and a seep was detected in the overlying pavement. SC DHEC and Cone were notified that chromium was discovered in these lines. Further investigation of the tank and lines was included in the RI.

1.2.3.7 Hydrocarbon Contamination

In April 1982, W-8 was installed by LAW. On the Observation Well Record, an "aroma of fuel oil in samples" was noted. In October 1987

R&C sampled W-8 and noted the odor and appearance of petroleum product in the water. In March 1988 R&C checked W-8 and noted approximately 6 inches of "free product."

In a memorandum from Mr. Richard W. Oldham (SC DHEC, Groundwater Protection Division) to Mr. Paul Wise (SC DHEC, Water Quality Assessment and Enforcement Division) dated May 2, 1988, the following is stated:

> "Strong hydrocarbon odor was observed by Department personnel (Wise, Milam and Oldham) in monitor well W-8 during the October 27, 1987 site visit. This well should be sampled and analyzed for Priority Pollutant organic compounds plus xylenes and total organic carbon. The analytical results should be submitted with the next routine monitoring report. If a hydrocarbon impact exists, the magnitude and horizontal and vertical extent will have to be determined."

The hydrocarbon does exist, and its extent was never determined by Cone.

In about September 1989 Cone collected and analyzed a sample from W-8. According to their Technical Services Report dated November 8, 1989, the sample contained 50 ppm volatiles from petroleum hydrocarbons. This sample had approximately 1 g of separate phase petroleum hydrocarbons floating on top; extraction found another 1.3 g, yielding a total of 2300 mg/l (ppm) Total Petroleum Hydrocarbons (TPH). GC/MS analysis showed this to be medium to long chain alkanes and alkanes typical of kerosene or diesel fuel. It is worth noting that MW-8 is located near a previous diesel powered fire pump site.

In about November 1989 Cone collected and analyzed a sample from W-8. According to a Cone Technical Services Report dated December 18, 1989, there was 0.4 ml separate phase petroleum hydrocarbons floating on top of 1 liter of water. There was an additional 0.4 ml petroleum hydrocarbons dissolved in the water, yielding a total of 800 ppm TPH. The petroleum hydrocarbons were a mix of alkanes and aromatics including methyl naphthalenes (not unusual for petroleum distillates).

No benzene, toluene or ethylbenzene were detected at the high sensitivity level of 500 ppb.

According to a Cone Technical Services Report dated January 15, 1990, two samples were collected from W-8 on December 18, 1989, and January 10, 1990. Neither had separate phase petroleum hydrocarbon. Both contained 0.5 ml of petroleum hydrocarbons in 1 liter of water or 500 ppm TPH. According to their February 28, 1990, Technical Services Report, a sample taken from W-8 contained 400 ppm TPH. The water had a "strong fuel smell and organic scum layer on top."

On March 6, 1990, both Cone's Consultant, RMT, and R&C sampled W-8. R&C sampled before purging the well and reported 250 mg/l (ppm) TPH; after purging the well, an additional sample was taken that contained 3600 mg/l TPH. RMT's results were 300 and 7300 mg/l, respectively. RMT stated that the "hydrocarbons present do not resemble diesel, although quantifies using a diesel standard." Cone collected another sample on March 22, 1990, that contained 250 mg/l.

According to Cone's Technical Services Report dated April 11, 1990, the water had a "strong fuel smell and organic layer on top." Cone further reported that the water contained 300 ppm TPH.

In summary, petroleum hydrocarbon has been suspected or observed in W-8 throughout its eight year history. The extent of this contamination needs to be determined.

1.2.3.8 Background Soil and Groundwater Quality

As discussed in previous sections, background conditions for groundwater and soil have been characterized at monitor well RMT-1 and soil boring B-1, respectively (Figure 8). Table 15 provides groundwater and soil quality data for these two locations. Other background wells were drilled as part of the RI and will be discussed later. As may be seen in Table 15, for groundwater, most of the constituents are below the respective detection levels. For soil, the constituents have relatively low concentrations that are within the range of concentrations of inorganic compounds in soil for Georgia, South Carolina, and North Carolina (Chronical analyses of soils and

Table 15. Background groundwater and soil quality results of 6/90 and 12/90 RMT-1 groundwater and 1/88 B-1 soil analyses.

| PARAMETER | RMT-1 (Groundwater) | | | | | | B-1 (Soil) |
|---|---|---|---|---|---|---|---|
| | 6/90 | | 12/90 | | | | 1/88 |
| | R & C (F) | RMT (F) | R & C | RMT | R & C (F) | RMT (F) | R & C * |
| Arsenic | <.01 | <.003 | <.01 | <.003 | <.01 | <.003 | 4.9 |
| Barium | .07 | .06 | .12 | .16 | .06 | .06 | 70 |
| Cadmium | <.01 | .0007 | <.01 | <.0003 | <.01 | .0004 | <1.0 |
| Chromium | <.02 | <.002 | <.02 | <.002 | <.02 | <.002 | 40 |
| Copper | <.01 | <.02 | <.01 | <.02 | <.01 | <.02 | 4.0 |
| Iron | <.02 | <.10 | --- | --- | --- | --- | --- |
| Lead | <.005 | <.003 | <.005 | .006 | <.005 | <.003 | <10 |
| Magnesium | .36 | <.50 | --- | --- | --- | --- | --- |
| Manganese | .01 | .011 | .08 | .16 | <.01 | .008 | --- |
| Mercury | <.001 | <.0002 | --- | --- | --- | --- | <0.1 |
| Selenium | <.01 | <.003 | <.01 | <.003 | <.01 | <.003 | <1.0 |
| Silver | <.01 | <.001 | <.01 | <.01 | <.01 | <.01 | <1.0 |
| Zinc | .13 | .02 | --- | --- | --- | --- | 18 |
| VOC's | --- | --- | --- | --- | --- | --- | ND |
| Semi-VOC's | --- | --- | --- | --- | --- | --- | ND |
| Phenol | --- | --- | --- | --- | --- | --- | <0.6 |
| Cyanide | --- | --- | --- | --- | --- | --- | <2.0 |
| Antimony | --- | --- | --- | --- | --- | --- | <20 |
| Beryllium | --- | --- | --- | --- | --- | --- | <1.0 |
| Nickel | --- | --- | --- | --- | --- | --- | 5.0 |
| Thallium | --- | --- | --- | --- | --- | --- | <10 |
| Alkalinity | <5.0 | <20 | --- | --- | --- | --- | --- |
| Hardness | <5.0 | 6.7 | --- | --- | --- | --- | --- |
| pH, units | 4.6 | --- | 5.0 | --- | --- | --- | --- |
| Cond, µmhos/cm | 40 | --- | 35 | --- | --- | --- | --- |
| T, C | 21 | --- | 15 | --- | --- | --- | --- |

Results in mg/l unless noted.
(F) = Filtered Sample
* Results in mg/kg
ND = Not Detected

other surficial materials of the conterminous United States, U.S. Geological Survey Report 81-197, 1981).

## 1.3 IDENTIFICATION OF OPERABLE UNITS FOR RI

Based on the suspected and known releases or threatened releases of hazardous substances discussed in Section 1.2.3, the following operable units were identified for the Remedial Investigation and Feasibility Study, Figure 11. The operable units are groupings of structures, disposal areas, and environmental media combined in order to expedite field investigations and remedial actions. Groundwater, as indicated in Figure 11, is identified as the Langston Creek Aquifer and is included as a separate operable unit, Operable Unit 9.

| | |
|---|---|
| Operable Unit 1 | Permitted Sludge Landfill |
| 2 | Aeration Lagoon |
| 3 | Reedy River Floodplain |
| 4 | Basement Sludges |
| 5 | Chromium Tank and Lines |
| 6 | Fuel Tank, Line, & W-8 |
| 7 | Caustic Plume |
| 8 | Blue Pond |
| 9 | Langston Creek Aquifer |

## 1.4 REPORT ORGANIZATION

This report is organized to facilitate the completion of the RI reporting requirements. The three sections of the report follow the suggested RI report format contained in the "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (EPA, 1988). Section 2 discusses the field activities associated with the site characterization; Section 3 provides the physical and chemical results of the field investigation.

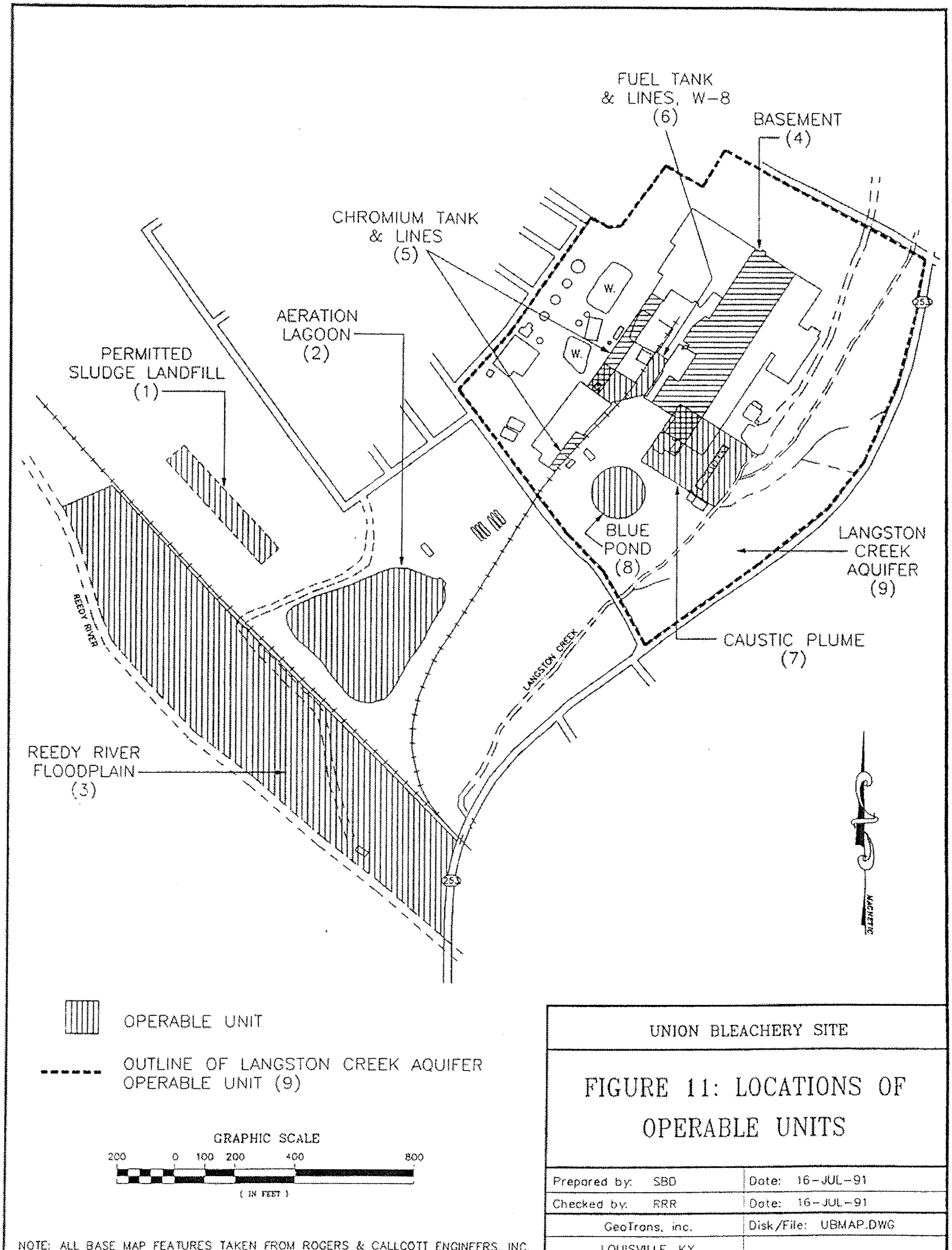
FUEL TANK & LINES, W-8 (6)
BASEMENT (4)
CHROMIUM TANK & LINES (5)
AERATION LAGOON (2)
PERMITTED SLUDGE LANDFILL (1)
BLUE POND (8)
LANGSTON CREEK AQUIFER (9)
CAUSTIC PLUME (7)
REEDY RIVER FLOODPLAIN (3)
REEDY RIVER
LANGSTON CREEK
OPERABLE UNIT
OUTLINE OF LANGSTON CREEK AQUIFER OPERABLE UNIT (9)
GRAPHIC SCALE
200 0 100 200 400 800
( IN FEET )
MAGNETIC
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FIGURE 11: LOCATIONS OF OPERABLE UNITS
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# 2 REMEDIAL INVESTIGATION

This section of the report describes the RI field investigations performed at the Union Bleachery site. The number and locations of monitor wells and soil borings, as well as surface samples are described for each operable unit. Because of the extensive laboratory analyses performed on the varying sample types, the descriptions of these analyses are referenced by each operable unit to the constituents listed in Table 16. The results of all sample analyses performed during the RI are presented and discussed in the next section (Section 3) of this report.

All sample collection, sample handling, and equipment decontamination procedures have been previously described in detail in GeoTrans Work Plans and Quality Assurance Plans submitted for the site (GeoTrans, 1990a, 1990b, 1991a). Therefore, these procedures are not discussed in the following presentation unless not previously addressed.

## 2.1 CONTAMINANT SOURCE INVESTIGATIONS

Sampling of soils, sludges, and/or contaminants was conducted at Operable Units one through eight to determine the nature and extent of contamination in the unsaturated zone above the water-table. Monitor wells were installed to determine if releases from the operable units to groundwater had occurred and if so, to determine the nature and extent of contamination.

Monitor wells that were installed in the Langston Creek Floodplain where the contaminant source was not clear, are discussed in Section 2.2. The scope of work performed at each operable unit is discussed below.

### 2.1.1 Permitted Sludge Landfill (Operable Unit 1)

Soil boring and sampling were conducted at the four locations designated with LB in Figure 12. The purpose of this sampling was to characterize the buried sludge through the collection and analyses of

Table 16. Union Bleachery site RI groundwater analyses.

| Metals | Anions |
|---|---|
| • Arsenic | • Sulfate |
| • Barium | • Chloride |
| • Cadmium | • Nitrate |
| • Total Chromium | • Phosphate |
| • Hexavalent Chromium | • Alkalinity |
| • Iron (II, III) | Others |
| • Lead | • Total Organic Carbon |
| • Mercury | • Total Dissolved Solids |
| • Selenium | • Total Suspended Solids |
| • Silver | • Volatile Organic Compounds |
| • Copper | |
| • Manganese | • Acid and Base Neutral Extractable Compounds |
| • Asbestos | |
| • Magnesium | Field Parameters |
| • Magnesium | • pH |
| • Calcium | • Eh |
| • Sodium | • Dissolved Oxygen |
| • Potassium | • Temperature |
| | • Conductivity |
| | • Turbidity |

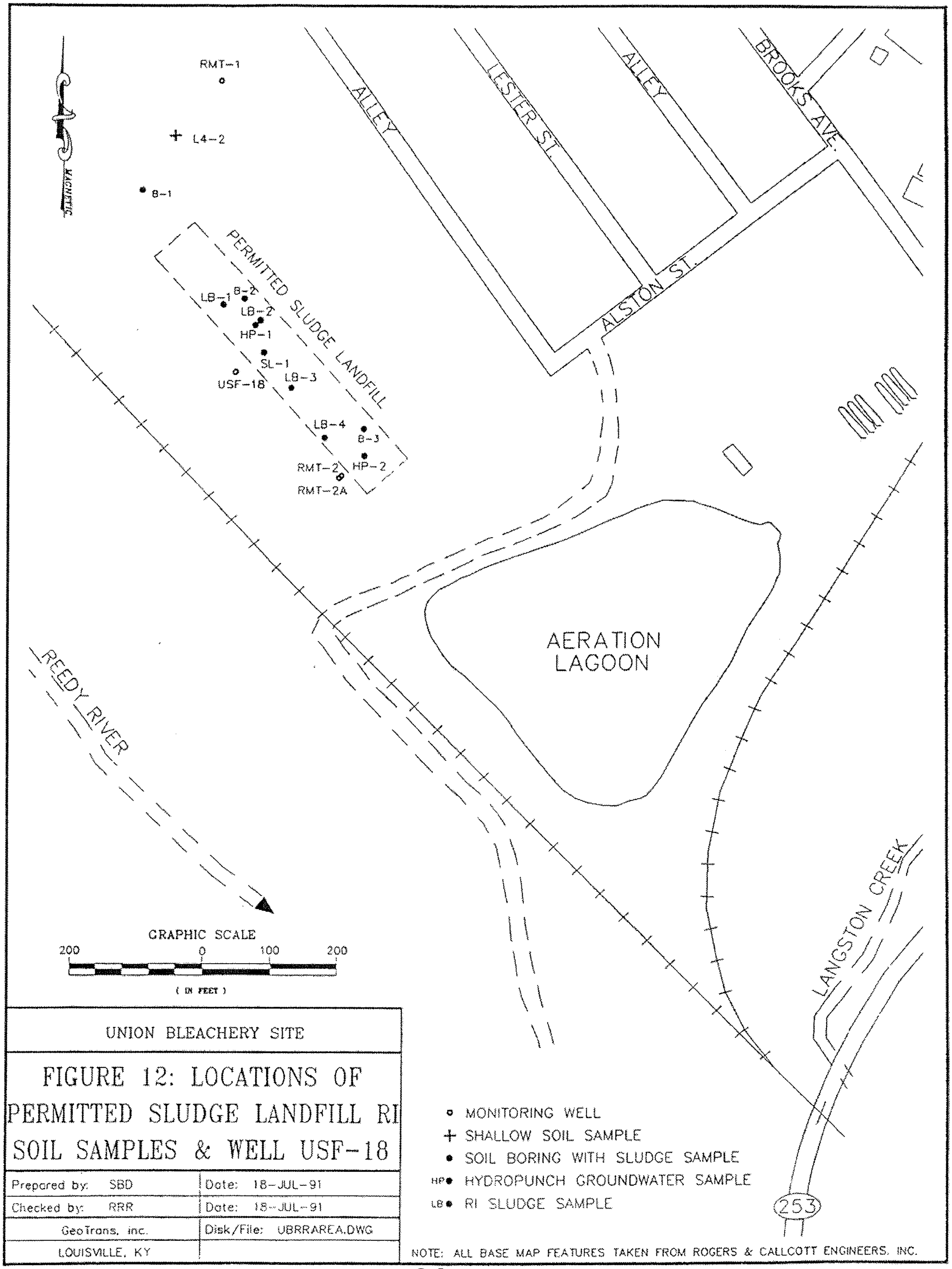


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FIGURE 12: LOCATIONS OF PERMITTED SLUDGE LANDFILL RI SOIL SAMPLES & WELL USF-18

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a representative number of samples. Sludge samples were analyzed for metals and Toxic Characteristic Leaching Procedure (TCLP) metals.

Monitor well USF-18 was installed by AFP on March 28, 1991 as a water-table well to complete the characterization of groundwater downgradient of the landfill. Well specifications for USF-18 are provided in Table C (Appendix C) and a well construction as-built diagram is included in Appendix C. Groundwater was sampled in April 1991 and analyzed for Table 16 constituents minus organics and asbestos to identify effects of the buried sludge.

### 2.1.2 Aeration Lagoon (Operable Unit 2)

A study to determine the volume and compositional characteristics of sludge in the Aeration Lagoon was conducted as part of the RI in the Spring of 1990. Aeration basin volume was calculated by a field survey of the water surface and by using a typical bank slope and water depth. Suspended and settled sludge was sampled on February 5, 1991, at approximately thirty locations in the basin. Samples were taken with a long clear plastic sampler ("sludge judge"), which provided a cross section of the entire liquid and sludge depth at the sample point. These samples were composited into four 5-gallon containers. A mixed sample of each container was analyzed for total suspended solids and total volatile suspended solids. Suspended sludge from the 5-gallon samples was dewatered by filtration. Fifteen gallons of sample were filtered through a pilot filter of approximately 6 inches of sand with effective size of 0.92 to 0.99 mm. Solids retained on the filter were allowed to air dry for 10 days. The sample of composite sludge was analyzed for metals and TCLP. Figure 13 identifies the locations of data collected during the RI and Preliminary Investigations for the Aeration Lagoon.

### 2.1.3 Reedy River Floodplain (Operable Unit 3)

#### 2.1.3.1 Groundwater Investigation

Three monitor wells were installed in September 1990 by AFP to characterize groundwater conditions in the Reedy River Floodplain.

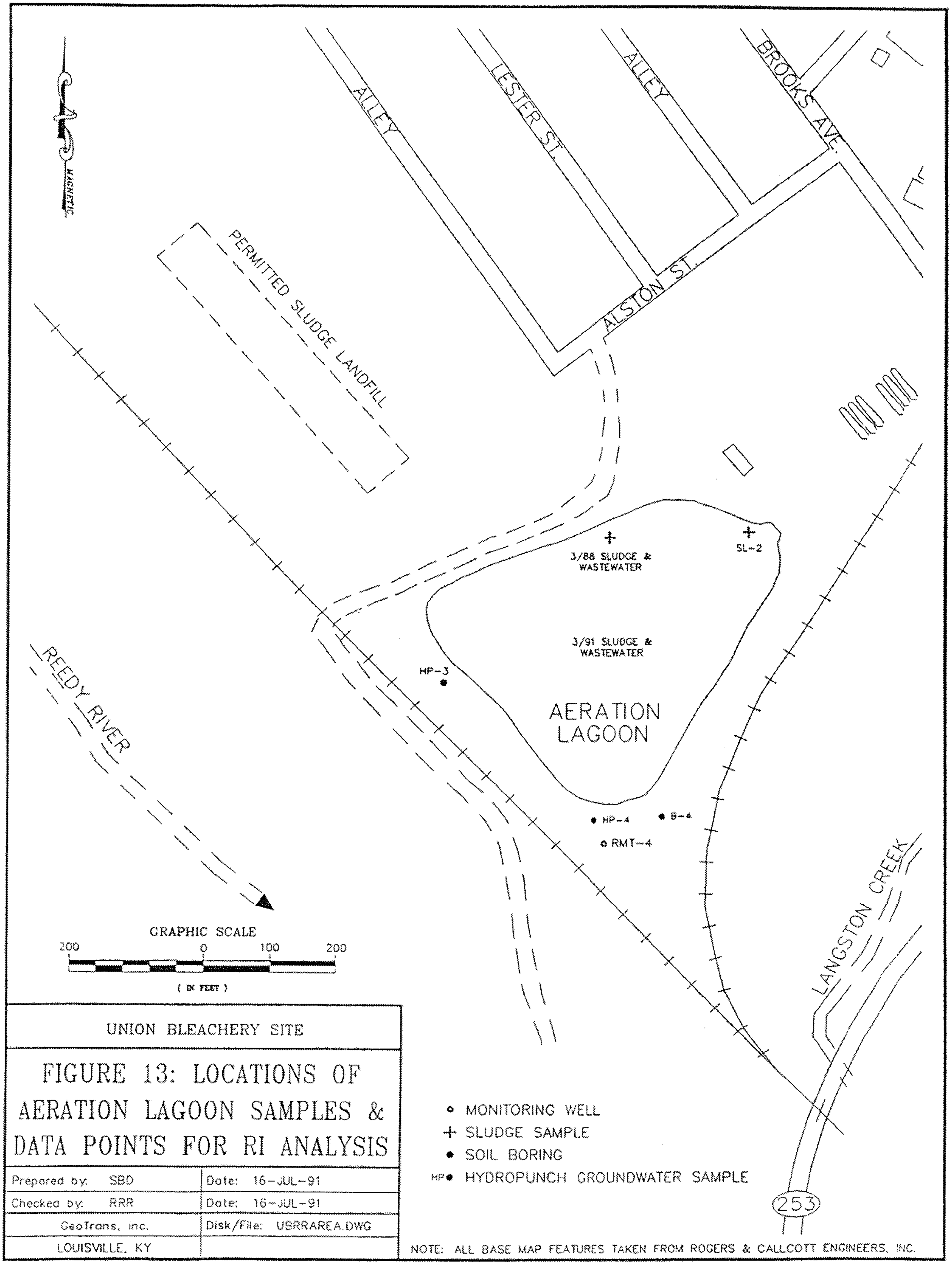


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FIGURE 13: LOCATIONS OF AERATION LAGOON SAMPLES & DATA POINTS FOR RI ANALYSIS

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Wells USF 1, 2, and 3 are completed within the water-table zone of the aquifer with screened intervals between 4 and 14 feet below landsurface. Well specifications are provided in Table C (Appendix C) and well construction as-built diagrams are included in Appendix C. Figure 14 illustrates the locations of these USF wells and previous sample locations. Groundwater from USF Wells 1, 2, and 3 was sampled on three occasions; 9/90, 12/90, and 4/91. Analyses included metals, VOAs, base neutrals and acids (BNAs), and asbestos.

VOC's?

2.1.3.2 Air Investigation

An aggressive air sampling of asbestos tile exposures was conducted in June 1991. The purpose of this sampling was to evaluate air migration of asbestos fibers. These samples were collected on June 16, 1991 and analyzed using Transmission Electron Microscopy (TEM) as per the Asbestos Hazard Response Act (AHERA), 40 CFR Part 763. TEM was the analysis method used because it is capable of quantifying the asbestos fibers concentration in the air.

Initial inspection of the site indicated that at least three major areas contained tile suspected of containing asbestos. Cone employees stated that this material was transite insulation originating from dye range hood insulation that was disposed of in the landfill during dye range renovations. As per the National Emission Standard for Hazardous Air Pollutants (NESHAP), the tile debris was classified as Category I, non-friable asbestos transite, which is a regulated material.

One TEM sample was collected in each area shown in Figure 14. A summary of the sample locations is presented below.

| Sample No. | Location |
|---|---|
| 01 | Hill area with tiles |
| 02 | Road area with tiles |
| 03 | Railroad track area with tiles |

The sample locations were selected randomly but in close proximity to the three identified areas. The actual sample media was positioned

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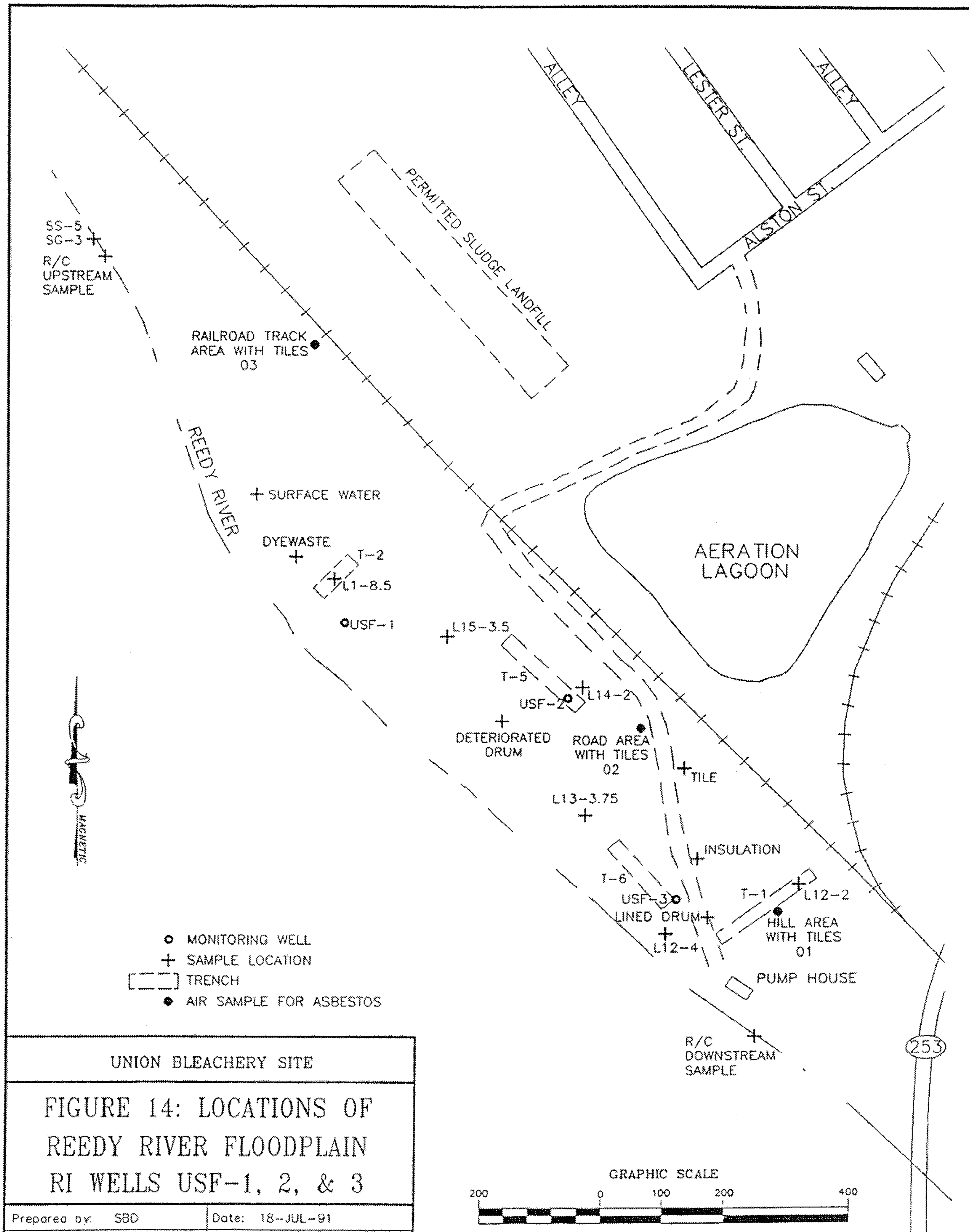


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FIGURE 14: LOCATIONS OF REEDY RIVER FLOODPLAIN RI WELLS USF-1, 2, & 3

| | |
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downward and approximately 5 feet from the ground. Aggressive walking within the subject areas was performed during the sampling to simulate human activity. Samples were collected for TEM analysis on 0.45 micrometer pore size, mixed cellulose filters. Air was drawn through the filter media using battery-operated air sampling pumps calibrated to collect a known volume of air. The pumps are calibrated using a precision rotometer traceable to a primary standard. The samples were sealed immediately after collection and transported to the laboratory for analysis. A detailed description of the asbestos sampling is included in Appendix E.

2.1.3.3 Surface Water Investigation

Surface water from the Reedy River was sampled twice: 9/90 and 4/91. Analyses included metals, organics, and asbestos. As it was determined that friable asbestos containing materials were buried in the Reedy River Floodplain, analyses of Reedy River water was required to determine if asbestos fibers were being discharged to the surface water. Two grab samples from the Reedy River, one upstream of the floodplain unit and one downstream of the floodplain unit (Figure 14), were collected on April 10, 1991. Analyses of these samples included turbidity and asbestos fibers. An ecological study was also conducted in the Reedy River and is described in Section 2.2.3.

2.1.4 <u>Basement (Operable Unit 4)</u>

A two-phase RI characterization of the sludge, shallow soils, and shallow groundwater within the Basement of the Union Bleachery facility was completed. The purpose of this investigation was to determine sludge composition, volume of sludge remaining in the Basement, and the environmental effects of the sludge.

The first phase of this investigation, conducted in August 1990, included six soil borings, samplings and analyses locations for shallow soils underlying the surficial sludge layer. As part of this phase, six shallow groundwater samples were collected via the hydropunch method in the soil borings. Soil and groundwater samples were analyzed for metals. The locations of these soil borings, designated HP-7 through HP-12, are shown in Figure 15.

In January 1991, a comprehensive sludge sampling and analysis was conducted as the second phase of the RI Basement sludge characterization. Approximately 45 sludge samples were collected and analyzed to determine the nature and extent of sludge beneath the facility. Samples were first analyzed for metals. Subsequently, samples with high metals concentrations were analyzed for TCLP. The locations of these Basement sludge samples are also shown in Figure 15.

2.1.5 Chromium Tank and Lines (Operable Unit 5)

To assess the chromium contamination related to the chromium tank, the chromium supply lines and delivery lines, a series of chromium line fluid sampling, shallow and deep soil sampling and groundwater sampling were performed (Table 17).

Cone hired Bryson Industries to clean out two of the chromium lines on August 27, 1990. R&C representatives were present for observations and split sampling. Fluids evacuated from both chromium lines were combined. A fluid sample from these lines was provided to R&C and RMT by Bryson. Analysis of the sample confirmed that the liquid was highly concentrated sodium dichromate with hexavalent chromium levels up to 405,000 mg/l.

The seep in the pavement discovered July 17, 1990, was excavated down to the fuel oil line, 3 feet below ground surface. A soil sample was split by R&C and RMT from a tight clay where there was evidence of a corrosion induced pinhole in the old fuel line. Total chromium levels here were measured at 20 to 54.9 mg/kg (Table 18), which are at background concentration for the plant. The excavated seep in the pavement coincided with an old fuel line which crossed the chromium delivery lines. Because the chromium holding tank had been used previously as a fuel tank, the old fuel line was suspect for chromium migration. Field and excavation tests of the fuel line confirmed that this pipe was not connected to the chromium system.

Table 17. Chronology of chromium tank and line investigations.

| | |
|---|---|
| 7/90 | Chromium delivery lines were pressurized. Older of two (2) lines did not hold pressure. Chromium discovered in chromium delivery lines. |
| 8/27/90 | RMT evacuated two chromium lines. RMT and R&C split soil and chromium line fluid samples. These samples were analyzed for total chromium and hexavalent chromium, respectively. |
| 10/1/90 | Four (4) soil samples from the CFA were taken and analyzed for total chromium by R&C. |
| 10/8-12/90 | Four Seasons removed chromium from and cleaned the chromium delivery and supply lines. Chromium delivery lines were pressurized with helium and a helium detector was used to locate leaks within the chromium delivery lines. |
| 10/16/90 | Soil samples from the single detected helium leak were taken and split by R&C and RMT. |
| 12/90-1/91 | Characterize and remove stainless steel and galvanized chromium delivery lines. Collect shallow soil samples in pipeline trench, beneath asphalt loading area, and in the CFA. Soil samples field screened for hexavalent chromium, and selectively analyzed for total chromium and TCLP chromium. |
| 1/16-25/91 | Drill and sample five (5) borings along alignment of CDL for vertical extent of chromium contamination in the unsaturated zone. Drill and sample three (3) borings in the CFA for vertical extent. Soil samples field screened for hexavalent chromium, and selectively analyzed for total chromium and TCLP chromium. |
| 2/91 | Sample Wells: USF-4, 5, 6, 7, 8, and 9 installed for nature and extent of contamination from chromium tank and lines. Groundwater analyses included metals. |
| 4/91 | Sample Wells: USF-9A, 15, and 24 installed for nature and extent of contamination from chromium tank and lines. Groundwater analyses included metals. |
| 1/91-2/91 | Drill and sample soil borings for nature and extent of contamination from chromium tank and lines. Soil samples field screened for hexavalent chromium, and selectively analyzed for total chromium and TCLP chromium. |

– Some wells were screened too deep to detect floating constituents.

Table 18. Chromium analyses related to chromium holding tank and associated lines.

Soil Samples

| Sample Description | Sample Date | Total Chromium Concentration (mg/kg)[1] |
|---|---|---|
| Fuel/chromium line excavation | 8/27/90 | 20[2]/54.9[3] |
| Chromium fill area #1 depth 0-6 inches | 10/1/90 | 6900[2] |
| Chromium fill area #1 depth 6-10 inches | 10/1/90 | 4700[2] |
| Chromium fill area #2 depth 0-6 inches | 10/1/90 | 4700[2] |
| Chromium fill area #2 depth 6-10 inches | 10/1/90 | 2400[2] |
| Old chromium line, soil composite above leak[5] | 10/16/90 | 11[2] |
| Old chromium line soil composite below leak[5] | 10/16/90 | 2980[2] |
| Old chromium line leak[5] | 10/16/90 | 2600[3] |

Water/Fluid Samples

| Sample Description | Sample Date | Hexavalent Chromium Concentration (mg/l)[4] |
|---|---|---|
| Fluids from chromium delivery lines | 8/27/90 | 285,000[2] |
| Fluids from chromium delivery lines | 8/27/90 | 405,000[3] |

[1]National Action Level is 400 mg/kg (Federal Register, 55(145)).
[2]Rogers & Callcott Engineers, Inc.
[3]RMT Laboratories
[4]National Drinking Water Standard is 0.05 mg/l
[5]Sample location corresponds to station CDL-9+7.6, Figure 16.

On October 1, 1990, four soil samples were taken in the area where chromium was delivered by rail car. This area was designated as the chromium fill area (CFA). These samples were taken at the chromium input location from soil beneath the terminus of the chromium tank fill line and from discolored soil beneath the chromium tank fill pump where the chromium line enters the warehouse. Shallow samples at 0 to 6 inches and 6 to 10 inches were taken; levels of total chromium ranged from 2400 to 6900 mg/kg. In addition, a TCLP analysis was performed on the top 6 inches of Sample CFA-1. The chromium TCLP concentration was 6.8 mg/l, which is above the regulatory level and thus this soil is a characteristic hazardous waste.

During the week of October 8-12, 1990, the chromium delivery lines were pressurized with helium, and a helium detector was used to locate leaks within the chromium lines. Only one helium leak was detected and on October 16, 1990, an excavation was made to locate the section of leaking pipe. A soil composite from each backhoe bucket removed above the located leak was taken by R&C. This composite represents about an 8-foot horizontal profile because the leak was not found immediately. A quarter-inch diameter leak was found in the old carbon steel chromium delivery line. An additional sample was taken below the chromium line leak location. Total chromium analysis of the sample above the chromium line had a level of 11 mg/kg whereas total chromium levels below the chromium line showed levels of 2600 to 2980 mg/kg.

AFP hired Four Seasons Company to remove the two chromium distribution lines (CDLs) in December 1990. Work performed by Four Seasons included removal of remaining chromium from the lines and cleaning of the lines, pressure testing the carbon steel line to determine the nature and extent of holes and breaks, and subsequent removal of both lines. R&C personnel with assistance from GeoTrans logged the locations of the pipeline breaks and collected soil samples from the pipeline trench for field screening for hexavalent chromium and subsequent selective analyses of total chromium and TCLP for chromium. The length of the CDL was divided in stations separated by 10-foot intervals for sample identification. Station 1 (Trench Sample

CDL-1) was located at the south end of the pipeline trench as shown in Figure 16, at the start of the pipeline from the chromium tank location. Station 2 (Sample CDL-2) was located 10 feet north of Station 1. Station 32 was located at the north end of the pipeline trench where the pipeline formerly exited the subsurface and traveled above grade. Remnants of the above grade portion of the pipeline can still be identified attached to the plant walls. Soil samples were also collected where breaks or holes in the pipeline or other concerns were identified during pipeline removal. These samples are identified by the distance in feet north of the nearest station. For example, a sample collected 6 feet north of Station 10 is designated CDL-10+6.0 as shown in Figure 16. Also, shallow soil samples were collected from beneath the asphalt loading area to the east of the chromium tank and lines to determine if the interface of the asphalt and the native soils provided a preferential pathway for chromium migration. The locations of these samples labelled A1 through A20 are shown in Figure 16. Pipeline removal and shallow soil sampling continued from December 19, 1990 through January 9, 1991. Shallow soil samples were collected from the chromium fill area (CFA) where shown in Figure 17. These samples were collected from the top 6 inches of surface soil to determine areal extent of chromium contamination. These soil samples were also field screened for hexavalent chromium and subsequent selective analyses of total chromium and TCLP for chromium. Approximately 84 soil samples were collected and analyzed during this first stage of the chromium tank and line investigation.

Based upon the review of the shallow soil sampling results, five areas of contamination were identified along the CDL for further investigation. In January 1991 five soil borings (CDL-1, 11+5, 14+2, 17+9, and 20+3.7) were drilled and sampled where shown in Figure 16 to determine the vertical extent of chromium contamination beneath the chromium lines. Three borings were also installed in the CFA (CFA-1B, 2B, and 14B) to determine vertical extent of chromium contamination where shown in Figure 17. Split-spoon samples were collected and soil samples were field screened for hexavalent chromium and subsequent selective analyses for total chromium and TCLP for chromium.

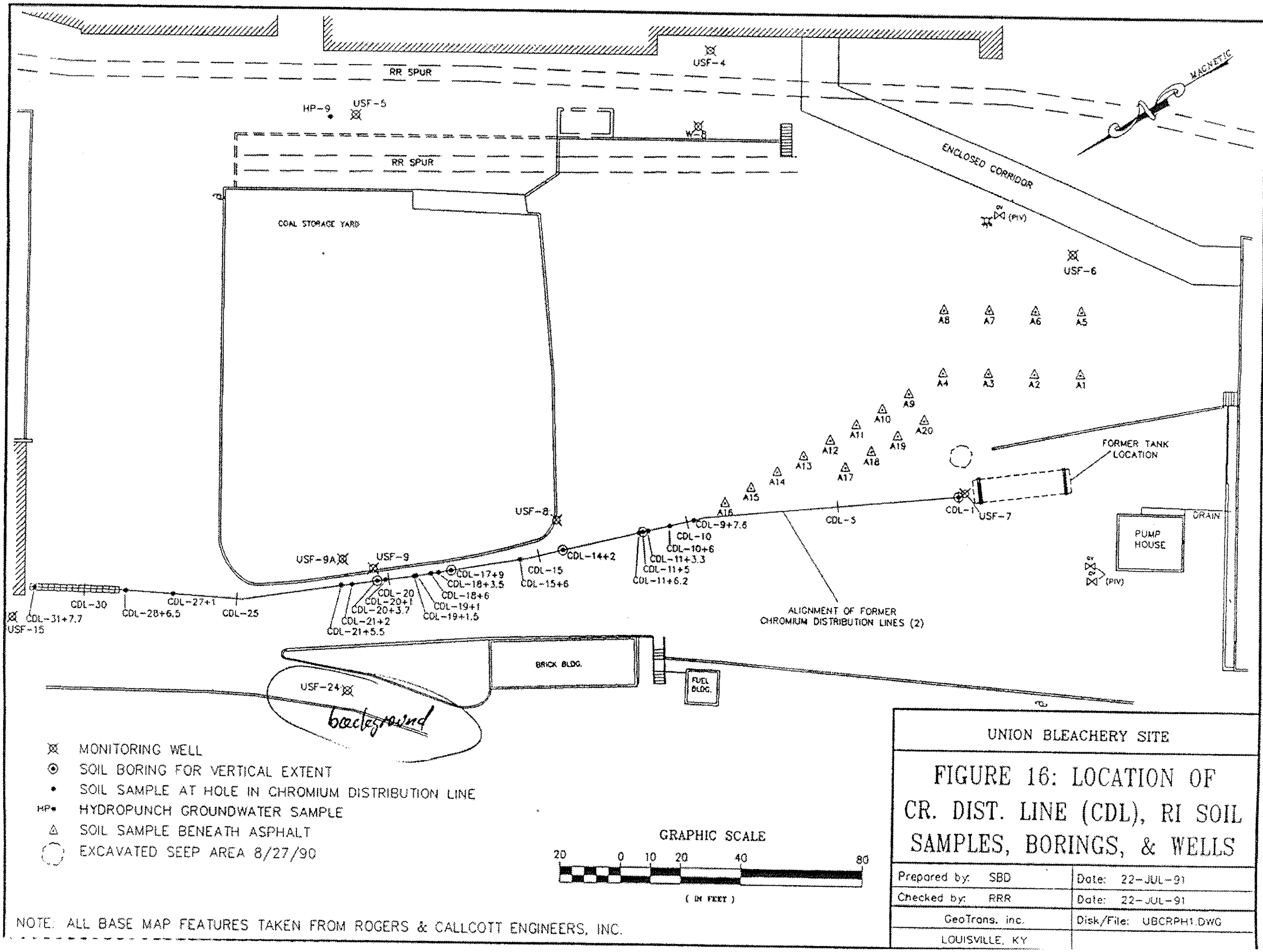


FIGURE 16: LOCATION OF CR. DIST. LINE (CDL), RI SOIL SAMPLES, BORINGS, & WELLS

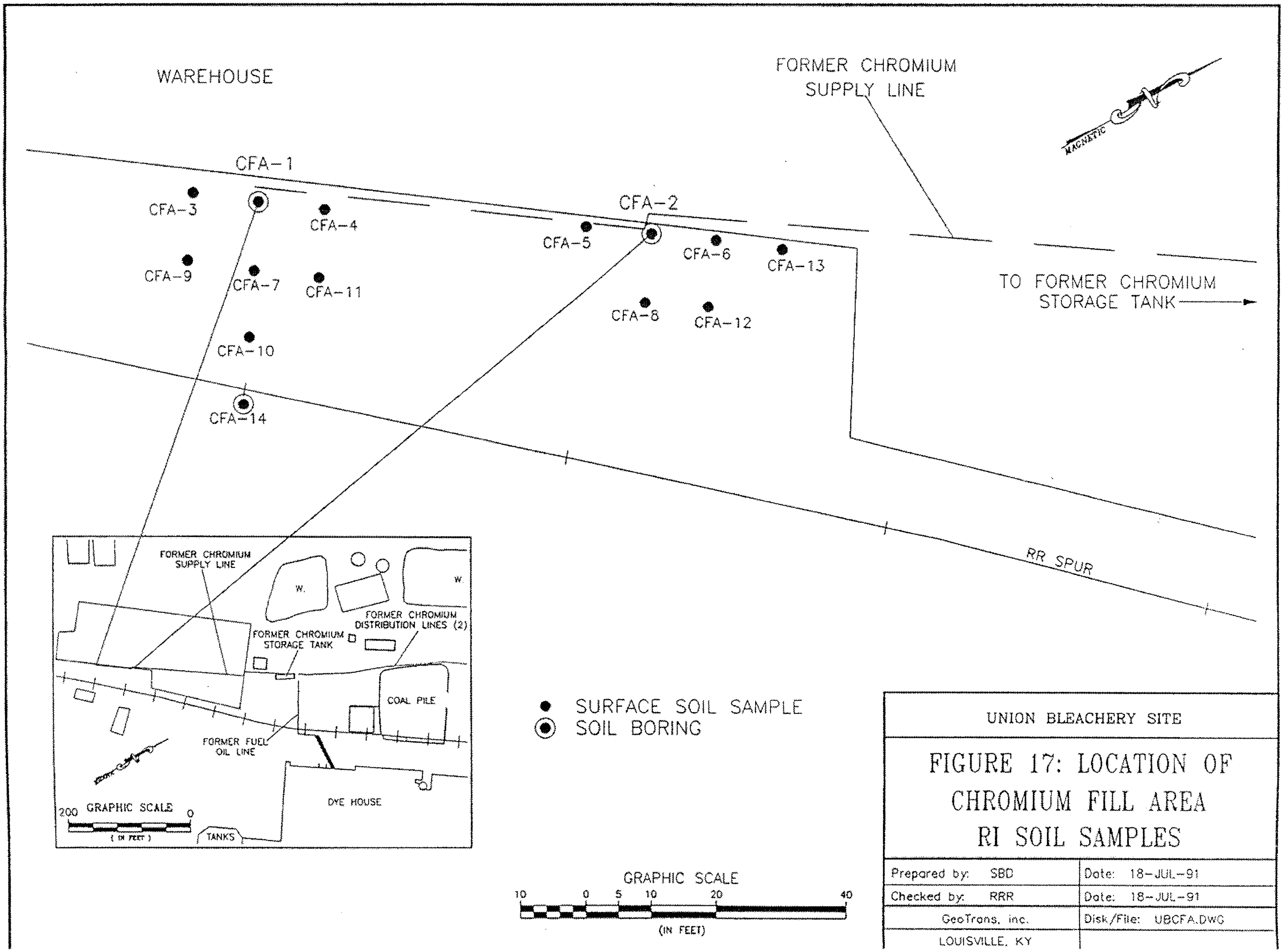


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FIGURE 17: LOCATION OF CHROMIUM FILL AREA RI SOIL SAMPLES

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The third and final stage of the nature and extent of chromium contamination in soils was investigated from January through March 1991. Approximately 79 soil borings were installed east and west of the chromium tank and lines to determine the areal and vertical extent of contamination. Soil borings installed adjacent to the former chromium tank location were designated CT borings. Soil borings that were installed as offset borings from the former chromium tank location were designated CT-#/#E or W. The first # after the CT- indicates where in relation to the former tank the offset boring was, and the # after the slash (/) indicates the distance from the tank location in feet of the boring to the east or west. Soil borings that were installed as offset borings from the CDLs were designated CDLB-#/#E or W. The # and direction designators followed the rules for the chromium tank offset borings. The locations of offset soil borings installed for nature and extent of chromium contamination are shown in Figures 18 and 19. Split-spoon samples were collected and soil samples adjacent to the distribution lines were field screened for hexavalent chromium and selective analyses for total chromium and TCLP for chromium. Because it was determined that the chromium tank historically was used for both fuel and chromium, split-spoon samples in proximity to the former tank location were selectively analyzed for chromium, TCLP for chromium, and Total Petroleum Hydrocarbons (TPH).

In conjunction with the nature and extent of chromium contamination in soils, a parallel investigation was initiated for chromium contamination in groundwater after releases from the CDLs had been verified. Three shallow Monitor Wells (USF-7, 8, and 9) were installed at locations along the alignment of the pipelines where chromium soil contamination was evident to the depth of groundwater (approximately 12 feet below land surface). USF-7 was installed on January 16, 1991 adjacent to soil boring location CDL-1. USF-8 was installed on January 16 adjacent to soil boring location CDL-14+2. USF-9 was installed on January 17 adjacent to soil boring location CDL-20+3.7. These wells were constructed to intercept the shallow water table. Well specifications for all USF wells are provided in

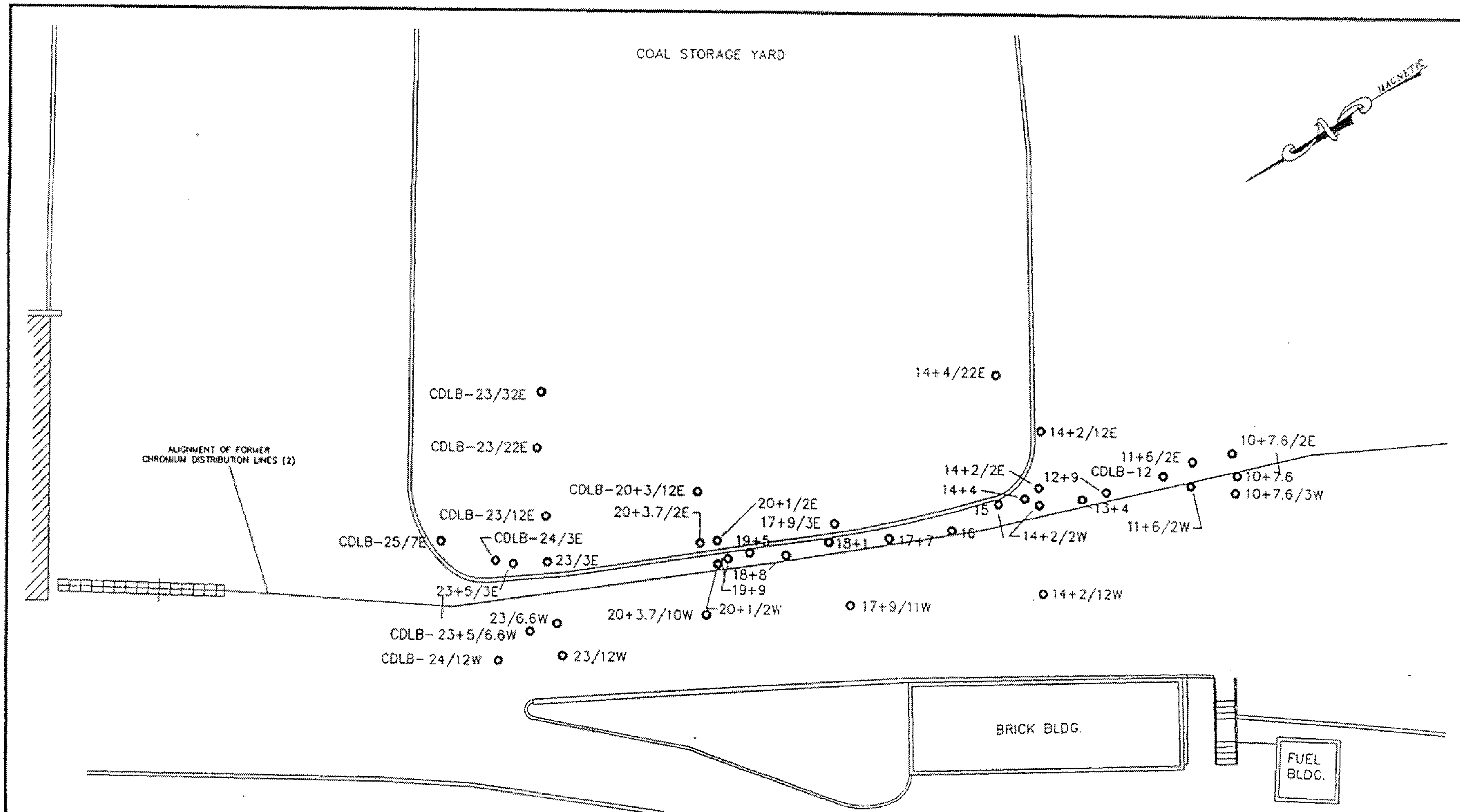


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FIGURE 18: LOCATION OF OFFSET RI BORINGS NEAR THE CHROMIUM DISTRIBUTION LINES

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GRAPHIC SCALE

20 0 10 20

( IN FEET )

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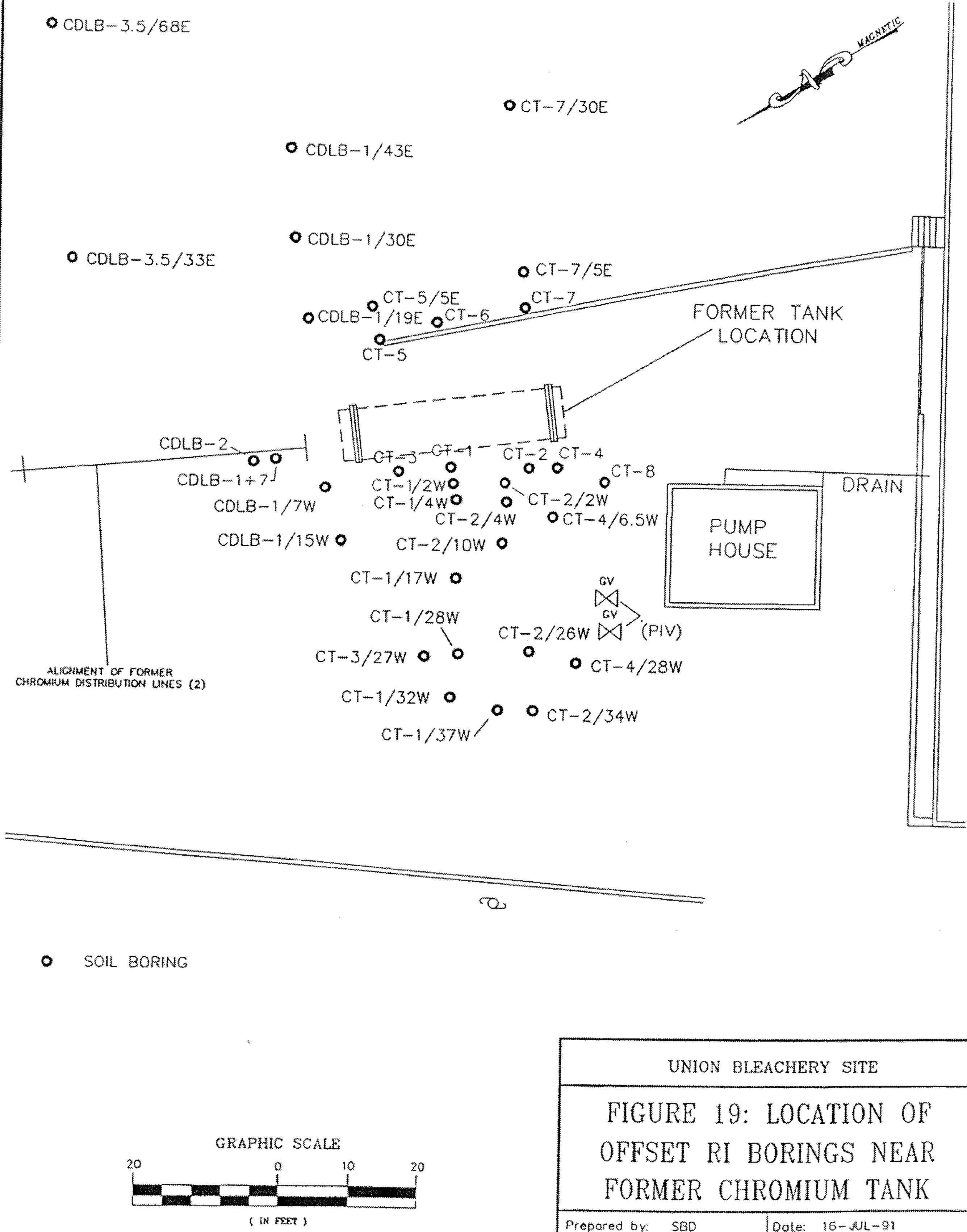


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FIGURE 19: LOCATION OF OFFSET RI BORINGS NEAR FORMER CHROMIUM TANK

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Table C and well construction as-built diagrams are included in Appendix C. Locations of these wells are shown in Figure 16. These wells were reconnaissance sampled and analyzed for hexavalent and total chromium in order to determine the need for additional nature-and-extent wells.

In January and February, Monitor Wells USF-4, 5, and 6 were installed downgradient to the east, to provide groundwater information regarding the extent of chromium contamination from the chromium tank and lines. The location of these wells is shown in Figure 16. These wells were constructed as LS wells at the top of the bedrock interface determined by auger refusal (approximately 45 to 50 feet below land surface). Well USF-4 was installed on January 9, 1991 and constructed as a LS well due to the availability of shallow groundwater samples from Well W-8. Well USF-5 was installed on February 5, and constructed as a LS well due to the availability of a shallow groundwater sample from Hydropunch location HP-9. During the construction of USF-6 as a LS well on February 5 a shallow groundwater sample was collected via the hydropunch method from a depth of 13-14 feet (USF-6 13-14') and analyzed for total and hexavalent chromium and TPH.

Groundwater samples were collected from Wells USF-4 through USF-9 in February. Samples were analyzed for constituents listed in Table 16 minus organics, TOC, TDS, and asbestos. Wells USF-4, 5, 6, and 7 included TPH analyses.

In March and April 1991 three final wells were installed where shown in Figure 16 to complete the nature and extent of chromium contamination from the CDLs to the west of the plant building. The first Well (USF-9A) was installed on March 21 adjacent to USF-9 on the CDL and is a LS well. This location corresponds to a confirmed leak in the chromium line. USF-9A was installed to determine the vertical extent of groundwater impacted at this location. The second Well (USF-24) was installed on April 4 as a background water-table well approximately 50 feet upgradient (west) of USF-9. The third Well (USF-15) was installed on March 21 in proximity of soil Sample CDL-32, approximately 120 feet north along the CDL from Well USF-9, and is also a water-table well. USF-15 was installed to determine the extent of groundwater impacted to the north, from the pipeline release identified in the area of Station 20+3.7.

Groundwater samples were collected from Wells USF-9A through USF-24 in April. Samples were analyzed for constituents listed in Table 16 minus organics and asbestos.

2.1.6 Fuel Tank, Line, and W-8 (Operable Unit 6)

In order to determine the nature and extent of contamination from Cone Well W-8, a RI field investigation was conducted. During the investigation of Operable Unit 5, the chromium tank and lines, additional petroleum hydrocarbon contamination was discovered to also originate from the former tank location. This section describes work performed at both Cone Well W-8 and the former fuel tank (chromium tank location).

2.1.6.1 Well W-8

To determine the nature and extent of TPH contamination around W-8, three soil borings were drilled and sampled to a depth of 14 feet below land surface. These borings are numbered W-8/27N, W-8/30W, and W-8/20S; and their locations are shown in Figure 20. The depth to groundwater at well W-8 is approximately 6 feet beneath land surface. Split-spoon samples were noted for visual and olfactory evidence of contamination, and selected samples were submitted to the laboratory for TPH analyses.

2.1.6.2 Former Fuel Tank And Line

During the investigation of the former chromium tank location, Operable Unit 5, subsurface borings were installed and field observations of fuel oil contamination were noted. Prior to conversion for use as a chromium tank in 1960, the tank was used for fuel oil storage. The duration of fuel oil storage is uncertain although the tank was installed sometime after June 1956. In addition, the subsurface pipeline that was historically identified as

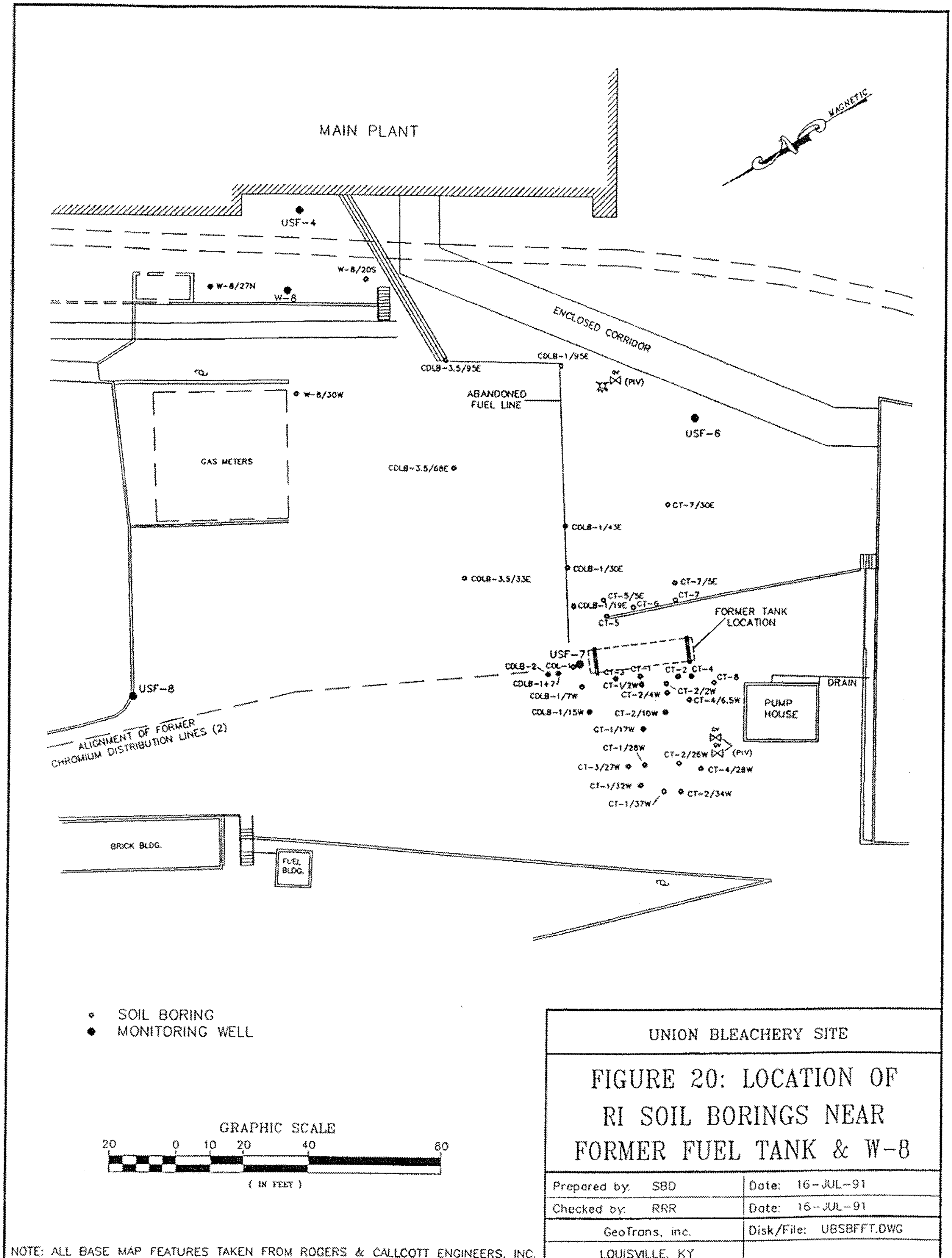


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FIGURE 20: LOCATION OF RI SOIL BORINGS NEAR FORMER FUEL TANK & W-8

a chromium line (Figure 20) was determined to be an abandoned fuel oil distribution line.

To determine the nature and extent of fuel oil (and chromium) contamination in soils in this area, a series of borings was installed and split-spoon sampled as described in Section 2.1.5. Visual and olfactory evidence of petroleum hydrocarbon contamination were noted, and selected samples were submitted for confirmatory TPH analysis. Figure 20 illustrates the soil sampling locations in the vicinity of the former tank location for which data were collected for petroleum hydrocarbon contamination. The boring identification numbers follow the same format as those described for the chromium investigation.

TPH was also analyzed from groundwater samples at USF-7 and the shallow Hydropunch Sample from USF-6, which were installed during the chromium investigation.

### 2.1.7 Caustic Plume (Operable Unit 7)

Caustic contamination was discovered by Cone in Wells W-3 and W-14 in 1982. There are no reports of efforts by Cone to determine either the source or extent of this contamination. These wells are located downgradient of the caustic recovery tanks and these tanks were generally believed to be the source of this contamination. AFP placed wells and borings upgradient of these caustic recovery tanks to determine whether either the Cone preparation activities, which reportedly discharged large quantities of caustic into the basement, or the caustic supply tanks, which reportedly leaked, were sources.

In order to determine the source and to characterize the nature and extent of the caustic plume historically identified in the shallow groundwater of the Langston Creek Aquifer by Cone Wells W-3 and W-14, and R&C Trenches #3 & #4, soil sampling and monitor wells were installed. Six soil borings designated CSTB-# were drilled and split-spoon sampled where shown in Figure 21. Soil samples were analyzed for pH and the results were utilized to locate Monitor Well USF-11. Well USF-11 was installed on January 22. Well USF-12 was installed in between the dye house and circular caustic reclamation tanks. Both wells are screened to intercept the water table, and their locations

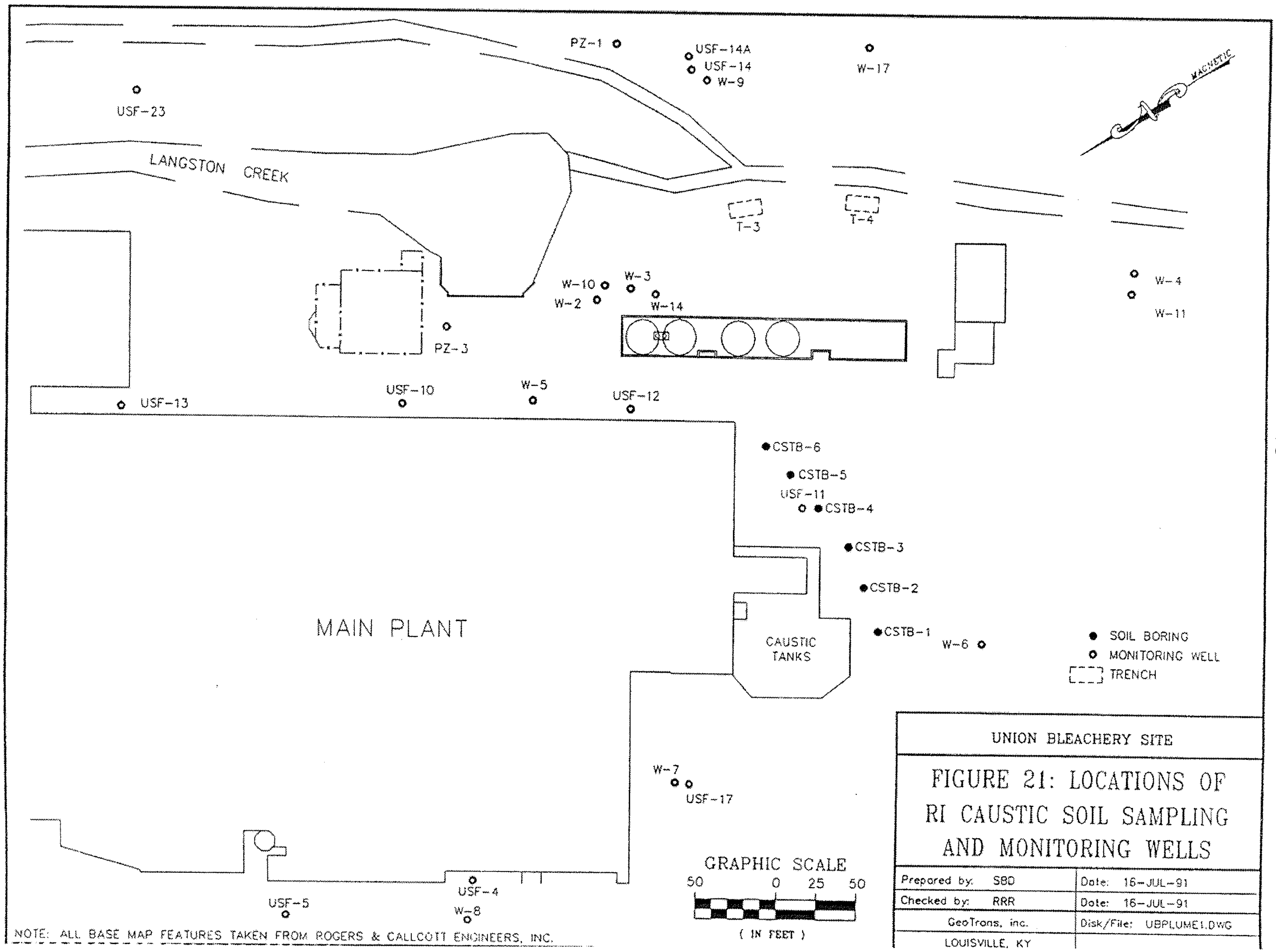


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FIGURE 21: LOCATIONS OF RI CAUSTIC SOIL SAMPLING AND MONITORING WELLS

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are shown in Figure 21. Well specifications for all USF wells are contained in Table C (Appendix C) and well construction as-build diagrams are also included in Appendix C. Groundwater was sampled from Wells USF-11 and 12 in February and analyses included constituents from Table 16 plus TPH, minus asbestos.

2.1.8 Blue Pond (Operable Unit 8)

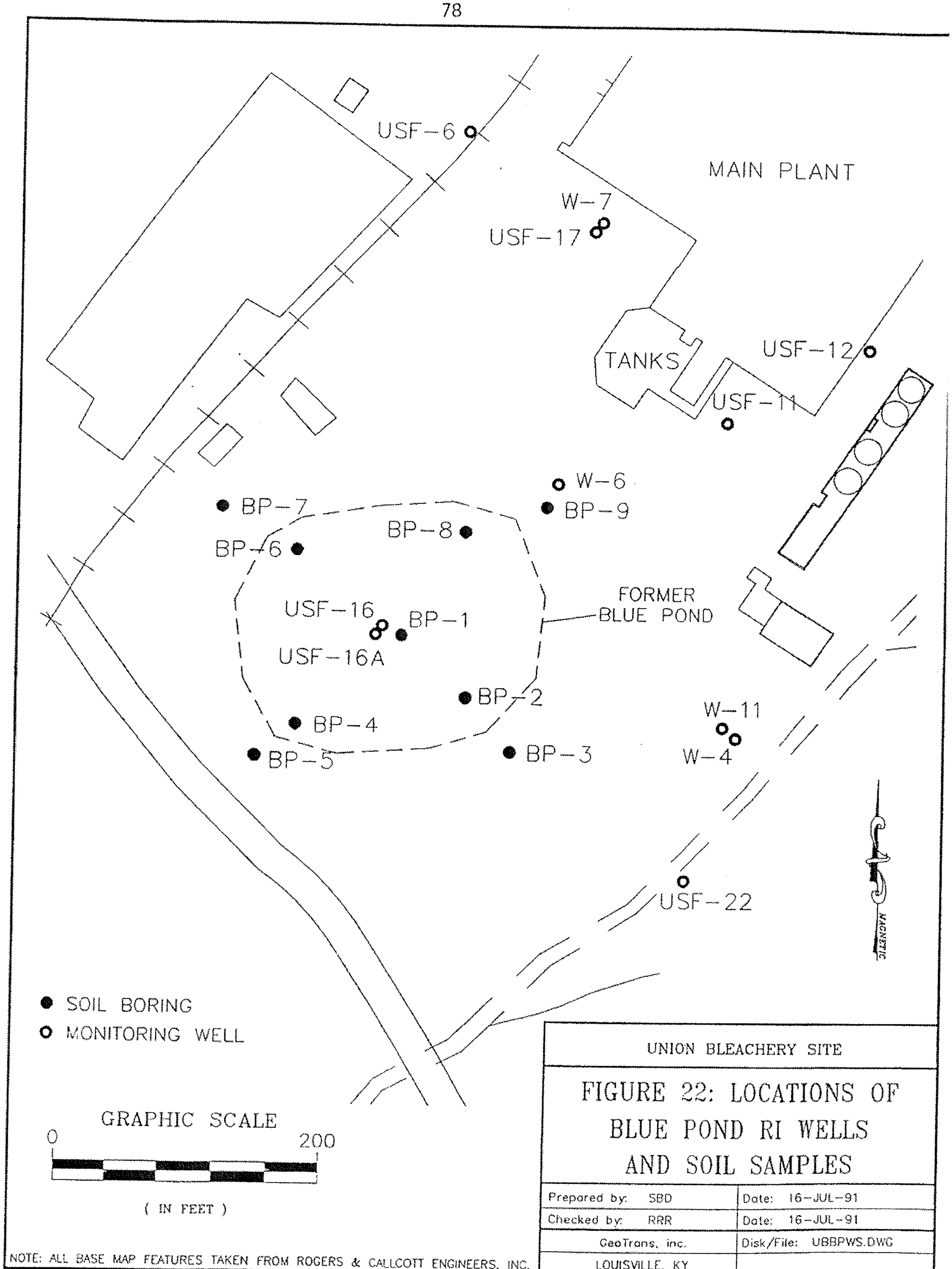
A review of site blue prints and aerial photographs during the RI indicated that the former location of the Blue Pond was not as shown in Figure 5. Therefore, monitor well W-6 shown in Figure 5, does not provide a representative groundwater quality sample from beneath the former Blue Pond location. An accurate location of the former Blue Pond is shown in Figure 22.

In order to confirm the absence or presence of soil and/or groundwater contamination in the area of the former Blue Pond, soil sampling was conducted and two monitor wells were installed as part of the RI. Nine soil borings, shown on Figure 22, were installed and split-spoon samples collected to characterize the nature and extent of any contaminant residuals from the former impoundment. Selected soil samples were analyzed for metals. In addition, a cluster of one water-table Well (USF-16) and one LS Well (USF-16A) was installed on March 25 and 27, 1991, respectively, and is shown in Figure 22. Groundwater samples collected in April from Wells USF-16 and 16A were analyzed for Table 16 constituents minus asbestos plus aluminum.

2.2 LANGSTON CREEK AQUIFER (OPERABLE UNIT 9)

2.2.1 Geological Investigation

Sufficient information was collected from previous investigations to describe the geology over most of the site for the purpose of the RI. One area of the site where data were needed regarding the depth to bedrock was west of the main plant in proximity to the CDLs. To collect geologic information in this area, one of the CDL borings (CDL-14+2) was drilled and split-spoon sampled to auger refusal.




NOTE: ALL BASE MAP FEATURES TAKEN FROM ROGERS & CALLCOTT ENGINEERS, INC.

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FIGURE 22: LOCATIONS OF BLUE POND RI WELLS AND SOIL SAMPLES

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Additional geologic information at to the depth of bedrock resulted from the installation of LS (auger refusal) monitor wells.

### 2.2.2 Site Groundwater Investigation In Floodplain

In addition to the 14 monitor wells that were previously described as installed at operable units within the boundaries of the Langston Creek Aquifer, Operable Unit 9, there were three more components of the site groundwater investigation for the RI. First, monitor wells were installed in the Langston Creek Aquifer Floodplain and groundwater samples analyzed to complete the nature and extent of contamination that was initiated in previous studies. Second, hydraulic (slug) testing was performed in each of the USF wells to estimate the ease with which the aquifer will allow groundwater and contaminants to travel (i.e., to estimate aquifer hydraulic conductivity). Third, a water-level survey of all the site wells was performed to determine groundwater flow directions and hydraulic gradients. Each of these tasks is described in more detail below.

#### 2.2.2.1 Well Installation and Sampling

To delineate the nature and extent of chromium contamination in groundwater in the Langston Creek Aquifer within the Floodplain, ten additional monitor wells and three piezometers were installed in a phased approach during the RI. After installation, the initial wells were reconnaissance sampled and analyzed for hexavalent and total chromium. If the well contained significant concentrations, an additional delineation well was installed. Proceeding in this manner, extent of contamination was delineated while the number of wells installed was kept to a minimum. The well numbers, types, and installation dates are listed in Table 19. The locations of these wells are shown in Figure 23. The LS wells and piezometers were installed using Work Plan protocols. The upper bedrock Wells (USF-14A & 19A) were constructed by boring a 12-inch diameter borehole to bedrock and pressure grouting 8-inch diameter PVC casing in the borehole. After the grout had cured, an 8-inch (nominal) diameter borehole was air hammer drilled approximately 10 feet into competent

Table 19. Langston Creek Aquifer wells and piezometers installed in the floodplain.

| WELL NUMBER | LOWER SAPROLITE | UPPER BEDROCK | DATE INSTALLED |
|---|---|---|---|
| USF-10 | X | | 2/08 |
| USF-13 | X | | 3/19 |
| USF-14 | X | | 3/19 |
| USF-14A | | X | 4/01 |
| USF-17 | X | | 3/22 |
| USF-19 | X | | 3/20 |
| USF-19A | | X | 4/01 |
| USF-20 | X | | 3/21 |
| USF-21 | X | | 3/22 |
| USF-22 | X | | 3/25 |
| USF-23 | X | | 4/03 |
| PZ-1 | X | | 4/08 |
| PZ-2 | X | | 4/08 |
| PZ-3 | X | | 4/09 |

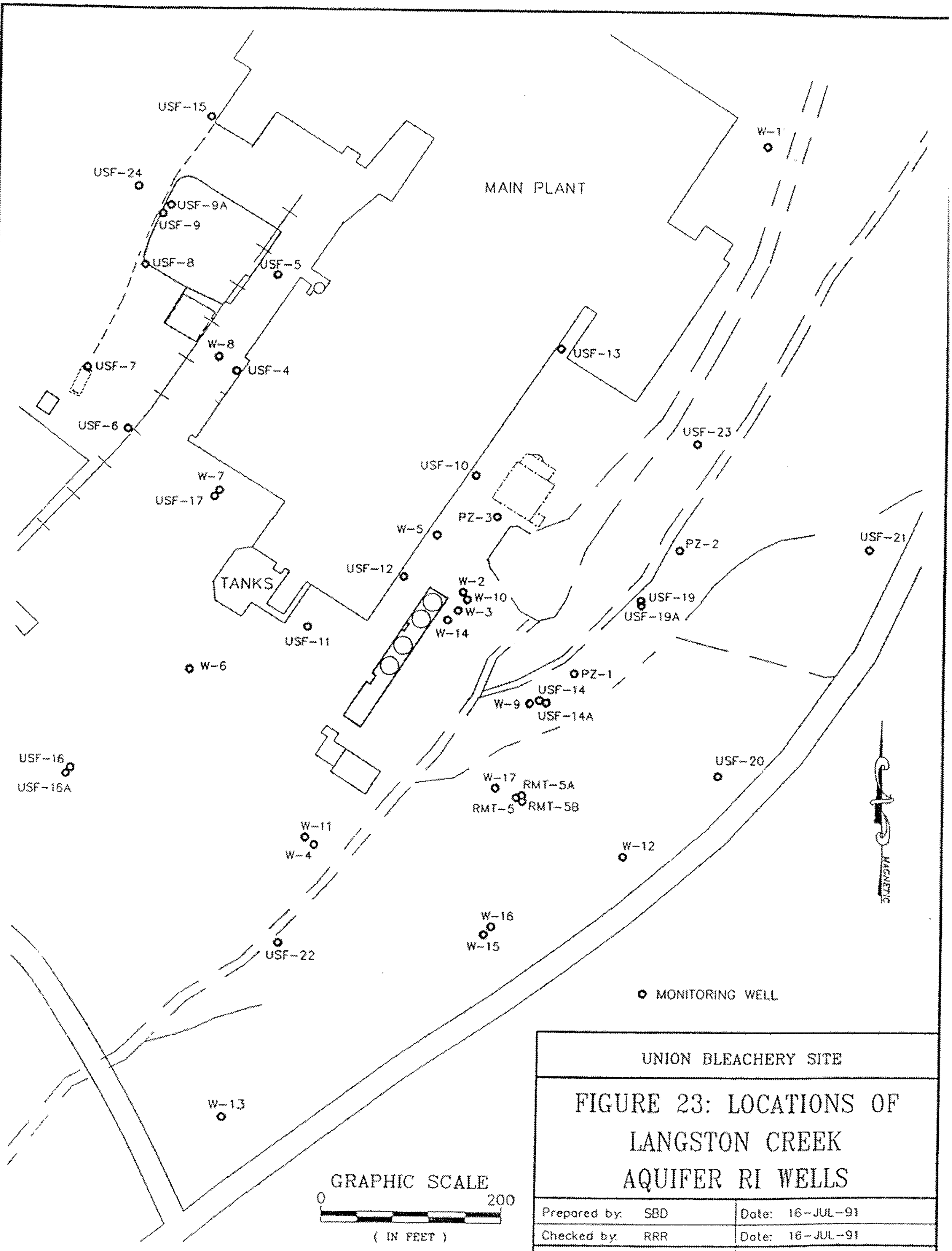


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FIGURE 23: LOCATIONS OF LANGSTON CREEK AQUIFER RI WELLS

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bedrock, and a 4-inch diameter PVC casing was pressure grouted into the bedrock. After grout curing, a borehole was drilled with a 4-inch core barrel.

Groundwater was sampled from Well USF-10 in February 1991 and analyses included constituents from Table 16 minus asbestos. Groundwater was sampled from Wells USF-13, 14, 14A, 17, 19, 19A, 20, 21, 22, and 23 in April and analyzed for Table 16 constituents minus organics and asbestos.

2.2.2.2 Hydraulic Testing

In order to estimate aquifer properties at the Union Bleachery site, aquifer (slug) tests were performed. Twenty-eight monitor wells were slug tested during the week of April 15, 1991.

A slug test is performed by creating an instantaneous water-level change within the well and measuring the rate at which the displaced water level returns to the pre-test level. The water-level change can be accomplished by using a weighted float either injected into (positive displacement) or withdrawn from (negative displacement) the well. The rate at which the displaced water level returns to its initial position is related to the hydraulic conductivity of the surrounding aquifer material.

Pre-test water levels were measured with a QED electric water-level probe. A weighted, PVC cylinder was used to affect the desired water-level displacement. A 1-inch diameter cylinder was used in the 2-inch diameter wells; a 3-inch diameter cylinder was used in the 4-inch diameter wells. The depth-time relationship resulting from insertion and withdrawal of the slug cylinder was recorded using an ORS brand, Model EL200, data logger and an accompanying 5 psi pressure transducer. The transducer has an accuracy of $\pm 0.01$ feet and the recorder has a minimum logging frequency of 0.2 seconds. The recorder was configured such that the readings were written directly to the display screen and to the recorder's RAM memory, thus allowing for real-time monitoring of the test progression. The PVC cylinder, transducer and cable, and electric water level probe were decontaminated prior to use at each well.

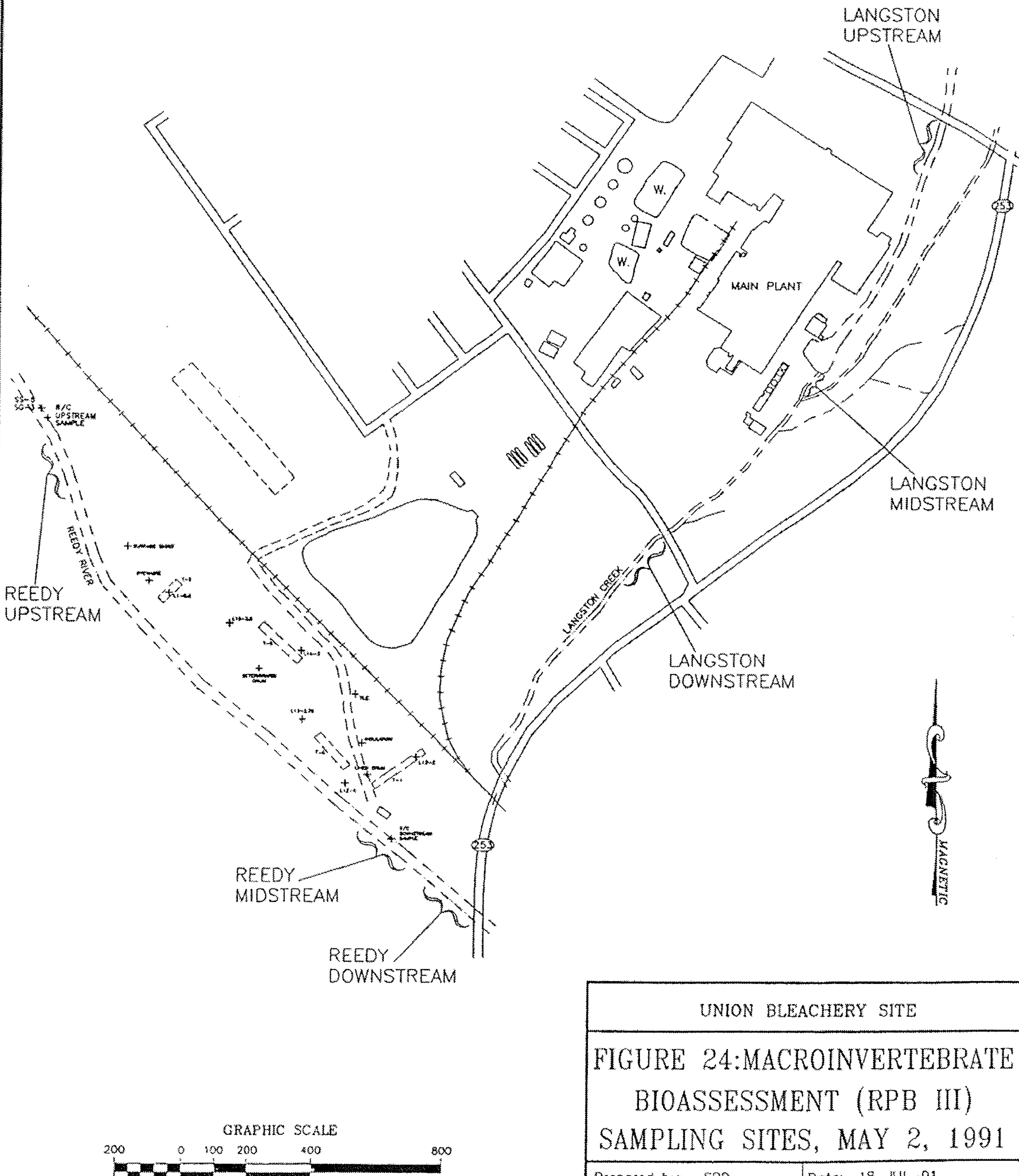
2.2.2.3 Water-Level Survey

A comprehensive water-level survey of all existing site wells was conducted on May 7, 1991. A total of fifty-five wells and piezometers were surveyed which included twenty-eight USF wells, three piezometers, seven RMT wells, and seventeen Cone W wells.

2.2.3 <u>Ecological Investigation In Langston Creek And Reedy River</u>

An ecological study was performed by Normandeau Associates, Inc. (NAI) to evaluate the macroinvertebrate community at three sites on the Reedy River and three sites on the Langston Creek (see Appendix F). The procedures used, known as the Rapid Bioassessment Protocol III (RBP III) developed by US EPA, are designed to provide a quick, cost-effective biological assessment of rivers and streams. The method evaluates physical factors influencing the structure of the macroinvertebrate community and ranks the pollution tolerance of important members of the community. The overall biotic "health" of each surface water body is determined on a weight of evidence basis; all factors are then summarized to calculate a final rank that determines the degree to which a site is impacted if impact has occurred.

Three sites physically similar in habitat on the Reedy River and three physically similar sites on the Langston Creek as shown in Figure 24, were chosen by R&C based on existing site characterization data. The upstream control site on the Reedy River was located at the gauging station approximately 930 yards upstream of the Highway 253 bridge. The midstream Reedy River site was located at the pumphouse approximately 220 yards upstream from the Highway 253 bridge. The downstream site was located in the vicinity of the Highway 253 bridge. The upstream Langston Creek site was located at the Old Buncombe Road bridge. The midstream site was located immediately below the dam east of the dye house. The downstream Langston Creek site was located at the Brooks Avenue Bridge.




NOTE: ALL BASE MAP FEATURES TAKEN FROM ROGERS & CALLCOTT ENGINEERS, INC.

| UNION BLEACHERY SITE | |
|---|---|
| FIGURE 24: MACROINVERTEBRATE BIOASSESSMENT (RPB III) SAMPLING SITES, MAY 2, 1991 | |
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| Checked by: RRR | Date: 18-JUL-91 |
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### 2.2.3.1 Field Procedures

Each site was defined by a transect that ran perpendicular to the flow of each waterbody. Comparable areas (e.g., 50-60 m upstream from the transect) at all three sites on each waterbody were sampled on May 2, 1991, for 30 man-minutes with a dipnet sampler. The frame of the sampler was placed securely against the substrate with the opening facing upstream. The substrate directly in front of the sampler opening was disturbed so that macroinvertebrates dislodged from the substrate would drift into the collecting net. Other submerged structures such as boulders, logs and tree trunks, undercut banks, and root masses were also sampled. The samples were rinsed into labeled 1 liter plastic jars, preserved in buffered formalin, and returned to the laboratory for processing and identification.

In addition to the dipnet sample, a coarse particulate organic matter (CPOM) sample was collected at each site. CPOM represents a food source for shredders, an important macroinvertebrate functional feeding group. The CPOM sample provides data on the relative abundance of this functional group. The CPOM sample consisted of collecting several handfuls of organic material (leaves, needles, twigs, leaf packs, debris accumulations, etc.) and washing over a sieve (US Standard No. 30). These samples were rinsed into labeled 1 liter plastic jars, preserved with buffered formalin, and returned to the laboratory for processing and separation. The CPOM samples were processed and analyzed separately from the dipnet samples. A habitat assessment was also performed to evaluate habitat quality on the basis of key parameters (e.g., sediment type, stream velocity, etc.) of the waterbody and surrounding land. Water quality parameters were also recorded at each station.

### 2.2.3.2 Laboratory Procedures

All samples were rinsed over a US Standard No. 30 (0.6mm mesh) floodplain. sieve. Organisms were sorted from the debris with the aid of a dissecting microscope and placed in vials containing 70% ethanol. Macroinvertebrates collected from the dipnet samples were identified to the lowest practical taxon, enumerated, and assigned to the appropriate functional feeding group according to classifications by Merritt and Cummins (1984; Table 3-1).

Macroinvertebrates from the CPOM samples were counted to obtain a ratio of shredders, a functional feeding group, to the total number of organisms in the sample.

# 3 RESULTS OF INVESTIGATION

This section of the report presents the physical and chemical results of the RI field investigations. For most sampling episodes during the RI as well as from previous investigations since 1988, sample splits were provided to Cone's consultant RMT for duplicate analysis if R&C conducted the sampling. When RMT has conducted samplings, sample splits have been received by R&C. Where data results have been received from RMT from their RI sample splits, they are included for comparison. In addition, Cone, as part of its compliance effort, samples the Cone wells and Langston Creek monthly.

Results from the RI investigation, combined with those results from previous investigations are used to delineate the nature and extent of contamination at the operable units.

## 3.1 CONTAMINANT SOURCE INVESTIGATIONS

### 3.1.1 Permitted Sludge Landfill (Operable Unit 1)

Four borings for the collection of sludge samples from the landfill were installed for the RI as shown in Figure 12. Sludge was identified as a 1-inch zone in the field notes from each of the borings. This sludge layer or zone was found within the depth range of 6 to 11.5 feet below land surface for the four borings. Tables 20 and 21 list the metals and TCLP metals results of the 4 landfill boring (LB) sludge samples. Also shown are the results of previous investigations for comparison. The only constituent identified above the RCRA action level is chromium (400 mg/kg) which ranges between 13,780 and 36,000 mg/kg for the four LB samples. Both R&C and RMT performed TCLP analyses on the sludge samples from the sludge burial area. As may be seen in Table 21, the TCLP values for chromium from the landfill sludge range from <0.05 to 2.8 mg/l. These values are below the regulatory limit of 5.0 mg/l but are significant considering the possible quarter million pounds of chromium contained in the landfill (Edwards, December 30, 1974) and the sandy soil within

Table 20. Metals analyses of sludge from Permitted Sludge Landfill in mg/kg.

previous results

| Parameter | HP-1 | HP-2 | SL-1 | B-1E | LB-1 | | LB-2 | |
|---|---|---|---|---|---|---|---|---|
| | R & C | R & C | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | 2.7 | 2.6 | 12 | 6.5 | <1.0 | 6.3 | <1.0 | 6.3 |
| Barium | 221 | 34 | 49 | 130 | 143 | 180 | 210 | 270 |
| Cadmium | - | - | .08 | 3.5 | 2.0 | 1.8 | 9.0 | 6.0 |
| Chromium | 38,460 | 5,860 | 143 | 16,000 | 13,780 | 19,000 | 36,000 | 30,000 |
| Copper | - | - | 1.8 | 200 | - | - | - | - |
| Iron | - | - | 530 | 48,000 | - | - | - | - |
| Lead | 48 | 8.6 | <0.2 | 32 | <2.0 | <30 | <2.0 | 60 |
| Magnesium | - | - | 1,400 | 1,500 | - | - | - | - |
| Manganese | - | - | 2.1 | 160 | - | - | - | - |
| Mercury | <0.1 | .14 | .22 | 0.5 | .38 | 1.0 | .54 | 1.4 |
| Selenium | - | - | <1.0 | <1.0 | <1.0 | 1.8 | <1.0 | <2.5 |
| Silver | 3.8 | <1.0 | 2.6 | <2 | <.94 | <2 | <.94 | <2 |
| Zinc | - | - | 7.1 | 790 | - | | - | - |

| Parameter | LB-3 | | LB-4 | |
|---|---|---|---|---|
| | R & C | RMT | R & C | RMT |
| Arsenic | <1.0 | 7.2 | <1.0 | 3.8 |
| Barium | 110 | 150 | 190 | 250 |
| Cadmium | 4.4 | 4.5 | 8.0 | 6.1 |
| Chromium | 16,470 | 25,000 | 24,100 | 27,000 |
| Copper | - | - | - | - |
| Iron | - | - | - | - |
| Lead | <2.0 | 50 | <2.0 | 60 |
| Magnesium | - | - | - | - |
| Manganese | - | - | - | - |
| Mercury | .32 | 0.9 | .88 | 1.8 |
| Selenium | <1.0 | <2.1 | <1.0 | <2.4 |
| Silver | <.94 | <2 | <.94 | <2 |
| Zinc | - | - | - | - |

Table 21. EP toxicity & TCLP analyses of sludge from Permitted Sludge Landfill in mg/l.

← previous results →

| Parameter | HP-1 | HP-2 | SL-1 | B-1E | LB-1 | LB-2 |
|---|---|---|---|---|---|---|
| | R & C | R & C | R & C | RMT | R & C | R & C |
| Arsenic | - | - | <.91 | <.003 | <.01 | <.01 |
| Barium | - | - | .56 | .72 | .45 | .43 |
| Cadmium | - | - | <.01 | .008 | .01 | .01 |
| Chromium | <.05 | - | 1.4 | 2.8 | .89 | .68 |
| Copper | - | - | .01 | <.02 | - | - |
| Iron | - | - | .21 | .80 | - | - |
| Lead | - | - | <.02 | <.01 | <.02 | <.02 |
| Magnesium | - | - | 16 | 13 | - | - |
| Manganese | - | - | 1.1 | 1.1 | - | - |
| Mercury | - | - | <.002 | <.0002 | <.002 | <.002 |
| Selenium | - | - | <.01 | <.003 | <.01 | <.01 |
| Silver | - | - | <.01 | <.01 | <.01 | <.01 |
| Zinc | - | - | 7.5 | 8.5 | - | - |

| Parameter | LB-3 | | LB-4 | |
|---|---|---|---|---|
| | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | <.003 | <.01 | <.003 |
| Barium | .35 | .37 | .47 | .46 |
| Cadmium | .01 | <.005 | .01 | <.005 |
| Chromium | .75 | .65 | 1.5 | .87 |
| Copper | - | - | - | - |
| Iron | - | - | - | - |
| Lead | <.02 | <.20 | <.02 | <.20 |
| Magnesium | - | - | - | - |
| Manganese | - | - | - | - |
| Mercury | <.002 | <.0004 | <.002 | <.0004 |
| Selenium | <.01 | <.003 | <.01 | <.003 |
| Silver | <.01 | <.02 | <.01 | <.02 |
| Zinc | - | - | - | - |

which the landfill is situated (Froehling & Robertson, February 26, 1975). The results of samples collected to date indicate that the sludge in the Permitted Sludge Landfill is heavily contaminated with chromium.

The groundwater sample results of RI well USF-18 are shown in Table 22. Also shown are the results of an additional sampling of monitor wells RMT-2 & 2A and the results of previous samples. The analyses results from RMT-2 & 2A for 9/90 and USF-18 are for unfiltered samples, while the results from RMT-2 & 2A for 6/90 and 12/90 are for filtered samples. As may be noted, filtering appears to have reduced concentrations of all parameters. This indicates that many of the metals are attached to fine particles. For example, given the iron content in the unfiltered samples, chromium is most likely sorbed to iron hydroxide. Puls and Barcelona (1989) point out that "Metal contaminants may move through fractured and porous media not only as dissolved species, but also as precipitated phases, polymeric species or adsorbed to inorganic or organic particles of colloidal dimensions." They further state "that use of a 0.45 micron filter was not useful, appropriate or reproducible in providing information on metals mobility in ground-water systems, nor was it appropriate for determination of truly 'dissolved' constituents in groundwater."

It should also be noted that drinking water wells are not generally filtered. From the drinking water perspective, maximum contaminant levels (MCLs) should be applied to unfiltered water. Note that MCLs for cadmium, chromium, and lead are exceeded in the unfiltered RMT-2 sample and for lead in the unfiltered USF-18 sample. Both of these samples are from alluvium wells.

A comparison of unfiltered groundwater results from the Permitted Sludge Landfill with the background water quality results of RMT-1, in Table 15, indicates that groundwater immediately downgradient of the landfill is also above background levels for several other constituents including Barium, Copper, Manganese, and Silver but not at levels that exceed MCLs.

Table 22. Results of groundwater analyses from Permitted Landfill.

| PARAMETER | RMT-2 | | | | | |
|---|---|---|---|---|---|---|
| | 06/19/90 (F) | | 09/18/90 | | 12/07/90 (F) | |
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <.003 |
| Barium | 0.07 | 0.06 | 1.0 | 0.73 | 0.20 | 0.19 |
| Cadmium | <0.01 | 0.0009 | 0.02 | <0.0003 | <0.01 | 0.0009 |
| Chromium | <0.02 | <0.002 | 0.06 | 0.14 | <0.02 | <0.002 |
| Chromium, Hex. | --- | --- | <0.01 | --- | --- | --- |
| Copper | <0.01 | <0.02 | 0.06 | 0.05 | <0.01 | <0.02 |
| Iron | 0.03 | <0.1 | 80 | 140 | --- | --- |
| Iron, Ferrous | --- | --- | --- | --- | --- | --- |
| Iron, Ferric | --- | --- | --- | --- | --- | --- |
| Lead | <0.005 | 0.007 | <0.005 | 0.12 | <0.005 | <0.003 |
| Magnesium | 1.7 | 1.7 | 7.6 | 14 | --- | --- |
| Manganese | 0.81 | 0.84 | 3.3 | 3.4 | 0.54 | 0.62 |
| Mercury | <0.001 | 0.0006 | <0.001 | 0.0013 | --- | --- |
| Selenium | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Silver | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.01 |
| Zinc | 0.02 | 0.02 | --- | 0.14 | --- | --- |
| Sulfate | --- | --- | --- | --- | --- | --- |
| Alkalinity | 6.5 | <20 | --- | --- | --- | --- |
| Chloride | --- | --- | --- | --- | --- | --- |
| Nitrate | --- | --- | --- | --- | --- | --- |
| Hardness | 15 | 16 | --- | --- | --- | --- |
| Dis. Oxy. | --- | --- | 3.6 | --- | --- | --- |
| Dis. Solids | --- | --- | --- | --- | --- | --- |
| Susp. Solids | --- | --- | --- | --- | --- | --- |
| Calcium | --- | --- | 3.5 | 3.5 | --- | --- |
| Phosphorus | --- | --- | --- | --- | --- | --- |
| Potassium | --- | --- | 13 | 12 | --- | --- |
| Sodium | --- | --- | 7.4 | 8 | --- | --- |
| TOC | --- | --- | --- | --- | --- | --- |
| pH units | 5.0 | --- | 4.8 | --- | 4.4 | --- |
| Cond, umhos/cm | 72 | --- | 50 | --- | 85 | --- |
| Eh, mV | --- | --- | 342 | --- | --- | --- |
| T, °C | 21 | --- | 17.5 | --- | 14.0 | --- |

F: Filtered Sample
Results in mg/l unless noted.

GeoTrans, inc.

Table 22. Results of groundwater analyses from Permitted Landfill (Continued).

| PARAMETER | RMT - 2A | | | | | | USF-18 | |
|---|---|---|---|---|---|---|---|---|
| | 06/19/90 (F) | | 09/18/90 | | 12/07/90 (F) | | 04/17/91 | |
| | R & C | RMT | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.010 | --- |
| Barium | 0.04 | <0.05 | 0.27 | 0.26 | 0.04 | <0.05 | 0.75 | --- |
| Cadmium | <0.01 | 0.0005 | 0.01 | <0.0003 | <0.01 | 0.0005 | <0.01 | --- |
| Chromium | <0.02 | <0.002 | 0.03 | 0.047 | <0.02 | <0.002 | <0.02 | <0.002(F) |
| Chromium, Hex. | --- | --- | <0.01 | --- | --- | --- | <0.01 (F) | <.01 |
| Copper | <0.01 | <0.02 | 0.03 | 0.03 | <0.01 | <0.02 | 0.02 | --- |
| Iron | <0.02 | <0.1 | 44 | 53 | --- | --- | 101 | <0.1 (F) |
| Iron, Ferrous | --- | --- | --- | --- | --- | --- | 0.84 | <0.1 |
| Iron, Ferric | --- | --- | --- | --- | --- | --- | --- | <0.1 |
| Lead | <0.005 | <0.003 | 0.023 | 0.019 | <0.005 | <0.003 | 0.056 | --- |
| Magnesium | 2.4 | 2.3 | 7.6 | 14 | --- | --- | 6.9 | --- |
| Manganese | 0.23 | 0.19 | 0.56 | 0.64 | <0.01 | <0.005 | 2.5 | --- |
| Mercury | <0.001 | <0.0002 | <0.001 | <0.0002 | --- | --- | <0.0010 | --- |
| Selenium | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.010 | --- |
| Silver | <0.01 | <0.001 | 0.14 | <0.001 | <0.01 | <0.010 | <0.01 | --- |
| Zinc | <0.01 | 0.04 | --- | 0.09 | --- | --- | --- | --- |
| Sulfate | --- | --- | --- | --- | --- | --- | <10 | --- |
| Alkalinity | 34 | 43 | --- | --- | --- | --- | 26 | 28 |
| Chloride | --- | --- | --- | --- | --- | --- | 6.6 | --- |
| Nitrate | --- | --- | --- | --- | --- | --- | 2.8 | --- |
| Hardness | 29 | 33 | --- | --- | --- | --- | --- | --- |
| Dis. Oxy. | --- | --- | --- | --- | --- | --- | 4.5 | --- |
| Dis. Solids | --- | --- | --- | --- | --- | --- | 176 | --- |
| Susp. Solids | --- | --- | --- | --- | --- | --- | 1052 | --- |
| Calcium | --- | --- | 7.9 | 8 | --- | --- | 1.7 | --- |
| Phosphorus | --- | --- | --- | --- | --- | --- | 0.29 | --- |
| Potassium | --- | --- | 13 | 17 | --- | --- | 6.2 | --- |
| Sodium | --- | --- | 6.6 | 6 | --- | --- | 15 | 21 (F) |
| TOC | --- | --- | --- | --- | --- | --- | 14 | --- |
| Turbidity, ntu | --- | --- | --- | --- | --- | --- | * | --- |
| pH units | 6.4 | --- | 6.4 | --- | 6.1 | --- | 5.3 | --- |
| Cond. umhos/cm | 100 | --- | 980 | --- | 105 | --- | 120 | --- |
| Eh, mV | --- | --- | 306 | --- | --- | --- | 287 | --- |
| T, °C | 22 | --- | 17.6 | --- | 14.0 | --- | 16.6 | --- |

* Unable to determine due to nature of sample.
F: Filtered Sample
Results in mg/l unless noted

3.1.2 Aeration Lagoon (Operable Unit 2)

Tables 23 and 24 show the metals and TCLP metals results, respectively, of the composite sludge sample collected during the RI. Also shown are the results of previous samples for comparison. For the most part, the results of the 1991 sludge composite fall within the range of or slightly less than the results of previous samples. The results of samples collected to date indicate that the sludge in the Aeration Lagoon ~~is contaminated with~~ contains chromium, but not to the extent that would classify the sludge as hazardous.

The R&C calculated volume of sludge contained in the lagoon is approximately 220,000 pounds. Details of this calculation can be found in the June 12, 1991 R&C letter report on Aeration Basin Sludge Removal contained in Appendix D.

The results of an additional sampling of monitor well RMT-4 are shown in Table 25 along with the results of previous samples. A sample was collected in December 1990 by RMT, subsequently filtered, and then split with R&C. The sample constituent values are similar to the filtered sample results from June 1990 and less than the unfiltered sample results of September 1990. This is probably due to the presence of particulate matter in the unfiltered sample that contained chromium.

A comparison of unfiltered groundwater results from the Aeration Lagoon with the background water quality results in Table 15 indicates that groundwater immediately downgradient of the Aeration Lagoon is above background levels for several constituents (Arsenic, Barium, Chromium, Lead, Manganese, and Silver) but not at levels that exceed MCLs.

3.1.3 Reedy River Flood Plain (Operable Unit 3)

3.1.3.1 Groundwater Investigation

The results of all groundwater samples collected to date from the Reedy River Flood Plain wells (USF-1, -2, & -3) are shown in Tables 26, 27, and 28, respectively. The comparison of this data with Table 15 background water quality conditions indicates that

Table 23. Results of metals analyses of sludge from Aeration Lagoon.

| PARAMETER | SLUDGE 3/16/88 | HP-3 SLUDGE/SOIL 4/26/89 | SL-2 4/24/90 | | COMPOSITE 3/20/91 |
|---|---|---|---|---|---|
| | | | R & C | R M T | |
| Antimony | <25 | --- | --- | --- | --- |
| Arsenic | 7.3 | 2.9 | <1.0 | 5.4 | 6.7 |
| Barium | 215 | 70 | 123 | 210 | 34 |
| Cadmium | 1.0 | --- | 2.6 | <0.8 | <1.0 |
| Chromium | 3200 | 190 | 1,750 | 1,900 | 398 |
| Cobalt | 8.0 | --- | --- | --- | --- |
| Copper | 650 | --- | 46 | 53 | 80 |
| Iron | --- | --- | 35,100 | 53,000 | --- |
| Lead | 70 | 20 | <2.0 | 30 | 7.1 |
| Magnesium | --- | --- | 1,050 | 1,500 | --- |
| Manganese | --- | --- | 342 | 590 | --- |
| Mercury | 0.23 | <0.1 | <0.2 | <0.1 | <.20 |
| Nickel | 91 | --- | --- | --- | --- |
| Phenol | 1.5 | --- | --- | --- | --- |
| Selenium | --- | --- | <1.0 | <1.0 | <5.0 |
| Silver | 1.0 | <1.0 | <1.0 | <2 | <1.0 |
| Thallium | <12 | --- | --- | --- | --- |
| Tin | 90 | --- | --- | --- | --- |
| Zinc | 1000 | --- | 82 | 160 | 143 |

Results in mg/kg.

Table 24. Results of TCLP analyses of sludge from Aeration Lagoon.

| PARAMETER | SLUDGE 3/16/88 | HP-3 SLUDGE/SOIL 4/26/89 | SL-2 4/24/90 | | COMPOSITE 3/20/91 |
|---|---|---|---|---|---|
| | | | R & C | R M T | |
| Arsenic | --- | --- | <.01 | .005 | <0.05 |
| Barium | --- | --- | 0.59 | 0.77 | 0.84 |
| Cadmium | --- | --- | <0.01 | <.005 | <0.01 |
| Chromium | --- | --- | 0.12 | 0.07 | 0.04 |
| Copper | --- | --- | <0.01 | <0.02 | --- |
| Iron | --- | --- | 38 | 390 | --- |
| Lead | --- | --- | <0.02 | <0.1 | <0.02 |
| Magnesium | --- | --- | 12 | 14 | --- |
| Manganese | --- | --- | 4 | 19 | --- |
| Mercury | --- | --- | <.002 | <.0002 | <0.001 |
| Selenium | --- | --- | <0.01 | <0.003 | <0.05 |
| Silver | --- | --- | <0.01 | <10 | 0.02 |
| Zinc | --- | --- | 0.24 | 2.4 | --- |

Results in mg/l.

Table 25. Results of groundwater analyses from Aeration Lagoon.

| PARAMETER | HP-3 4/89 | HP-4 4/89 | R M T-4 6/90 (F) | | R M T-4 9/90 | | R M T-4 12/90 (F) | |
|---|---|---|---|---|---|---|---|---|
| | | | R & C | R M T | R & C | R M T | R & C | R M T |
| Arsenic | .012 | .014 | <.01 | <.003 | <.01 | <.003 | <.01 | <.003 |
| Barium | <0.1 | 0.2 | .08 | 0.07 | .21 | .13 | .07 | .060 |
| Cadmium | --- | --- | <.01 | 0.0004 | .01 | .0004 | <.01 | <.0003 |
| Chromium | .06 | .07 | <.02 | .003 | .04 | .029 | <.02 | <.002 |
| Chromium, Hex. | --- | --- | --- | --- | <.01 | --- | --- | --- |
| Copper | --- | --- | <.01 | 0.03 | .02 | <.02 | <.01 | <.02 |
| Iron | --- | --- | 1.1 | 1.2 | 24 | 14 | --- | --- |
| Lead | <.01 | <.01 | <.005 | <.003 | .046 | .012 | <.005 | <.003 |
| Magnesium | --- | --- | .47 | <0.5 | 2.4 | 1.4 | --- | --- |
| Manganese | --- | --- | .42 | 0.42 | .30 | .26 | .98 | 1 |
| Mercury | <.001 | <.001 | <.001 | <.0002 | <.001 | <.0002 | --- | --- |
| Selenium | --- | --- | <.01 | <.003 | <.01 | <.003 | <.01 | <.003 |
| Silver | <.01 | <.01 | <.01 | <.001 | .03 | <.001 | <.01 | <.01 |
| Zinc | --- | --- | <.01 | <.02 | --- | <.02 | --- | --- |
| Alkalinity | --- | --- | 620 | 600 | --- | --- | --- | --- |
| Hardness | --- | --- | 9.9 | 6.6 | --- | --- | --- | --- |
| Dis. Oxy | --- | --- | --- | --- | 2.0 | --- | --- | --- |
| Calcium | --- | --- | --- | --- | 1.1 | .5 | --- | --- |
| Potassium | --- | --- | --- | --- | 3.2 | 2.2 | --- | --- |
| Sodium | --- | --- | --- | --- | 305 | 410 | --- | --- |
| pH units | --- | --- | 6.4 | --- | 6.5 | --- | 6.5 | --- |
| Cond, umhos/cm | --- | --- | 1,300 | --- | 135 | --- | 1,300 | --- |
| Eh, mV | --- | --- | --- | --- | 131 | --- | --- | --- |
| T, °C | --- | --- | 21 | --- | 20.2 | --- | 16.0 | --- |

F: Filtered Sample
Results in mg/L unless noted.

Table 26. Results of groundwater analyses from Reedy River monitor well USF-1.

| PARAMETER | 09/90 | | 12/90 (F) | | 04/91 | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | <.003 | <.01 | <.003 | --- | --- |
| Barium | .15 | .14 | .09 | .08 | --- | --- |
| Cadmium | <.01 | <.0003 | <.01 | .0004 | --- | --- |
| Chromium | .03 | .023 | <.02 | <.002 | --- | --- |
| Chromium, Hex. | <.01 | --- | --- | --- | --- | --- |
| Copper | .02 | .02 | <.01 | <.02 | --- | --- |
| Iron | 13 | 13 | --- | --- | --- | --- |
| Lead | <.005 | .024 | <.005 | <.003 | --- | --- |
| Magnesium | 4.6 | 5.2 | --- | --- | --- | --- |
| Manganese | .24 | .26 | .26 | .25 | --- | --- |
| Mercury | <.001 | <.0002 | --- | --- | --- | --- |
| Selenium | <.01 | <.003 | <.01 | <.003 | --- | --- |
| Silver | <.01 | <.001 | <.01 | <.01 | --- | --- |
| Zinc | --- | .09 | --- | --- | --- | --- |
| VOCs | ND | --- | ND | ND | --- | --- |
| Semi-VOCs | ND | ND | --- | --- | --- | --- |
| Sulfate | 9.8 | <10 | --- | --- | --- | --- |
| Alkalinity | 6.2 | 49 | --- | --- | --- | --- |
| Chloride | 7.1 | 11 | --- | --- | --- | --- |
| Nitrate | .7 | .55 | --- | --- | --- | --- |
| Dis. Oxygen | 2.2 | --- | --- | --- | 3.3 | --- |
| Calcium | 11 | 11 | --- | --- | --- | --- |
| Phosphorus | .08 | .51 | --- | --- | --- | --- |
| Potassium | 3.4 | 3.7 | --- | --- | --- | --- |
| Sodium | 7.6 | 6.6 | --- | --- | --- | --- |
| TOC | 5.5 | 4.1 | 39 | --- | --- | --- |
| Turbidity, ntu | --- | --- | --- | --- | 32 | 47 |
| pH, units | 5.8 | --- | 6.6 | --- | 6.7 | --- |
| Cond, umhos/cm | 90 | --- | 450 | --- | 484 | --- |
| Eh, mV | 200 | --- | --- | --- | 40 | --- |
| Asbestos, fibers/l | --- | --- | --- | --- | $1.59 \times 10^{6}$* | 0% |
| T, °C | 17.0 | --- | 14.5 | --- | 15.0 | --- |

* 1 fiber each of Chrysotile and Grunerite (Amosite) asbestos.
F: Filtered Sample
Results in mg/l unless noted.

Table 27. Results of groundwater analyses from Reedy River monitor well USF-2.

| PARAMETER | 09/90 | | 12/90 (F) | | 04/91 | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | <.003 | <.01 | <.003 | --- | --- |
| Barium | .32 | .41 | .33 | .3 | --- | --- |
| Cadmium | <.01 | <.0003 | <.01 | <.0003 | --- | --- |
| Chromium | .02 | .011 | <.02 | <.002 | --- | --- |
| Chromium, Hex. | <.01 | --- | --- | --- | --- | --- |
| Copper | .02 | <.02 | <.01 | <.02 | --- | --- |
| Iron | 4 | 2.5 | --- | --- | --- | --- |
| Lead | .0067 | .005 | <.005 | <.003 | --- | --- |
| Magnesium | 6.8 | 11 | --- | --- | --- | --- |
| Manganese | .3 | .37 | .54 | .510 | --- | --- |
| Mercury | <.001 | <.0002 | --- | --- | --- | --- |
| Selenium | <.01 | .014 | <.01 | <.003 | --- | --- |
| Silver | <.01 | <.001 | <.01 | <.01 | --- | --- |
| Zinc | --- | .03 | --- | --- | --- | --- |
| VOCs | ND | --- | ND | --- | --- | --- |
| Semi-VOCs | ND | ND | --- | --- | --- | --- |
| Sulfate | 57 | 70 | --- | --- | --- | --- |
| Alkalinity | 46 | 32 | --- | --- | --- | --- |
| Chloride | 198 | 220 | --- | --- | --- | --- |
| Nitrate | <0.2 | <.05 | --- | --- | --- | --- |
| Dis. Oxygen | 6.0 | --- | --- | --- | 2.9 | --- |
| Calcium | 26 | 34 | --- | --- | --- | --- |
| Phosphorus | .04 | .36 | --- | --- | --- | --- |
| Potassium | 3.2 | 3.8 | --- | --- | --- | --- |
| Sodium | 83 | 110 | --- | --- | --- | --- |
| TOC | 7.0 | 5.9 | --- | --- | --- | --- |
| Turbidity, ntu | --- | --- | --- | --- | 39 | 104 |
| pH, units | 6.3 | --- | 6.0 | --- | 6.2 | --- |
| Cond, umhos/cm | 640 | --- | 1,300 | --- | 656 | --- |
| Eh, mV | 268 | --- | --- | --- | 22 | --- |
| Asbestos, fibers/l | --- | --- | --- | --- | NSD* | 0% |
| T, °C | 18.2 | --- | 15.0 | --- | 15.1 | --- |

* NSD = No Asbestos Structures Detected.
F: Filtered Sample
Results in mg/l unless noted.

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Table 28. Results of groundwater analyses from Reedy River monitor well USF-3.

| PARAMETER | 09/90 | | 12/90 (F) | | 04/91 | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | .007 | <.01 | .008 | --- | --- |
| Barium | .31 | .39 | .11 | .1 | --- | --- |
| Cadmium | .01 | <.0003 | <.01 | <.0003 | --- | --- |
| Chromium | .13 | .17 | <.02 | <.002 | --- | --- |
| Chromium, Hex. | <.01 | --- | --- | --- | --- | --- |
| Copper | .03 | .03 | <.01 | <.02 | --- | --- |
| Iron | 47 | 60 | --- | --- | --- | --- |
| Lead | <.005 | .031 | <.005 | <.003 | --- | --- |
| Magnesium | 7.6 | 12 | --- | --- | --- | --- |
| Manganese | 0.9 | 1.1 | .98 | .940 | --- | --- |
| Mercury | <.001 | <.0002 | --- | --- | --- | --- |
| Selenium | <.01 | <.003 | <.01 | <.003 | --- | --- |
| Silver | <.01 | <.001 | <.01 | <.01 | --- | --- |
| Zinc | --- | .11 | --- | --- | --- | --- |
| VOCs | ND | --- | ND | ND | --- | --- |
| Semi-VOCs | ND | ND | --- | --- | --- | --- |
| Sulfate | 34 | 41 | --- | --- | --- | --- |
| Alkalinity | 135 | 92 | --- | --- | --- | --- |
| Chloride | 22 | 27 | --- | --- | --- | --- |
| Nitrate | .5 | <.05 | --- | --- | --- | --- |
| Dis. Oxygen | 4.0 | --- | --- | --- | 4.6 | --- |
| Calcium | 18 | 20 | --- | --- | --- | --- |
| Phosphorus | .22 | 2.66 | --- | --- | --- | --- |
| Potassium | 4.6 | 5.2 | --- | --- | --- | --- |
| Sodium | 30 | 37 | --- | --- | --- | --- |
| TOC | 10 | 23 | 37 | --- | --- | --- |
| Turbidity, ntu | --- | --- | 39 | --- | 37 | 158 |
| pH units | 5.7 | --- | 6.6 | --- | 6.6 | --- |
| Cond. umhos/cm | 270 | --- | 500 | --- | 532 | --- |
| Eh, mV | 80.5 | --- | --- | --- | -42 | --- |
| Asbestos, fibers/l | --- | --- | --- | --- | NSD* | 0% |
| T, °C | 17.0 | --- | 15.5 | --- | 15.2 | --- |

* NSD = No Asbestos Structures Detected
F: Filtered Sample
Results in mg/l unless noted.

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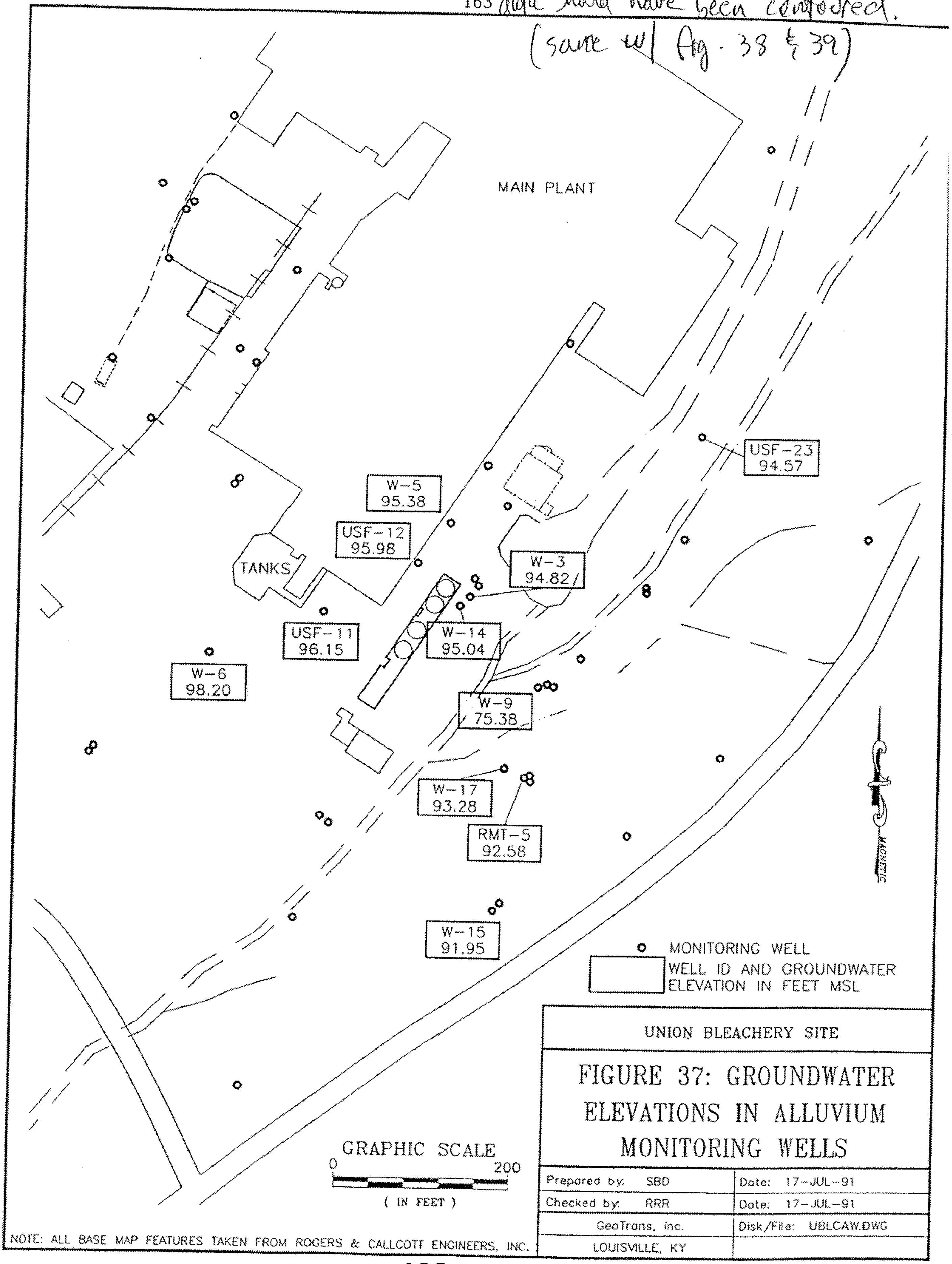
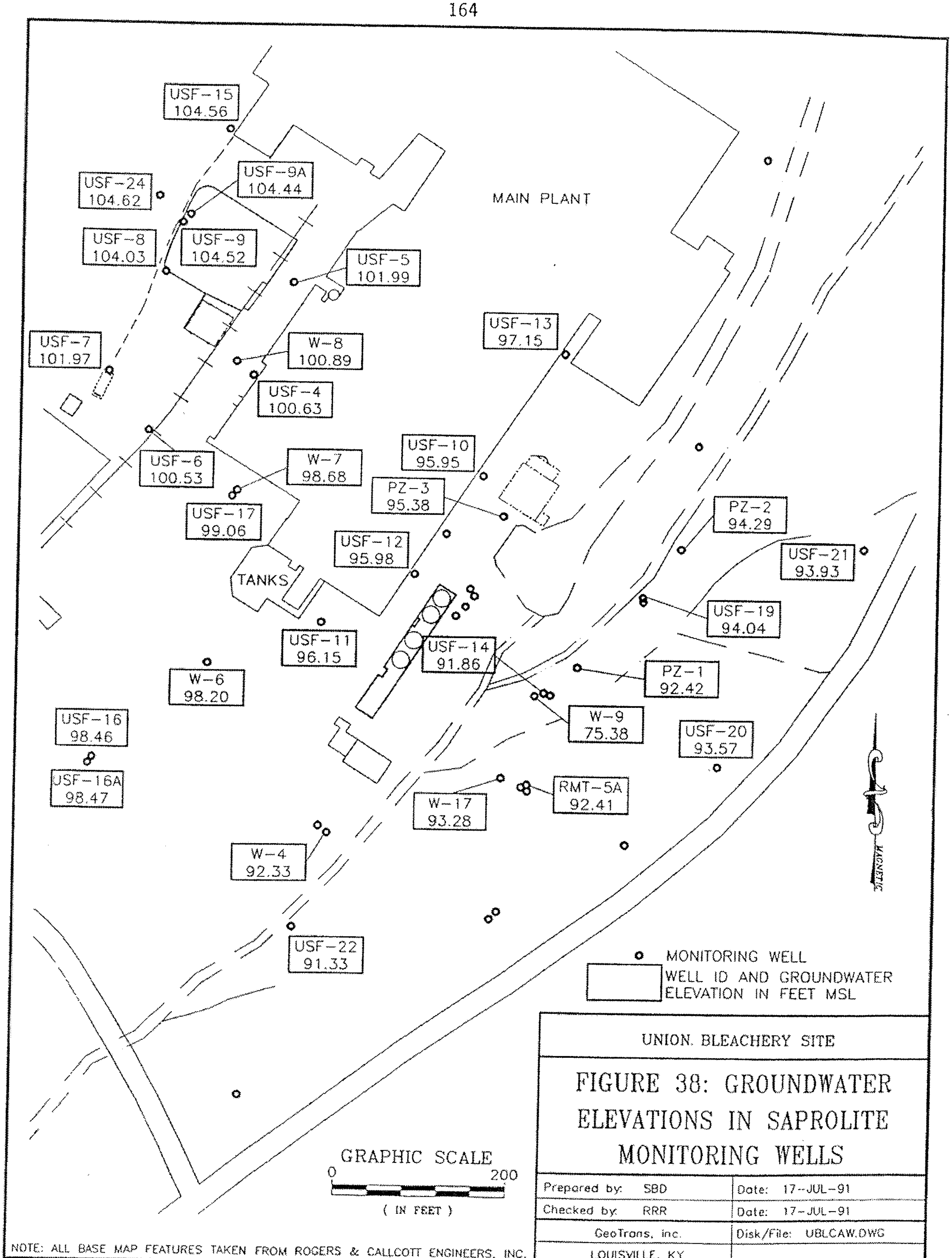
163 data should have been contoured.
(same w/ Fig. 38 & 39)




UNION BLEACHERY SITE

FIGURE 37: GROUNDWATER ELEVATIONS IN ALLUVIUM MONITORING WELLS

| | |
|---|---|
| Prepared by: SBD | Date: 17-JUL-91 |
| Checked by: RRR | Date: 17-JUL-91 |
| GeoTrans, inc. | Disk/File: UBLCAW.DWG |
| LOUISVILLE, KY | |

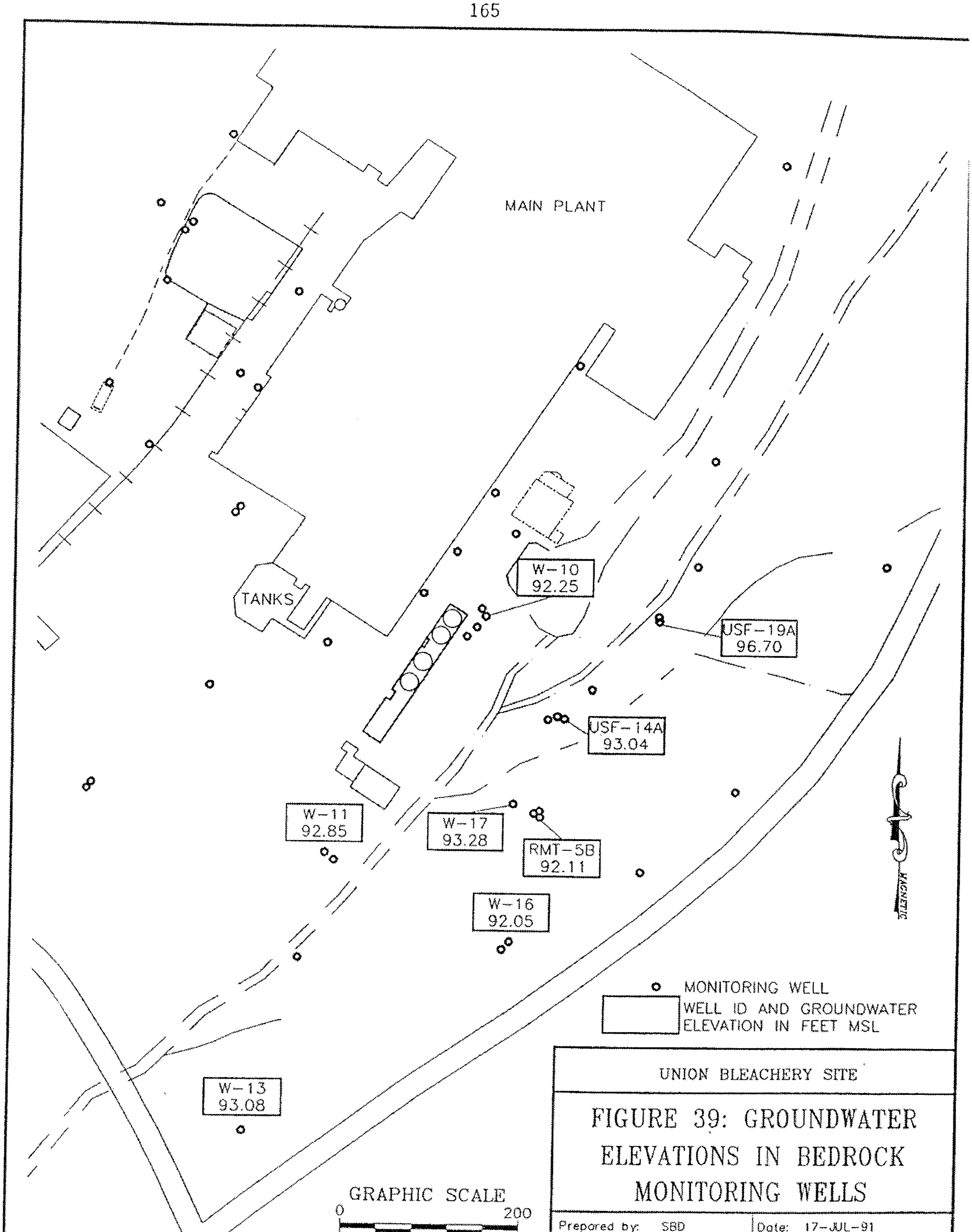



UNION BLEACHERY SITE

FIGURE 38: GROUNDWATER ELEVATIONS IN SAPROLITE MONITORING WELLS

| | | | |
|---|---|---|---|
| Prepared by: | SBD | Date: | 17-JUL-91 |
| Checked by: | RRR | Date: | 17-JUL-91 |
| GeoTrans, inc. | | Disk/File: | UBLCAW.DWG |
| LOUISVILLE, KY | | | |

NOTE: ALL BASE MAP FEATURES TAKEN FROM ROGERS & CALLCOTT ENGINEERS, INC.




UNION BLEACHERY SITE

FIGURE 39: GROUNDWATER ELEVATIONS IN BEDROCK MONITORING WELLS

| | |
|---|---|
| Prepared by: SBD | Date: 17-JUL-91 |
| Checked by: RRR | Date: 17-JUL-91 |
| GeoTrans, inc. | Disk/File: UBLCAW.DWG |
| LOUISVILLE, KY | |

NOTE: ALL BASE MAP FEATURES TAKEN FROM ROGERS & CALLCOTT ENGINEERS, INC.

Table 48. Summary of hydraulic conductivities (K) from USF well slug tests.

| Well ID | r (in) | L (ft) | Bouwer & Rice Pos.[1] | Bouwer & Rice Neg.[2] | Bouwer & Rice $\alpha$ | Cooper et al Pos.[1] | Cooper et al $\alpha$ | Cooper et al Neg.[2] |
|---|---|---|---|---|---|---|---|---|
| USF-1 | 1 | 10.8 | 14 | 16 | $10^{-2}$ | 22 | $10^{-5}$ | 30 |
| USF-2 | 1 | 11.5 | 2.4 | 2.4 | $10^{-6}$ | 5.2 | $10^{-5}$ | 4.6 |
| USF-3 | 1 | 11.5 | 0.16 | 0.08 | $10^{-2}$ | 0.12 | $10^{-3}$ | 0.08 |
| USF-4 | 1 | 12.5 | 4.1 | 3.7 | $10^{-2}$ | 3.2 | $10^{-3}$ | 4.3 |
| USF-5 | 1 | 11.9 | 4.9 | 3.5 | $10^{-2}$ | 4.5 | $10^{-3}$ | 3.9 |
| USF-6 | 1 | 12.1 | 3.3 | 3.6 | $10^{-3}$ | 3.3 | $10^{-2}$ | 3.1 |
| USF-7* | 1 | 10.9 | 16 | 25 | $10^{-1}$ | 23 | $10^{-4}$ | 57 |
| USF-8* | 1 | 12.2 | 7.9 | 6.0 | $10^{-1}$ | 5.1 | $10^{-1}$ | 10 |
| USF-9* | 1 | 16.6 | 6.2 | 28 | $10^{-3}$ | 8.2 | $10^{-2}$ | 28 |
| USF-9A | 1 | 13.5 | 1.8 | 1.6 | $10^{-8}$ | 4.4 | $10^{-4}$ | 2.2 |
| USF-10 | 1 | 12.4 | 8.3 | 6.5 | $10^{-3}$ | 11 | $10^{-4}$ | 9.7 |
| USF-11 | 1 | 8.7 | 1.6 | 1.4 | $10^{-2}$ | 1.5 | $10^{-3}$ | 2.0 |
| USF-12 | 1 | 6.8 | 0.03 | No data | $10^{-1}$ | 0.04 | N/A | No data |
| USF-13 | 1 | 12.0 | 7.3 | 8.2 | $10^{-3}$ | 8.8 | $10^{-3}$ | 11 |
| USF-14 | 1 | 12.0 | 0.45 | 0.47 | $10^{-6}$ | 0.83 | $10^{-3}$ | 0.42 |
| USF-14A | 2 | 15.0 | Bad data | 0.23 | N/A | Bad data | $10^{-3}$ | 0.18 |
| USF-15* | 1 | 13.0 | 15 | 7.2 | $10^{-1}$ | 6.9 | $10^{-1}$ | 7.2 |
| USF-16 | 1 | 9.0 | 0.41 | 0.17 | $10^{-1}$ | 0.27 | $10^{-1}$ | 0.13 |
| USF-16A | 1 | 14.0 | 1.1 | 0.15 | $10^{-2}$ | 1.21 | N/A | N/A |
| USF-17 | 1 | 12.4 | 2.7 | 2.3 | $10^{-3}$ | 3.6 | $10^{-3}$ | 2.4 |
| USF-18 | 1 | 13.5 | 3.7 | 4.7 | $10^{-3}$ | 5.7 | $10^{-6}$ | 10 |
| USF-19 | 1 | 12.1 | 3.7 | 2.3 | $10^{-6}$ | 6.0 | $10^{-3}$ | 2.5 |
| USF-19A | 2 | 15.0 | N/A | 0.16 | N/A | N/A | $10^{-3}$ | 0.14 |
| USF-20 | 1 | 12.0 | 18 | 13 | $10^{-4}$ | 25 | $10^{-1}$ | 5.7 |
| USF-21 | 1 | 12.6 | 12 | 17 | $10^{-8}$ | 27 | $10^{-5}$ | 26 |
| USF-22 | 1 | 12.0 | 1.5 | 0.39 | $10^{-6}$ | 8.8 | $10^{-1}$ | 1.1 |
| USF-23 | 1 | 11.2 | 1.4 | 1.4 | $10^{-1}$ | 0.54 | $10^{-1}$ | 0.6 |
| USF-24 | 1 | 12.0 | 13 | 9.2 | $10^{-10}$ | 22 | $10^{-2}$ | 9.0 |

*Water level changing w/in screened interval, therefore, calculated values may be biased toward higher values.
[1]Positive displacement test (ft/d)
[2]Negative displacement test (ft/d)

Table 49. Summary of slug and pump test hydraulic conductivity and storage data in the Langston Creek Area, pre-November 1990 wells.

| Well | Screened Interval | Test Type | Analytical Method | Conductivity (ft/day) | Hydraulic Transmissivity ($ft^2$/day) | Storage Coefficient | Source |
|---|---|---|---|---|---|---|---|
| W-9 | saprolite | pump | CJ | 17 | 300 | --- | 1 |
| W-9 | saprolite | pump | CJ | 9 | 160 | --- | 1 |
| W-9 | saprolite | pump | JR | 6 | 100 | --- | 1 |
| W-9 | saprolite | pump | TH | 8 | 150 | --- | 1 |
| W-2* | saprolite | pump | CJ | 70 | 1300 | $1.7 \times 10^{-3}$ | 1 |
| W-2 | saprolite | slug | unknown | 5.7 | --- | --- | 2 |
| W-3 | alluvium | slug | unknown | 2.3 | --- | --- | 2 |
| W-2 | saprolite | slug | USBR | 4-7 | --- | --- | 3 |
| W-9 | saprolite | slug | USBR | 5-9 | --- | --- | 3 |
| W-3 | alluvial | slug | USBR | 2.2-2.5 | --- | --- | 3 |
| W-10 | bedrock | slug | FH | 6.8 | --- | --- | 3 |
| RMT-5 | alluvial | slug | CPB | 24.0 | --- | $10^{-6}$ | 4 |
| RMT-5A | saprolite | slug | CPB | 12.0 | --- | $10^{-3}$ | 4 |
| RMT-5B | bedrock | slug | CPB | 0.13 | --- | $10^{-4}$ | 4 |
| RMT-5 | alluvial | slug | BR | 5.8 | --- | --- | 4 |
| RMT-5A | saprolite | slug | BR | 4.6 | --- | --- | 4 |
| RMT-5B | bedrock | slug | BR | 0.090 | --- | --- | 4 |

CJ = Cooper-Jacob method
JR = Jacob Recovery method
TH = Theis residual Drawdown method
USBR = United States Bureau of Reclamation, Method E-18
FH = Falling head method
CBP = Cooper, Bredehoeft, and Papadopulos, WRR 1967
BR = Bouwer and Rice, GW 1976
*Observation well
[1] S&ME, 1985
[2] Letco from S&ME, 1985
[3] Law Engineering Notes, date unknown
[4] GeoTrans analysis of RMT data, 1990

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saprolite varies from approximately (depending in part on the method of analysis) 0.42 to 70 ft/day. The specific storage of the saprolite is estimated from Walton (1988) to range from $10^{-4}$ to $10^{-5}$ $ft^{-1}$. The aquifer test results for the alluvium wells indicates a hydraulic conductivity range of 0.08 to 30 ft/day. The alluvium is estimated to have a specific yield ranging from 0.1 to 0.3 (Walton, 1988). In general, the material underlying the Union Bleachery site is nonhomogeneous and exhibits significant spatial variability.

Groundwater analyses results from the February and April 1991 samplings are provided in Tables 50 and 51, respectively. A preliminary review of the results indicates that there are three types of contamination. First, monitor wells USF-11 and 12, which were discussed in the Caustic Plume section of this report, contain arsenic, lead, mercury, and volatile organics. Second, monitor wells USF-9 and 23, which are located in two separate areas of the site, contain barium in exceedence of the MCL. Finally, the majority of the newly installed wells are contaminated with chromium. To illustrate the chromium concentrations as a function of location at the site, Figure 40 is provided. This figure shows that chromium contamination is significantly higher and more wide spread adjacent to Langston Creek than has been indicated. Also shown in this figure is significant groundwater contamination to the northwest of the main plant which originated from the releases at the chromium delivery line.

### 3.2.3 Ecological Investigation

The results of the ecological investigation performed on the Reedy River and Langston Creek are summarized in this section. Further details and laboratory results of the work conducted can be found in Appendix F. On May 2, 1991, a study was performed by Normandeau Associates of Aiken, South Carolina, to assess the biological condition of sites on the Reedy River and Langston Creek adjacent to the Union Bleachery site.

Locations upstream and downstream of previously impacted sites on the Reedy River and Langston Creek were chosen by R&C personnel. Each

Table 50. Results of 2/91 groundwater analyses from Union Bleachery Site.

| PARAMETER | USF-4 R & C | USF-4 RMT | USF-5 R & C | USF-5 RMT | USF-6 R & C | USF-6 RMT |
|---|---|---|---|---|---|---|
| Arsenic | <.01 | <.003 | <.01 | <.003 | <.01 | <.003 |
| Barium | .08 | <.260 | .07 | .080 | .06 | .090 |
| Cadmium | <.01 | <.0003 | <.01 | <.0003 | <.01 | <.0003 |
| Chromium | 2.1 | 2.6 | 1.5 | 1.7 | <.02 | .010 |
| Chromium, Hex. | 1.8 | 2.6 | 1.3 | 1.8 | <.02 | <.050 |
| Copper | <.01 | .006 | <.01 | .003 | <.01 | .007 |
| Iron | 15.9 | 13 | 5.97 | 3.3 | 8.86 | 6.8 |
| Iron, Ferrous | .66 | .510 | .39 | .560 | .06 ck | .100 |
| Iron, Ferric | --- | 12 | --- | 2.7 | --- | 6.8 |
| Lead | <.005 | .004 | <.005 | <.003 | <.005 | <.003 |
| Magnesium | 3.3 | 8.4 | 2.8 | 3.3 | 1.2 | 2.7 |
| Manganese | .13 | .330 | .55 | .590 | .13 | .240 |
| Mercury | <.0005 | <.0002 | <.0005 | .0002 | <.0005 | <.0002 |
| Selenium | <.01 | <.003 | <.01 | <.003 | <.01 | <.003 |
| Silver | <.01 | <.001 | <.01 | <.001 | <.01 | <.001 |
| VOCs | --- | --- | --- | --- | --- | --- |
| Semi-VOCs | --- | --- | --- | --- | --- | --- |
| TPH | <20 | --- | <20 | --- | <10 | --- |
| Sulfate | <5.0 | <10 | 15 | 20 | 15 | 19 |
| Alkalinity | 48 | 57 | 34 | 41 | 30 | 28 |
| Chloride | 125 | 140 | 8.2 | 9.7 | 4.0 | 4.6 |
| Nitrate | 1.6 | 1.7 | 1.5 | 1.5 | 0.8 | 0.88 |
| Dis. Oxygen | 3.5 | --- | 6.5 | --- | 4.6 | --- |
| Dis. Solids | 252 | 290 | 76 | 100 | 104 | 82 |
| Susp. Solids | 54 | 37 | 46 | 59 | 74 | 68 |
| Calcium | 14 | 17 | 5.7 | 7.2 | 6.2 | 7.3 |
| Phosphorus | .13 | .17 | .21 | .25 | .17 | .15 |
| Potassium | 3.3 | 6.9 | 3.3 | 2.3 | 2.0 | 3.4 |
| Sodium | 63 | 78 | 16 | 18 | 9.5 | 11 |
| TOC | 11 | 2.0 | 7.0 | 1.0 | 5.2 | 0.30 |
| Turbidity, ntu | 32 | 48* | 27 | 63* | 42 | 80* |
| pH, units | 6.9 | --- | 6.5 | --- | 6.2 | --- |
| Eh, us/cm | 200 | --- | 232 | --- | 185 | --- |
| T, °C | 17.0 | --- | 18.0 | --- | 17.5 | --- |
| Cond, umhos/cm | 543 | --- | 147 | --- | 108 | --- |

* Note that 48 hr. hold time was exceeded upon arrival.
Results in mg/l unless noted.

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Table 50. Results of 2/91 groundwater analyses from Union Bleachery Site (continued).

| PARAMETER | USF-7 | | USF-8 | | USF-9 | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | <.003 | <.01 | <.003 | <.01 | <.003 |
| Barium | .06 | .220 | .39 | .590 | .72 | 1.6 |
| Cadmium | <.01 | <.0003 | <.01 | .0003 | <.01 | <.0003 |
| Chromium | .16 | .420 | .50 | 2.7 | 82 | 110 |
| Chromium, Hex. | <.02 | <.05 | <.01 | <.050 | 78 | 110 |
| Copper | .02 | .009 | .02 | .016 | .02 | .020 |
| Iron | 46.1 | 23 | 40.2 | 37 | 152 | 140 |
| Iron, Ferrous | 2.14 | 1.2 | 1.64 | .770 | 6.39 | .690 |
| Iron, Ferric | --- | 22 | --- | 36 | --- | 140 |
| Lead | .0052 | .0012 | .0092 | .015 | .036 | .032 |
| Magnesium | .29 | 6.7 | 6.3 | 13 | 9.6 | 39 |
| Manganese | .17 | .440 | 1.2 | .990 | .82 | 2.4 |
| Mercury | <.0005 | <.0002 | <.0005 | .0002 | .0011 | .0008 |
| Selenium | <.01 | <.003 | <.01 | <.003 | <.01 | .003 |
| Silver | <.01 | <.001 | <.01 | <.001 | <.01 | <.001 |
| VOCs | --- | --- | --- | --- | --- | --- |
| Semi-VOCs | --- | --- | --- | --- | --- | --- |
| TPH | <10 | --- | --- | --- | --- | --- |
| Sulfate | 9.6 | 11 | <5.0 | <10.0 | 89 | 80 |
| Alkalinity | 22 | 26 | 60 | 58 | 26 | 380 |
| Chloride | 5.0 | 6.1 | 146 | 180 | ** | 77 |
| Nitrate | 0.4 | .36 | 0.2 | .10 | 8.1 | 1.8 |
| Dis. Oxygen | 4.7 | --- | 2.4 | --- | 2.6 | --- |
| Dis. Solids | 72 | 60 | 276 | 350 | 430 | 450 |
| Susp. Solids | 672 | 860 | 292 | 370 | 1,380 | 2100 |
| Calcium | 0.9 | 1.0 | 6.5 | 5.7 | 1.4 | 1.7 |
| Phosphorus | 0.16 | 0.54 | 1.2 | 1.8 | .10 | 3.8 |
| Potassium | 1.1 | 6.2 | 2.8 | 4.4 | 6.6 | 27 |
| Sodium | 13 | 16 | 110 | 100 | 100 | 120 |
| TOC | 11 | 2.8 | 12 | 3.4 | 12 | 1.7 |
| Turbidity, ntu | 75 | 455* | 76 | 310* | ** | 1960* |
| pH, units | 6.0 | --- | 6.1 | --- | 5.5 | --- |
| Cond. umhos/cm | 100 | --- | 437 | --- | 599 | --- |
| Eh, us/cm | 108 | --- | 155 | --- | 308 | --- |
| T, °C | 16.9 | --- | 19.1 | --- | 18.7 | --- |

* Note that 48 hr. hold time was exceeded upon arrival.
** Unable to determine due to high Cr.
Results in mg/l unless noted.

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Table 50. Results of 2/91 groundwater analyses from Union Bleachery Site (continued).

| PARAMETER | USF-10 | | USF-11 | | USF-12 | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | <.003 | .143 | .230 | .143 | .170 |
| Barium | .08 | .160 | .02 | <.050 | .07 | .110 |
| Cadmium | <.01 | <.0003 | <.01 | <.0003 | <.01 | .0008 |
| Chromium | 16 | 20 | <.02 | .019 | <.02 | .074 |
| Chromium, Hex. | 15 | 19 | <.10** | <.050 | <.10** | <.050 |
| Copper | <.01 | .004 | <.01 | .007 | .07 | .0260 |
| Iron | 25.3 | 17 | 3.25 | 3.3 | 23.5 | 160 |
| Iron, Ferrous | .86 | <.100 | .83 | --- | 6.85 | 1.1 |
| Iron, Ferric | --- | 17 | --- | --- | --- | 15 |
| Lead | <.005 | .006 | <.005 | .009 | .057 | .120 |
| Magnesium | 2.8 | 6.0 | .09 | .600 | .29 | .800 |
| Manganese | .50 | .890 | .02 | .023 | .14 | .180 |
| Mercury | <.0005 | <.0002 | .0023 | .0023 | <.0005 | .0020 |
| Selenium | <.01 | <.003 | <.01 | .004 | <.01 | .004 |
| Silver | <.01 | <.001 | <.01 | <.001 | <.01 | <.001 |
| VOCs | ND | *** | ND | *** | ND | *** |
| Semi-VOCs | ND | --- | ND | --- | ND | --- |
| TPH | --- | --- | <10 | --- | <10 | --- |
| Sulfate | 25 | 25 | 146 | 100 | <100** | 62 |
| Alkalinity | 34 | 88 | 7,700 | 7,800 | 4,400 | 5,300 |
| Chloride | 18 | 21 | 45 | 210 | 28 | 330 |
| Nitrate | 2.1 | 1.7 | <0.2 | 0.34 | 0.3 | <0.05 |
| Dis. Oxygen | 5.8 | --- | 0.4 | --- | 1.3 | --- |
| Dis. Solids | 160 | 160 | 6,790 | 6,900 | 5,410 | 5,800 |
| Susp. Solids | 139 | 140 | 70 | 80 | 269 | 88 |
| Calcium | 10 | 11.0 | 0.68 | 0.800 | 6.9 | 6.9 |
| Phosphorus | .17 | .59 | 18 | 28 | 8.9 | 11 |
| Potassium | 2.9 | 5.9 | 14 | 14 | 2.3 | 39 |
| Sodium | 20 | 24 | 2,570 | 2,800 | 1,970 | 2,200 |
| TOC | 6.5 | <.25 | 165 | 500 | 530 | 340 |
| Turbidity, ntu | 56 | 170* | 1.6 | 51* | 6.3 | 75* |
| pH, units | 6.2 | --- | 12.5 | --- | 10.1 | --- |
| Cond. umhos/cm | 212 | --- | 15,750 | --- | 6,280 | --- |
| Eh, us/cm | 185 | --- | -370 | --- | --- | --- |
| T, °C | 21.3 | --- | 21.1 | --- | 19.7 | --- |

* Note that 48 hr. hold time was exceeded upon arrival.
** Unable to increase detection due to color of sample.
*** See Table _____ below for estimated concentrations.
Results in mg/l unless noted.

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Table 50. Results of 2/91 groundwater from Union Bleachery Site, (Continued).

| COMPOUND | RMT | | |
|---|---|---|---|
| | USF-10 | USF-11 | USF-12 |
| 1,1-Dichloroethane | ND | ND | 0.0009 |
| Chloroform | 0.0010 | ND | ND |
| Toluene | ND | 0.0010 | 0.0030 |
| Ethylbenzene | ND | 0.0007 | 0.0009 |
| Xylenes, Total | ND | 0.0090 | 0.013 |
| 1,2-Dichlorobenzene | ND | 0.0030 | 0.0070 |

Results in mg/l.

Table 51. Results of 4/91 groundwater analyses from Union Bleachery Site.

| PARAMETER | W-7 | | USF-9 | | USF-9A | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | --- | --- | --- | --- | <.01 | --- |
| Barium | --- | --- | --- | --- | .13 | --- |
| Cadmium | --- | --- | --- | --- | <.01 | --- |
| Chromium | 1.5 | 1.5(F) | 100(71)** | 92(F) | .24 | .350(F) |
| Chromium, Hex. | 1.5(F) | 1.7 | 110(F) | 90 | .28(F) | .340 |
| Copper | --- | --- | --- | --- | .01 | --- |
| Iron | --- | <.100(F) | --- | <.100(F) | 9.9 | <.100(F) |
| Iron, Ferrous | --- | <.100 | --- | <.100 | 0.6 | <.100 |
| Iron, Ferric | --- | <.100 | --- | <.100 | --- | <.100 |
| Lead | --- | --- | --- | --- | <.005 | --- |
| Magnesium | --- | --- | --- | --- | 2.9 | --- |
| Manganese | --- | --- | --- | --- | .09 | --- |
| Mercury | --- | --- | --- | --- | <.001 | --- |
| Selenium | --- | --- | --- | --- | <.01 | --- |
| Silver | --- | --- | --- | --- | <.01 | --- |
| VOCs | --- | --- | --- | --- | --- | --- |
| Semi-VOCs | --- | --- | --- | --- | --- | --- |
| Sulfate | --- | --- | --- | --- | 22 | --- |
| Alkalinity | --- | <20 | --- | 26 | 40 | 45 |
| Chloride | --- | --- | --- | --- | 7.6 | --- |
| Nitrate | --- | --- | --- | --- | 2.1 | --- |
| Dis. Oxygen | 4.5 | --- | 3.0 | --- | 8.7 | --- |
| Dis. Solids | --- | --- | --- | --- | 92 | --- |
| Susp. Solids | --- | --- | --- | --- | 163 | --- |
| Calcium | --- | --- | --- | --- | 5.9 | --- |
| Phosphorus | --- | --- | --- | --- | .12 | --- |
| Potassium | --- | --- | --- | --- | 3.1 | --- |
| Sodium | --- | 1,700(F) | --- | 120(F) | 19 | 26(F) |
| TOC | --- | --- | --- | --- | <5.0 | --- |
| Turbidity, ntu | --- | --- | --- | --- | 88. | --- |
| pH, units | 5.2 | --- | 5.5 | --- | 6.7 | --- |
| Cond. umhos/cm | 7710 | --- | 638 | --- | 183 | --- |
| Eh, mV | 349 | --- | 274 | --- | 165 | --- |
| T, °C | 20.3 | --- | 17.5 | --- | 17.2 | --- |

**Filtered, not digested, due to interference. Total digested chromium result in parenthesis.
F = Filtered Sample
Results in mg/l unless noted.

Table 51. Results of 4/91 groundwater analyses from Union Bleachery Site (Continued).

| PARAMETER | USF-13 | | USF-14 | | USF-14A | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | --- | <.01 | --- | <.01 | --- |
| Barium | .36 | --- | .39 | --- | .09 | --- |
| Cadmium | <.01 | --- | <.01 | --- | <.01 | --- |
| Chromium | 4.8 | 6.3(F) | 590(520)** | 640(F) | 6.9(5.3)**** | 7.0(F) |
| Chromium, Hex. | 4.4(F) | 5.8 | 610(F) | 640 | 6.7(F) | 6.8 |
| Copper | .03 | --- | <.01 | --- | .02 | --- |
| Iron | ** | <.100(F) | 13 | <.100(F) | 7.51 | <.100(F) |
| Iron, Ferrous | ** | <.100 | 9.45 | <.100 | 3.22 | <.100 |
| Iron, Ferric | --- | <.100 | --- | <.100 | --- | <.100 |
| Lead | .023 | --- | <.005 | --- | <.005 | --- |
| Magnesium | 8.9 | --- | 55 | --- | 8.9 | --- |
| Manganese | .22 | --- | .69 | --- | .06 | --- |
| Mercury | <.001 | --- | <.001 | --- | <.001 | --- |
| Selenium | <.01 | --- | <.01 | --- | <.01 | --- |
| Silver | <.01 | --- | <.01 | --- | <.01 | --- |
| VOCs | --- | --- | --- | --- | --- | --- |
| Semi-VOCs | --- | --- | --- | --- | --- | --- |
| Sulfate | <10 | --- | <250*** | --- | 146 | --- |
| Alkalinity | 23 | 26 | 272 | 280 | 64 | 68 |
| Chloride | * | --- | * | --- | 146 | --- |
| Nitrate | 1.2 | --- | 18 | --- | <0.2 | --- |
| Dis. Oxygen | 6.7 | --- | 4.0 | --- | 3.5 | --- |
| Dis. Solids | 132 | --- | 2,050 | --- | 656 | --- |
| Susp. Solids | 227 | --- | 244 | --- | 105 | --- |
| Calcium | 8.1 | --- | 330 | --- | 110 | --- |
| Phosphorus | 0.4 | --- | .05 | --- | .24 | --- |
| Potassium | 7.0 | --- | 30 | --- | 7.8 | --- |
| Sodium | 7.0 | 8.5(F) | 120 | 150(F) | 12 | 15(F) |
| TOC | <5.0 | --- | 5.3 | --- | 5.0 | --- |
| Turbidity, ntu | 76 | --- | * | --- | * | --- |
| pH, units | 6.1 | --- | 6.3 | --- | 8.4 | --- |
| Cond, umhos/cm | 120 | --- | 2,663 | --- | 877 | --- |
| Eh, mV | 284 | --- | 260 | --- | 61 | --- |
| T, °C | 20.7 | --- | 19.0 | --- | 18.0 | --- |

* Unable to determine due to sample interference.
** Filtered, not digested, due to interference. Total digested chromium result in parenthesis.
*** High detection limit due to nature of sample.
****Broken by subcontractor.
Results in mg/l unless noted.
F = Filtered Sample

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Table 51. Results of 4/91 groundwater analyses from Union Bleachery Site (Continued).

| PARAMETER | USF-15 | | USF-16 | | USF-16A | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | --- | <.01 | --- | <.01 | <.003(F) |
| Barium | .06 | --- | .84 | --- | .10 | .220(F) |
| Cadmium | <.01 | --- | <.01 | --- | <.01 | <.0003(F) |
| Chromium | <.02 | .002(F) | <.02 | <.002(F) | <.02 | .016(F) |
| Chromium, Hex. | <.01(F) | <.010 | <.01(F) | <.010 | <.02(F) | <.010 |
| Copper | <.01 | --- | <.01 | --- | <.01 | .011(F) |
| Iron | 16.2 | <.100(F) | .562 | <.100(F) | 46.1 | 40(F) |
| Iron, Ferrous | <0.1 | <.100 | <.01 | <.100 | 4.69 | <.100 |
| Iron, Ferric | --- | <.100 | --- | <.100 | --- | 40 |
| Lead | <.005 | --- | .0067 | --- | <.005 | .010(F) |
| Magnesium | 5.8 | --- | 3.8 | --- | 1.9 | 9.9(F) |
| Manganese | .08 | --- | <.01 | --- | .44 | .910(F) |
| Mercury | <.001 | --- | <.001 | --- | <.001 | <.0002(F) |
| Selenium | <.01 | --- | <.01 | --- | <.01 | <.003(F) |
| Silver | <.01 | --- | <.01 | --- | <.01 | <.001 |
| VOCs | --- | --- | ND | ND | ND | ND |
| Semi-VOCs | --- | --- | ND | ND | ND | ND |
| Sulfate | <10 | --- | 11 | --- | 45 | 43 |
| Alkalinity | 9.5 | <20 | 40 | 45 | 49 | 64 |
| Chloride | 3.1 | --- | 448 | --- | 86 | 67 |
| Nitrate | <0.2 | --- | <0.2 | --- | 1.0 | .90 |
| Dis. Oxygen | 5.4 | --- | 2.3 | --- | 8.0 | --- |
| Dis. Solids | 928 | --- | 1,100 | --- | 304 | 260 |
| Susp. Solids | 210 | --- | 185 | --- | 434 | 330 |
| Calcium | 1.1 | --- | 57 | --- | 22 | 36 |
| Phosphorus | .06 | --- | 0.10 | --- | 0.08 | .98 |
| Potassium | .57 | --- | 5.5 | --- | 1.8 | 12(F) |
| Sodium | 5.8 | 5.7(F) | 160 | 230(F) | 32 | 59(F) |
| TOC | 5.2 | --- | <5.0 | --- | <5.0 | 9.2 |
| Turbidity, ntu | 37 | --- | 24 | --- | 85 | 248 |
| pH, units | 6.1 | --- | 6.1 | --- | 6.9 | --- |
| Cond, umhos/cm | 38 | --- | 1,498 | --- | 425 | --- |
| Eh, mV | 238 | --- | --- | --- | 144 | --- |
| T, °C | 19.3 | --- | 17.8 | --- | 18.6 | --- |

ND = Not Detected
Results in mg/l unless noted.
F = Filtered Sample

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Table 51. Results of 4/91 groundwater analyses from Union Bleachery Site (Continued).

| PARAMETER | USF-17 | | USF-19 | | USF-19A | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | --- | <.01 | --- | <.01 | --- |
| Barium | .45 | --- | .20 | --- | .05 | --- |
| Cadmium | <.01 | --- | <.01 | --- | <.01 | --- |
| Chromium | 1.0 | 1.4(F) | 130(119)** | 330(F) | <.02 | <.002(F) |
| Chromium, Hex. | 1.2(F) | 1.4 | 122(F) | 140 | <.01(F) | <.010 |
| Copper | <.01 | --- | <.01 | --- | .02 | --- |
| Iron | 1.65 | <.100(F) | .373 | <.100(F) | 3.95 | <.100(F) |
| Iron, Ferrous | 0.5 | <.100 | 0.1 | <.100 | 3.75 | <.100 |
| Iron, Ferric | --- | <.100 | --- | <.100 | --- | <.100 |
| Lead | <.005 | --- | <.005 | --- | <.005 | --- |
| Magnesium | 4.0 | --- | 9.5 | --- | 3.3 | --- |
| Manganese | .03 | --- | .25 | --- | .02 | --- |
| Mercury | <.001 | --- | <.001 | --- | <.001 | --- |
| Selenium | <.01 | --- | <.01 | --- | <.01 | --- |
| Silver | <.01 | --- | <.01 | --- | <.01 | --- |
| VOCs | --- | --- | --- | --- | --- | --- |
| Semi-VOCs | --- | --- | --- | --- | --- | --- |
| BNAs | --- | --- | --- | --- | --- | --- |
| Sulfate | <10 | --- | <50*** | --- | 66 | --- |
| Alkalinity | 35 | 40 | 69 | 77 | 61 | 67 |
| Chloride | 328 | --- | * | --- | 1.5 | --- |
| Nitrate | 1.0 | --- | 3.4 | --- | <0.2 | --- |
| Dis. Oxygen | 7.4 | --- | 2.9 | --- | 3.7 | --- |
| Dis. Solids | 640 | --- | 524 | --- | 176 | --- |
| Susp. Solids | 20 | --- | 95 | --- | 17 | --- |
| Calcium | 14 | --- | 38 | --- | 4.3 | --- |
| Phosphorus | .45 | --- | .13 | ---- | .10 | --- |
| Potassium | 1.8 | --- | 7.8 | --- | 9.1 | --- |
| Sodium | 180 | 230(F) | 71 | 87(F) | 7.4 | 8.8(F) |
| TOC | <5.0 | --- | 5.2 | --- | <5.0 | --- |
| Turbidity, ntu | 13 | --- | * | --- | 0.5 | --- |
| pH, units | 6.7 | --- | 6.2 | --- | 9.0 | --- |
| Cond. umhos/cm | 1,315 | --- | 712 | --- | 293 | --- |
| Eh, mV | 239 | --- | 106 | --- | 35 | --- |
| T, °C | 18.6 | --- | 22.6 | --- | 20.2 | --- |

* Unable to determine due to nature of sample.
** Filtered, not digested, due to interference. Total digested chromium result in parenthesis.
***High detection limit due to nature of sample.
Results in mg/kg unless noted.
F = Filtered Sample

GeoTrans, inc.

Table 51. Results of 4/19 groundwater analyses from Union Bleachery Site (Continued).

| PARAMETER | USF-20 | | USF-21 | | USF-22 | |
|---|---|---|---|---|---|---|
| | R & C | RMT | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | --- | <.01 | --- | <.01 | --- |
| Barium | .10 | --- | .08 | --- | .13 | --- |
| Cadmium | <.01 | --- | <.01 | --- | <.01 | --- |
| Chromium | <.02 | .002(F) | <.02 | <.002(F) | .02 | .002(F) |
| Chromium, Hex. | <.01(F) | <.010 | <.01(F) | <.010 | <.01(F) | <.010 |
| Copper | <.01 | --- | .01 | --- | .01 | --- |
| Iron | --- | <.100(F) | --- | <.100(F) | --- | <.100(F) |
| Iron, Ferrous | --- | <.100 | --- | <.100 | --- | <.100 |
| Iron, Ferric | --- | <.100 | --- | <.100 | --- | <.100 |
| Lead | <.005 | --- | <.005 | --- | <.005 | --- |
| Magnesium | 2.8 | --- | 3.3 | --- | 4.6 | --- |
| Manganese | .26 | --- | .06 | --- | .79 | --- |
| Mercury | <.001 | --- | <.001 | --- | <.001 | --- |
| Selenium | <.01 | --- | <.01 | --- | <.01 | --- |
| Silver | <.01 | --- | <.01 | --- | <.01 | --- |
| VOCs | --- | --- | --- | --- | --- | --- |
| Semi-VOCs | --- | --- | --- | --- | --- | --- |
| Sulfate | <10 | --- | 27 | --- | 28 | --- |
| Alkalinity | 21 | 83 | 80 | 23 | 51 | 55 |
| Chloride | 4.6 | --- | 3.1 | --- | 24 | --- |
| Nitrate | 1.0 | --- | 0.6 | --- | 1.1 | --- |
| Dis. Oxygen | 8.9 | --- | 4.0 | --- | 6.8 | --- |
| Dis. Solids | 80 | --- | 156 | --- | 164 | --- |
| Susp. Solids | 74 | --- | 28 | --- | 123 | --- |
| Calcium | 3.5 | --- | 27 | --- | 9.3 | --- |
| Phosphorus | 0.11 | --- | 0.22 | --- | 0.15 | --- |
| Potassium | 3.6 | --- | 3.8 | --- | 6.1 | --- |
| Sodium | 3.4 | 7.3(F) | 5.1 | 4.5(F) | 26 | 39(F) |
| TOC | <5.0 | --- | <5.0 | --- | <5.0 | --- |
| Turbidity, ntu | 18 | --- | 20 | --- | 56 | --- |
| pH, units | 6.0 | --- | 9.6 | --- | 6.8 | --- |
| Cond. umhos/cm | 70 | --- | 216 | --- | 263 | --- |
| Eh, mV | 202 | --- | -31 | --- | 216 | --- |
| T, °C | 16.3 | --- | 16.9 | --- | 18.9 | --- |

Results in mg/l unless noted.
F = Filtered Sample

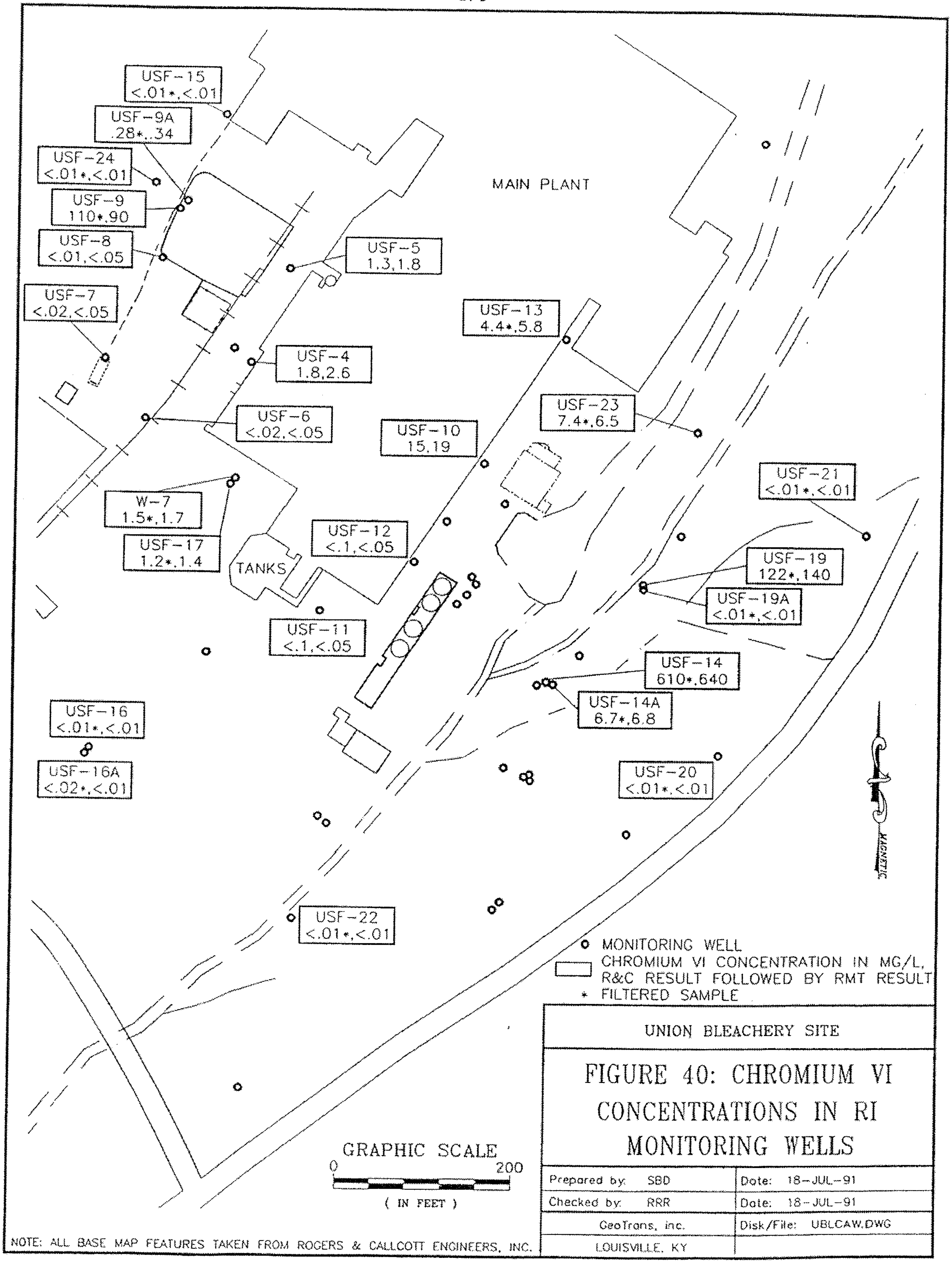
GeoTrans, inc.

Table 51. Results of 4/91 groundwater analyses from Union Bleacher Site (Continued).

| PARAMETER | USF-23 | | USF-24 | |
|---|---|---|---|---|
| | R & C | RMT | R & C | RMT |
| Arsenic | <.01 | --- | <.01 | --- |
| Barium | 1.2 | --- | .10 | --- |
| Cadmium | <.01 | --- | <.01 | --- |
| Chromium | 7.0 | 7.7(F) | <.02 | <.002(F) |
| Chromium, Hex. | 7.4(F) | 6.5 | <.01(F) | <.010 |
| Copper | .04 | --- | <.01 | --- |
| Iron | --- | <.100(F) | 34.9 | <.100(F) |
| Iron, Ferrous | --- | <.100 | 0.4 | <.100 |
| Iron, Ferric | --- | <.100 | --- | <.100 |
| Lead | .017 | --- | <.005 | --- |
| Magnesium | 27 | --- | .84 | --- |
| Manganese | .65 | --- | .04 | --- |
| Mercury | <.001 | --- | <.001 | --- |
| Selenium | <.01 | --- | <.01 | --- |
| Silver | <.01 | --- | <.01 | --- |
| VOCs | --- | --- | ND | ND |
| Semi-VOCs | --- | --- | ND | ND |
| Sulfate | 17 | --- | <10 | --- |
| Alkalinity | 24 | 31 | 5.3 | <20 |
| Chloride | * | --- | 7.6 | --- |
| Nitrate | 1.2 | --- | 1.6 | --- |
| Dis. Oxygen | 4.2 | --- | 7.5 | --- |
| Dis. Solids | 604 | --- | 68 | --- |
| Susp. Solids | 848 | --- | 332 | --- |
| Calcium | 18 | --- | 1.3 | --- |
| Phosphorus | .79 | --- | .06 | --- |
| Potassium | 18 | --- | .65 | --- |
| Sodium | 14 | 17(F) | 6.0 | 9.1(F) |
| TOC | <5.0 | --- | <5.0 | --- |
| Turbidity, ntu | * | --- | * | --- |
| pH, units | 6.0 | --- | 5.0 | --- |
| Cond, umhos/cm | 187 | --- | 67 | --- |
| Eh, mV | 425 | --- | 321 | --- |
| T, °C | 15.6 | --- | 18.6 | --- |

*Unable to determine due to nature of sample.
Results in mg/l unless noted.
F = Filtered Sample

GeoTrans, inc.




UNION BLEACHERY SITE

FIGURE 40: CHROMIUM VI CONCENTRATIONS IN RI MONITORING WELLS

| | |
|---|---|
| Prepared by: SBD | Date: 18-JUL-91 |
| Checked by: RRR | Date: 18-JUL-91 |
| GeoTrans, inc. | Disk/File: UBLCAW.DWG |
| LOUISVILLE, KY | |

site was characterized by normally shallow (0.5 m - 1.5 m), slow moving water and a sand/silt substrate. One week prior to the sampling date, a heavy rainfall event occurred and both the Reedy River and Langston Creek water levels were still higher than normal when sampling occurred.

The health of the benthic macroinvertebrate community was assessed by assigning a value to each of eight metrics. Although values assigned these individual metrics were suggestive of impaired conditions, final scores based on a compilation of all eight metric values for a given site, and compared to the reference site, indicated no impairment or slight impairment at the downstream locations as compared to the reference stations.

The site specific upstream control sites chosen by R&C, were of comparable habitat to the study sites. The rapid bioassessment protocols (RBP) used in this study are based on comparing unimpaired or least-impacted reference waters that operationally represent best attainable conditions. Without proper reference conditions biosurveys tend to underestimate impairment. The upstream control sites appear to have been impacted by non-point source pollution from the farther upstream urban areas or other sources. The use of these potentially impaired control sites for comparison would skew the scores obtained through the RBP metrics.

# 4 CONTAMINANT FATE AND TRANSPORT

The sections of this chapter are divided according to operable unit. For each operable unit, the following are discussed: potential routes of migration, contaminant persistence, and contaminant migration. Throughout this report, action levels have been referenced. The action levels used are shown in Table 52. For water, the action levels are Maximum Contaminant Levels (MCL), developed as drinking water standards as part of the Safe Drinking Water Act. The soil action levels are part of the Resource Conservation and Recovery Act (RCRA) proposed requirements for corrective action for solid waste management units. They are used here to provide guidance on when a corrective action may be required. These MCL and RCRA action levels are appropriate or relevant and appropriate requirements (ARARs) for CERCLA.

## 4.1 PERMITTED SLUDGE LANDFILL (OPERABLE UNIT 1)

The potential route of migration of contaminants from the Sludge Landfill is groundwater migration. Landfill borings indicate a soil cover that ranges from 6 to 11.5 feet; therefore, surface water migration or wind-blown transport are not likely. The source of contaminants in the vicinity of the Sludge Landfill is the landfill itself. As infiltration and flowing groundwater passes through the landfill, chemicals are leached and migrate with the groundwater. As a measure of its leachability, TCLP values for chromium from the landfill sludge ranged from <0.05 to 2.8 mg/l, which is less than the regulatory level (i.e., the sludge is not a hazardous waste). The persistence of contaminants will continue as long as the landfill exists and leaches. In terms of sludge concentrations, the only constituent identified above the proposed RCRA action level is chromium that ranged between 13,780 and 36,000 mg/kg for the four LB samples.

The water table in the vicinity of the Sludge Landfill tends to mimic the topography, which slopes toward the Reedy River. Therefore,

Table 52. Potential action levels for water and soil.

| Constituent | MCL (mg/l) Water | Soils (mg/kg) |
|---|---|---|
| Arsenic | 0.05 | 80.0 |
| Barium | 1.0 | 4000.0 |
| Cadmium | 0.01 | 40.0 |
| Chromium | 0.05 | 400.0 |
| Lead | 0.05 | -- |
| Mercury | 0.002 | 20.0 |
| Silver | 0.05 | 200.0 |

[1]Source: Federal Register, Vol. 55, No. 145, Friday, July 27, 1990, Proposed Rules, pp. 30865-30868.

groundwater, and contaminants leaching from the Sludge Landfill, will tend to flow toward the Reedy River. The shallow native material in this area has been described as a sandy soil (Froehling & Robertson, February 26, 1975), and is therefore fairly transmissive. A slug test at USF-18 showed an interpretive range for hydraulic conductivity that varied between 3.7 - 10 ft/d. Slug test results for RMT-2 provided a slightly higher range.

Groundwater samples near the Sludge Landfill have been collected and analyzed for both filtered and unfiltered conditions. MCLs are exceeded for cadmium, chromium, and lead in unfiltered samples. Filtering generally reduces concentrations for all parameters. This indicates that many of the metals are attached to fine particles. For example, given the iron content in the unfiltered samples, chromium is most likely sorbed to or coprecipitated with iron hydroxide. Thus, most of the metals that can leach from the Sludge Landfill will sorb to some degree and will move less rapidly than the water moves. Sorbed chromium will be mobile if the fine particles are mobile.

In summary, the concentrations of cadmium, chromium, and lead in monitor well RMT-2, which is downgradient of the Permitted Sludge Landfill, indicate a release to the environment. Concentrations of cadmium, chromium, and lead in RMT-2 as a result of this release, exceed MCLs and, thus are in violation of South Carolina Water Quality Standards set forth in R61-68 (South Carolina Code of Laws Ann. 1976 as amended). Concentrations of these constituents in the Reedy River did not indicate that surface water had been impacted at the time of the Reedy River sampling.

## 4.2 AERATION LAGOON (OPERABLE UNIT 2)

Apparently, after the dredging of the Aeration Lagoon was accomplished in 1975, chromium continued to accumulate in the lagoon. The only source that could have caused significant concentrations after the 1975 sludge removal was chromium contaminated sludge under the dye house. As stormwater runoff washed through the basement from 1975 through 1989, it carried chromium-contaminated dye sludge with it into the lagoon. When this situation was recognized by AFP in 1989, the stormwater was diverted from the basement so that no further entrainment of the contaminated dye sludge could occur.

Upon entering the lagoon, chromium-contaminated sludge would settle to the bottom of the lagoon. The potential routes of migration of contaminants from the Aeration Lagoon include discharge to the Greenville Sewer System and via groundwater flow. The Aeration Lagoon generally acts as a source of groundwater recharge. Slug test results from RMT-4 provide a hydraulic conductivity similar to that discussed above for USF-18. Groundwater flow is away from the lagoon, primarily toward Langston Creek and Reedy River. Contaminants that are leached from the sludge on the bottom of the lagoon will migrate away from the lagoon. TCLP values for chromium from the lagoon sludge ranged from 0.04 to 0.12 mg/l, which is less than the regulatory level needed to classify the sludge as a hazardous waste. The persistence of contaminants will continue as long as the sludge remains in the lagoon and continues to leach. In terms of sludge concentrations, the only constituent identified above the proposed RCRA action level is chromium, with a high of 3200 mg/kg for the 3/16/88 sample.

Groundwater samples taken down gradient of the Aeration Lagoon were collected using a hydropunch as part of an interim scoping. Results for chromium exceeded the MCL. Subsequent samples from monitor well RMT-4 down gradient of the lagoon have been less than MCLs. The difference in results is partially explained by sorbed chromium on fine particles in the hydropunch samples.

In summary, the concentrations of chromium in groundwater samples HP-3 and HP-4 down gradient of the Aeration Lagoon indicate a release to the environment. The groundwater concentration of chromium exceeds MCLs and thus is in violation of South Carolina Water Quality Standards set forth in R61-68 (South Carolina Code of Laws Ann. 1976 as amended). Concentrations of these constituents in the Reedy River did not indicate that surface water had been impacted at the time of the Reedy River Sampling.

4.3 REEDY RIVER FLOODPLAIN (OPERABLE UNIT 3)

Because the area adjacent to the Reedy River was used as a landfill, which contains a variety of materials including asbestos, the potential routes of migration of contaminants include: (1) groundwater migration, (2) surface water migration in the Reedy River, and, (3) wind-blown migration of asbestos. All three potential routes of migration were sampled. As indicated in previous sections of this report, the study of the Reedy River Floodplain took place in phases.

The source of the contamination in the Reedy River Floodplain is the solid waste landfill. This landfill can not be defined by specific boundaries; instead, the general area appears to have been used for random dumping. Samples of soil and sediment show elevated concentrations of metals, but are generally below the proposed RCRA action levels. The persistence of contaminants will continue in the Reedy River Floodplain as long as the landfill continues to leach.

As an indication of leaching, groundwater samples collected from trenches and wells show elevated concentrations of metals. Samples collected from trenches exceeded MCLs. In addition, unfiltered groundwater from well USF-3 exceeds the MCL for chromium. (Note R&C 9/90 sample from USF-3 had cadmium at its MCL of 0.01 mg/l.) As with other operable units, the elevated concentrations in unfiltered samples are probably due to the presence of particulate matter containing chromium. USF-1, 2, and 3 were also sampled and analyzed for a suite of organic compounds, with no constituent having concentrations above the respective detection limits. Shallow groundwater flows to the Reedy River. The hydraulic gradient in the floodplain is fairly flat and hydraulic conductivities for USF-1, 2, and 3 are listed in Table 48.

The Reedy River was sampled upstream and downstream to see if the river is impacted by the presence of the landfill. The results in Table 29 indicate no discernable impact at the time of sampling. The upstream and downstream samples were very similar in composition with no constituents above MCLs.

Another concern at the Reedy River Floodplain is asbestos. Asbestos was detected in well USF-1. The results of the aggressive air sampling detected no asbestos in the air in any of the tested areas. Thus, although present in the form of tiles in the floodplain, migration of asbestos in air appears not to be occurring.

In summary, the concentrations of chromium in groundwater at monitor well USF-3 indicate a release to the environment resulting from dumping activities. The groundwater concentration of chromium at USF-3 exceeds MCLs and thus is in violation of South Carolina Water Quality Standards set forth in R61-68 (South Carolina Code of Laws Ann. 1976 as amended). Concentrations of chromium in the Reedy River did not indicate an impact at the time of the Reedy River sampling.

4.4 BASEMENT SLUDGES (OPERABLE UNIT 4)

With stormwater now being diverted from the basement, there should be minimal groundwater recharge through the basement since plant process waste water is piped directly to concrete ditches. The potential route of migration of contaminants from the Basement is groundwater migration. Although some sludge was removed in 1984, just prior to the sale of the facility to AFP, contaminated sludge and soil are still present in the basement. Of the 15 suspect basement sludge areas for which data are available, sludge samples from 11 of these exceed the proposed RCRA action levels. These sludges leach, but with the exception of one analysis by RMT, are below regulatory limits for hazardous waste classification. Thus, the persistence of contaminants will continue as long as the sludge remains in place and continues to leach.

The impact this leaching has on groundwater was determined via hydropunch samples. Of a total of seven hydropunch (HP-5, HP-7 through HP-12) installed in the basement, all but one (HP-10) contained constituents that exceeded their respective MCLs in unfiltered samples. For chromium, the maximum value was 5.2 mg/l in HP-8. Groundwater beneath the basement flows toward Langston Creek, carrying contaminants with it. Thus, although Basement contamination has contributed to contamination found in the Langston Creek Floodplain, it does not appear to be the source of the high chromium concentrations associated with hexavalent chromium contaminated wells including extraction well W-9, and the USF monitor wells.

4.5 CHROMIUM TANK AND LINES (OPERABLE UNIT 5)

The chromium tank and lines have been suspected as a source of the chromium contamination found near Langston Creek. The potential route of migration of chromium from the chromium tank and lines is via groundwater migration. According to an invoice dated April 11, 1981, "One used Toxic Chrome Dye Tank (sold uncleaned as is)" was sold to the City of Travelers Rest, S.C. Therefore, the tank is no longer a continuing source. Although the tank was removed in 1981, the buried lines, containing chromium, were not removed until December 1990 by AFP. The current source of contamination is soil that was contaminated by the tank and lines. Of approximately 50 shallow soil samples within the pipeline trench, 20 exceeded proposed RCRA action levels, with a high of 18,000 mg/kg. At three locations that were examined, soil contaminated with chromium extended to the water table. The areal extent of contaminated soil exceeding the action level of 400 mg/kg is shown in Figures 27 and 28 for the chromium distribution lines and tank, respectively.

Based on TCLP results for chromium, the soil leaches, and at a number of locations, is greater than the regulatory level, which means it would be classified as a hazardous waste. The persistence of contaminants will continue as long as the contaminated soil remains in place and continues to leach.

Along the alignment of the chromium pipelines, the water table is approximately 12 feet below land surface. Chromium leaching from the contaminated soil will tend to move vertically in the unsaturated zone until it reaches the water table. Groundwater underlying the pipelines flows toward Langston Creek, and will be discussed in Section 4.9.

In addition to the chromium tank and lines, the chromium fill area (CFA) was also investigated (see Figure 29). For this area, soil action levels were exceeded at eight locations. TCLP results show that the soil leaches, and at one location, exceeds the regulatory limit indicating a hazardous classification. Results of hydropunch groundwater samples indicate that chromium contamination exceeds the MCL (0.40 mg/l: RMT shallow sample).

## 4.6 FUEL TANK, LINE, AND W-8 (OPERABLE UNIT 6)

### 4.6.1 Well W-8

Well USF-4 was installed as a lower saprolite well (at top of bedrock) adjacent to well W-8. Sampling and analysis of well USF-4 indicated that concentrations of Total Petroleum Hydrocarbon (TPH) were less than 20 mg/l for two samplings, January 22 and February 21, 1991. Analyses of split samples from Cone for TPH from well W-8 for a similar time period indicated that TPH concentrations in well W-8 ranged from 68 to 125 mg/l. This information indicated that the petroleum hydrocarbon contamination at well W-8 is limited to the water-table zone and does not extend to the top of bedrock. W-8 is screened from 5 to 15 feet, and well USF-4 is screened from 40.5 to 50.5 feet. In addition, volatile organics, and acid/base/neutrals were analyzed for wells USF-10, 11, and 12 downgradient of W-8 on the east side of the plant. Only trace amounts of organics were found in USF-11 and -12, which also supports the limited nature of contamination associated with W-8.

detection limit is too high

wells are too far from sourc

Finally, three borings were drilled and sampled to a depth of 14 feet below land surface. These borings are numbered W-8/27N, W-8/30W, and W-8/20S; their locations are shown in Figure 30. The depth to groundwater at well W-8 is approximately 6 feet beneath land surface. Split-spoon samples were noted for visual and olfactory evidence of contamination, and selected samples were analyzed for TPH. The results are provided in Table 41 and shown in Figure 30. As may be seen, there was no visual evidence of a second phase liquid. This further supports the hypothesis that the hydrocarbon contamination associated with W-8 is limited. The chromium contamination at W-8, however, is part of Operable Unit 9.

4.6.2 Former Fuel Tank and Line

To determine the nature and extent of TPH contamination associated with the former fuel tank, soil borings were installed and groundwater was sampled at two locations downgradient of the tank. TPH soil contamination is shown in Figure 30, with tabulated data listed in Table 41. This figure illustrates that TPH soil concentrations are highest in the vicinity of the former tank and line location. Concentrations above background are located adjacent to and extend southeast of the former tank location.

Although the soil contains elevated TPH, groundwater downgradient (toward the southeast) of the former tank location appears to be unaffected. TPH analysis from 2/26/91 for a groundwater sample at USF-7, adjacent to the former tank location, and the shallow hydropunch sample collected during the installation of USF-6, which is approximately 80 feet downgradient, were <10 and <20 mg/l TPH, respectively.

wells screened too deep. detection limit too high

4.7 CAUSTIC PLUME (OPERABLE UNIT 7)

Although the caustic plume is in Langston Creek, it is treated as a separate operable unit because of the different contaminants and potentially different treatment requirements. The caustic plume was discovered when wells W-3 and W-14 were installed in 1982 and has existed unremediated since. The route of migration has been demonstrated to be groundwater, although overland flow of caustic may have occurred in the past. This is suggested by soil boring data that shows pH decreasing with depth.

The caustic plume is persistent, having maintained uniform contaminant concentrations for the nine-year period data have been collected. The source of the plume is the historical usage of caustic. The plume is downgradient (toward Langston Creek) of the basement area and the caustic tanks (Figure 31) used to store delivered caustic. These tanks are probably a principal source of caustic groundwater contamination, resulting from either overfills or leaks. Subsequent to the purchase of Union Bleachery by AFP, significant repairs were made to the concrete floor and berm that underlies and surrounds these tanks (Luther Woodcock, oral communication, 1991). Another principal source appears to be the usage of caustic within the bleach house, as indicated by the elevated pH at hydropunch HP-12. All of the caustic-contaminated wells also contain arsenic, which is a contaminant commonly found in the basement sludge. Another potential source includes the circular caustic reclaim tanks near well W-14.

The caustic plume and associated contaminants (e.g., arsenic) are flowing toward Langston Creek. In 1989, Trench #3 was dug 50 feet downgradient of well W-3. Because of the slightly elevated pH and the arsenic content, this trench is probably near the leading edge of the caustic plume. The pH in wells W-2 and W-10 have also increased slightly over time, with no noticeable increase occurring subsequent to their remedial pumping that began in April 1990.

Hydraulic conductivities for wells USF-11, USF-12, and W-3 are provided in Tables 48 and 49. As may be seen, they are fairly low, ranging from 0.03 to 2.5 ft/day. The hydraulic gradient in this area is fairly flat. For example, USF-11 is separated from W-14 by about 160 ft and on May 7, 1991 had a hydraulic head difference of 1.11 feet. This yields a horizontal hydraulic gradient of 0.007. If a hydraulic conductivity of 1.5 ft/day and a porosity of 0.3 are used, an interstitial velocity can be calculated as 0.035 ft/day or almost 13 ft/yr. This provides an estimate of how fast the caustic plume may be moving (i.e., it ignores variations in hydraulic conductivity and other processes such as dispersion).

The caustic plume contains hazardous constituents. The first is the caustic itself, which at well USF-11 has a pH of 12.5. MCLs are also exceeded for chromium, lead and arsenic. Finally, historical sampling (10/87) of well W-3 has exceeded the MCL of 1,1-dichloroethene (0.007 mg/l) with a value of 0.022 mg/l. The more recent sampling of wells USF-11 and 12, however, only showed low concentrations of organics (Table 50).

Of the constituents that exceed MCLs, arsenic was examined in detail and plotted on Figure 31. The source of the arsenic might have been boll weevil pesticide that was leached from the cotton in the bleach house. Dye sludge also contains arsenic and is a potential source. Another possible source of the arsenic may be the soil material, where the caustic is causing the arsenic to leach. The background soil boring B-1 shows that arsenic is present in the native soils (Table 15). Arsenic chemistry can be complex and is beyond the scope of this effort. It is of interest to note, however, that, with very few exceptions, there is a direct correlation between pH values and arsenic concentrations. Thus, although arsenic concentrations in the soil are low, the soil could be leaching arsenic as a result of the caustic.

## 4.8 BLUE POND (OPERABLE UNIT 8)

Of the soil borings and wells installed to investigate the Blue Pond, only one shallow soil sample from 2-4 feet below land surface exceeded the proposed RCRA action level for chromium (BPB-9: 1900 mg/l). Groundwater in the vicinity of the Blue Pond does not appear to be impacted, with the exception of aluminum at a concentration of 2.2 mg/l.

## 4.9 LANGSTON CREEK AQUIFER (OPERABLE UNIT 9)

The routes of migration of contaminants in the Langston Creek Floodplain are groundwater and surface water migration.

### 4.9.1 Groundwater System

Between March 1982 and May 1990, 20 wells were installed along Langston Creek to address chromium contamination, to measure water levels, and to provide for chromium extraction by pumping (Figure 23). During late 1990 and early 1991, an additional 24 wells and 3 piezometers were installed in the Langston Creek aquifer (Figure 23). Through these well installations, four stratigraphic horizons were identified:

- Fill - consisting of crushed rock, cinders, and sand;
- Alluvium - red brown to gray sand and silt;

- Saprolite - weathered bedrock consisting of sands and silts; and

- Bedrock - fractured, weathered biotite gneiss.

Classification of the open interval of these wells has been divided into alluvial, saprolite, and bedrock. Well specifications and borehole stratigraphy for the pre-November 1990 wells are presented in Table 1; those for the more recent wells are provided in Table 46. The stratigraphic units that underlie Langston Creek exhibit significant spatial variability. Although the division of units appears straight forward, the heterogeneous nature of the materials results in complex patterns. This complex distribution affects groundwater flow and contamination distributions.

The site conceptualization presented here is similar to that presented in GeoTrans (1989). In this conceptualization, the upper weathered portion of the bedrock and, in places, the lower part of the saprolite, form a confined aquifer. Overlying this aquifer, upper portions of the saprolite that have low permeability form a confining bed. This is overlain by alluvium and fill that form a water-table aquifer. This conceptualization is highly generalized; the Langston Creek aquifer system is actually highly variable spatially, exhibiting varying degrees of hydraulic connection, both horizontally and vertically.

The sediments and saprolite that constitute a part of the Langston Creek aquifer system extend toward the west behind the dye house (Figures 33, 34, and 35). The earlier conceptualization (GeoTrans, 1989) indicated that the bedrock rose toward the basement of the dye house. This was based on a hydropunch that was thought to have encountered bedrock at a shallow depth. Recent studies have shown this not to be the case. Thus, the Langston Creek aquifer extends beyond and west of the main plant. The aquifer system extends south towards the Reedy River; it extends north up Langston Creek an unknown distance. The aquifer system may extend toward the east beyond Highway 253. In addition to the lack of wells in this direction, at certain locations in this direction, the topography increases steeply representing a possible bedrock high.

4.9.2 Flow System

Water-level data are provided in Figures 37 to 39. Based on these data and historical water-level data, the groundwater flow system can be described as follows. Generally, groundwater is flowing toward Langston Creek from the west, and perhaps from the east, and then in a southwesterly direction along the Langston Creek Floodplain. In the southeastern portion of the site, near Highway 235, the groundwater flow direction is toward the east away from the Union Bleachery site.

In general, the well clusters away from Langston Creek (USF-9 and USF-9A, and RMT-5A and RMT-5B) exhibit a slight, downward, hydraulic gradient. The well clusters in close proximity to Langston Creek (USF-14 and USF-14A, USF-19 and USF-19A, and W-4 and W-11) exhibit a medium to strong, upward, gradient. This upward hydraulic gradient was also noted by Law Engineering Testing upon drilling W-9.

Aquifer properties have been estimated through the use of various aquifer tests, primarily slug tests (Tables 48 and 49). Five bedrock wells have been slug tested; the results indicate a range of hydraulic conductivities (depending in part on the method of analysis) - 0.09-9.2 ft/d. The specific storage of the bedrock is estimated from Walton (1988) to range from $10^{-5}$ - $10^{-6}$ $ft^{-1}$. Over 15 saprolite wells have been slug tested. The results show the hydraulic conductivity varies from approximately (again, this depends in part on the method of analysis) 0.42 - 70 ft/d. The specific storage is estimated from Walton (1988) to range from $10^{-4}$ - $10^{-5}$ $ft^{-1}$. Approximately six alluvial wells were slug tested. The results indicate a range, depending in part on the method of analysis, of 0.08 - 30 ft/d. The alluvium is estimated to have a specific yield ranging from 0.0 - 0.3 (Walton, 1988). In order to better understand the flow system and enhance the existing remediation, additional aquifer testing has been proposed (GeoTrans, 1991b).

4.9.3 Chromium Contamination

Historical chromium data for groundwater are listed in Table 2; data collected as part of this RI are posted in Figure 40. Based on the results from the RI, the chromium contamination at the Union Bleachery site is more extensive than previously characterized. The plume extends northward, up Langston Creek, north of the pond to at least well USF-23, some 350 feet from extraction well W-9. Toward the south, chromium in well W-15 has increased in concentration, indicating that the current pump-and-treat system is not containing the chromium plume, and that off-site migration is most likely occurring, as this well is near the property boundary. Chromium-contaminated groundwater (associated with the chromium supply line) also has been detected toward the west behind the main facility building. In addition, chromium contamination has been found at greater depths than previous wells had indicated.

The specific source of the chromium beneath Langston Creek has been connected to the leaks from the chromium line. Cone used chromium primarily as an oxidizing agent (bath) for sulfur dye colors. The box (unit) would overflow and drain to the same system as the overflows and drains from the dye baths. These mixed flows would then be pumped together. If the spent oxidizing agent were the source, much of the chromium would have been reduced to its trivalent form and it would be mixed with "color, BOD and COD." This is not the case with chromium beneath Langston Creek.

When discovered, chromium in W-9 exceeded 3000 mg/l, and this hexavalent chromium is the only contaminant of significance in W-9. The source was thought to be unused chromium, probably from a leak in a chromium supply line. Data collected as part of this RI supports this hypothesis. Chromium in the line had a concentration of 405,000 mg/l. The line was discovered to have leaks, with contaminated soil covering an extensive area and down to the water table. Groundwater beneath the line had a chromium concentration at USF-9 of 97 mg/l in 1991. This is at least 17 years after this chromium line's use was discontinued. Additionally, there is a downward hydraulic gradient at USF-9. Considerable effort was expended to determine the pathway that chromium may have moved from the chromium line to Langston Creek. Although no precise path could be determined, USF-9, 5, and 10 are in a direct line with USF-19, which indicates one probable path of chromium contamination migration. Given the heterogeneous nature of the geologic material combined with the anthropogenic effects (e.g., numerous pipelines) in the vicinity of Union Bleachery, the exact pathway is difficult to determine.

4.9.4 Existing Pump-and-Treat System

Remedial groundwater pumping to recover chromium-contaminated groundwater at the Union Bleachery site has been operating since November 11, 1982. According to a Consent Order dated May 14, 1984,

> NOW, THEREFORE, IT IS ORDERED, pursuant to Section 48-1-50 of the 1976 Code, as amended, and with the consent of the parties, that Cone Mills shall continue to recover and treat the contaminated groundwater beneath this property, in a Department-approved fashion, until an agreed upon level is reached, at which time the remaining groundwater will be recovered until the Department determines that background levels have been met.

Well W-9, a two-inch PVC monitor well, has been pumped intermittently at a maximum withdrawal rate of about 6.6 gpm. The net process rate or the rate at which water is being treated was calculated from Cone Mills monthly records and is presented in terms of gallons per minute in Figure 41. As shown all net process rates thus far are below 6.2 gpm. Because of the heterogeneous nature of the Langston Creek Aquifer system, and the widespread and complex distribution of chromium contamination, extraction at W-9 is insufficient to effectively capture all contamination. The increase in chromium concentrations at W-15 indicates that the chromium plume is moving beyond the effective capture zone of W-9.

The approximate amount of chromium removed by the remedial pumping system on a monthly basis is depicted in Figure 42. The mass of chromium removed was calculated using the amount of chromium batch processes over the month and the monthly concentration measurement of chromium at W-9. The rate of chromium removal by pumping at W-9 has

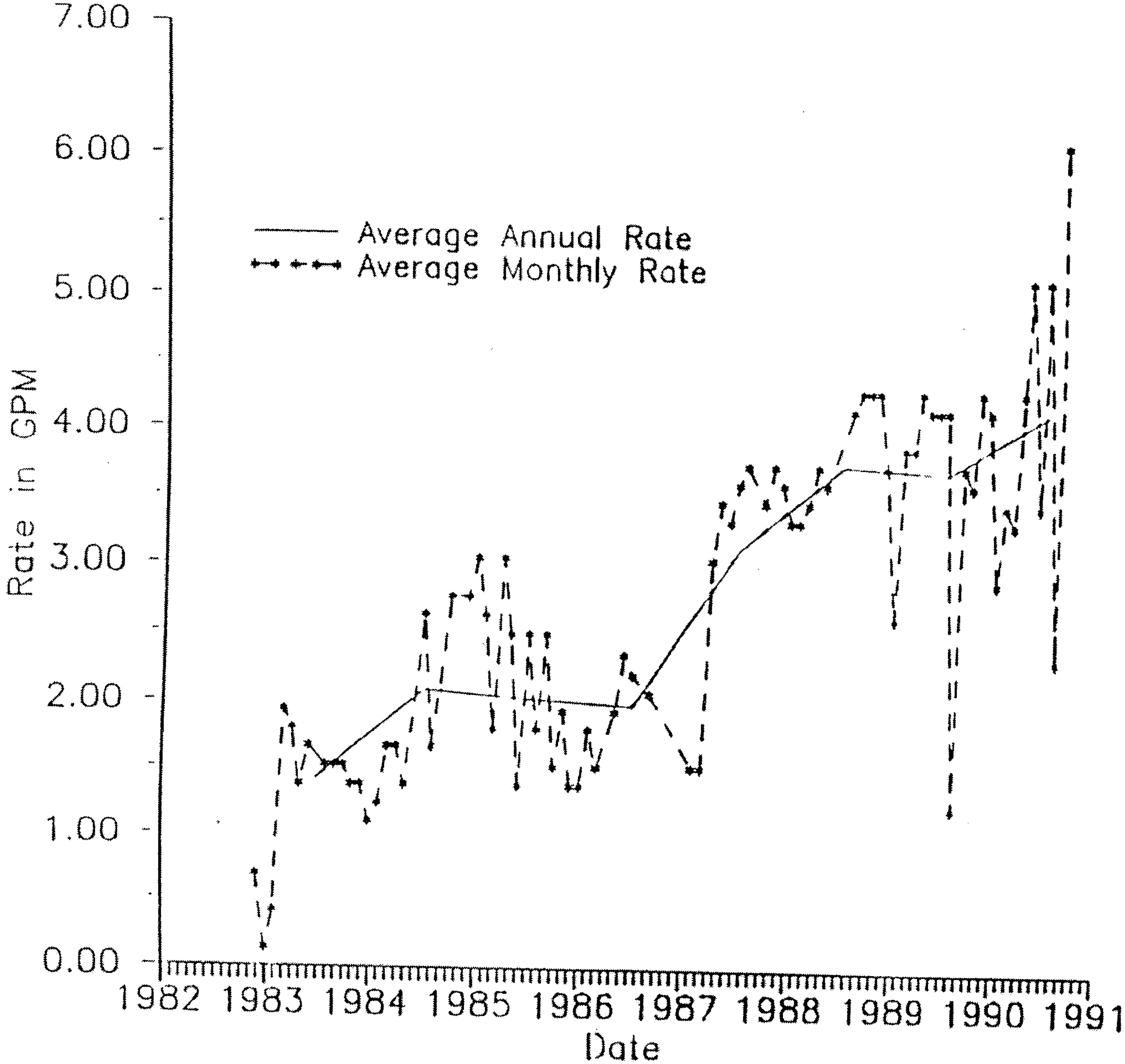



Figure 41. Net process rate for the chromium batch treatment system in gallons per minute, November 1982 to August 1990.



GeoTrans, inc.

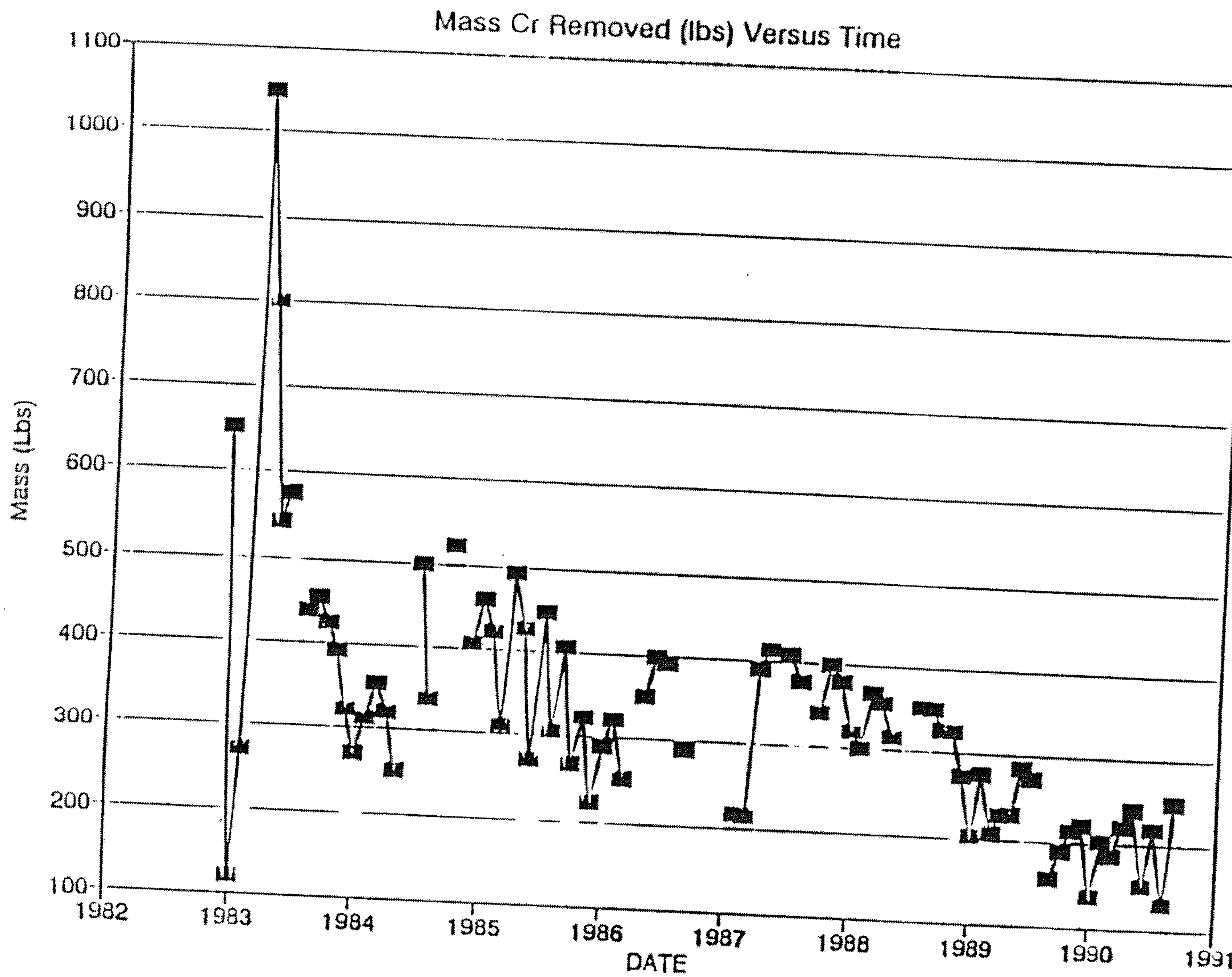



Figure 42. Monthly chromium removal by pumping at W-9, 1982 to 1990.

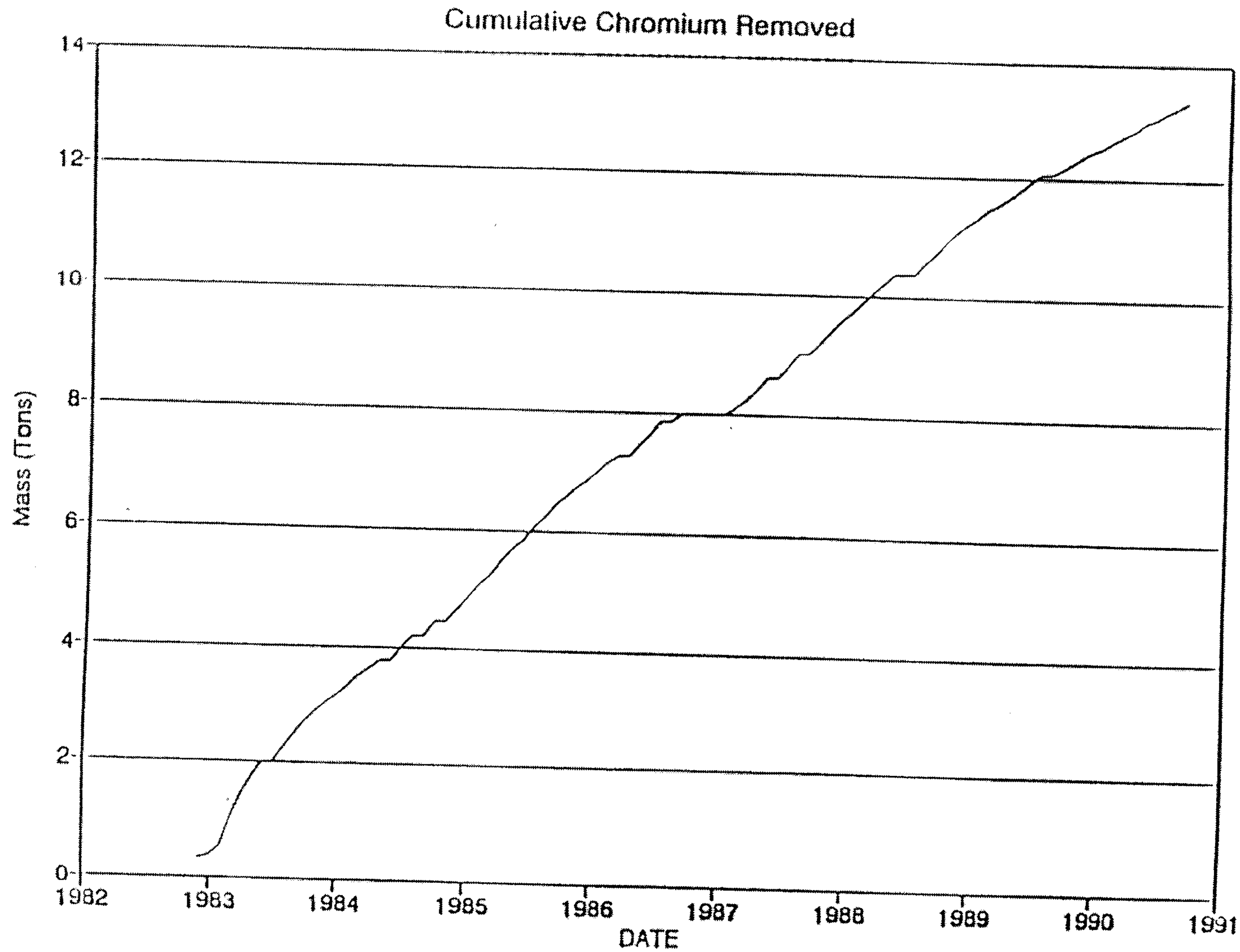



Figure 43. Cumulative chromium removal by pinpoint at W-9, 1983 to 1990.

decreased slightly since remediation startup. Overall the calculated amount of chromium removed by the end of 1990 is thirteen tons. The cumulative amount of chromium removed (Figure 43) shows that no significant leveling off of chromium removal has been reached.

Average annual chromium distributions are presented in Appendix B. As shown in these figures, average chromium concentrations have shown marked reductions at the remedial pumping well, W-9. To a lesser degree, wells directly west of W-9 but east of the main plant: W-2, W-10, W-3, W-14, and W-5 also showed decreasing average chromium concentrations from 1983 to 1989. In 1990, however, all of these wells except W-3 showed increasing chromium concentrations.

Reductions in chromium concentrations at W-9, W-2, W-3, W-5, W-10, and W-14 may represent chromium capture by the W-9 chromium recovery system. Increases in chromium concentration in 1990, especially near the main plant, may be partly due to the pumping at W-2 and W-10, which began in April 1990. This pumping may be recovering some of the contaminated groundwater that extends under the main plant. Chromium concentration at W-10, a bedrock well, has more than doubled from 40 mg/l on April 27, 1990 to 98 mg/l on August 8, 1990.

Chromium concentrations in wells not directly upgradient from W-9 and those wells beyond the downgradient capture zone will not be affected by groundwater pumping at W-9. This is particularly significant for those downgradient wells which have increasing chromium concentrations with time. Well W-15, for example, had an average chromium concentration of 7.2 mg/l in 1987 and 10.6 mg/l in 1990. As of April 1991, chromium concentration in W-15 had reached 44 mg/l. These results suggest that chromium currently downgradient of W-9 is migrating off site.

Chromium contamination has been found in all units: alluvium, saprolite and bedrock. Although W-9 has been recovering chromium from the alluvium and saprolite material, its impact on the bedrock aquifer probably is limited. Drilling, as part of the RI, indicates that W-9 terminates approximately 20 feet above the top of bedrock. As previously indicated, the significance of a portion of the saprolite as a confining bed is demonstrated by well cluster RMT-5, RMT-5A, and RMT-5B, which are completed in the alluvium, saprolite, and bedrock, respectively. Sampling results by R&C from a sample taken on June 20, 1990 from RMT-5, RMT-5A, and RMT-5B showed chromium concentrations of 7.1 mg/l for the alluvium, <0.02 mg/l for the saprolite, and 18.00 mg/l for the bedrock. Because chromium occurs in the alluvial and bedrock wells, but not the saprolite well at this location, multiple plumes, with at least one plume in the alluvium are suggested. It also should be noted that the chromium concentrations are higher in the bedrock well (5B) than in the alluvial well (5). Because the RMT-5 series cluster is outside the expected capture zone of W-9, chromium within these wells will most likely continue to migrate.

### 4.9.5 Langston Creek

One of the goals of the pump-and-treat system is to protect Langston Creek. As pointed out in previous sections, the MCL for chromium has often been exceeded in Langston Creek (see Table 3). The impact of benthic macroinvertebrate in Langston Creek and Reedy River was assessed using rapid bioassessment protocols (RBP) and is described in Appendix F.

The results of the study indicated no impairment or slight impairment at the downstream locations in Langston Creek. These results are uncertain because (1) the upstream reference station may have been impacted by upstream contaminant sources and/or (2) at the time of the sampling high water level conditions existed due to a prior flood event that could have altered the composition of the macroinvertebrate community through scouring or drift.

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APPENDIX A - MARCH AND JUNE 1990 RMT AND R&C GROUNDWATER RESULTS

Table A.1. Composition of sludge samples in mg/kg where SL-1 (B-1E) is from the landfill, SL-2 is from the lagoon, and SL-3 & SL-4 are from the dye range.

UNION BLEACHERY

| | SL-1 | | SL-2 | | SL-3 | | SL-4 | |
|---|---|---|---|---|---|---|---|---|
| | 5/9/90 | 5/8/90 | 4/24/90 | 4/24/90 | 4/24/90 | 4/24/90 | 4/24/90 | 4/24/90 |
| PARAMETER | R&C | RMT | R&C | RMT | R&C | RMT | R&C | RMT |
| Arsenic | 12 | 6.5 | <1.0 | 5.4 | 17 | 43 | <1.0 | 11 |
| Barium | 49 | 130 | 123 | 210 | 7 | 280 | 136 | 79 |
| Cadmium | 0.08 | 3.5 | 2.6 | <0.8 | 2.5 | <2.0 | 15 | <0.7 |
| Chromium | 143 | 16000 | 1750 | 1900 | 1520 | 2100 | 136 | 350 |
| Copper | 1.8 | 200 | 46 | 53 | 272 | 370 | 545 | 680 |
| Iron | 530 | 48000 | 35100 | 53000 | 21500 | 71000 | 50900 | 470000 |
| Lead | <0.02 | 32 | <2.0 | 30 | 234 | 290 | 127 | 70 |
| Magnesium | 1400 | 1500 | 1050 | 1500 | 696 | 820 | 1360 | 930 |
| Manganese | 2.1 | 160 | 342 | 590 | 41 | 200 | 1910 | 2300 |
| Mercury | 0.22 | 0.5 | <0.2 | <0.1 | 2.2 | 4.8 | <0.2 | 0.2 |
| Selenium | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <0.8 | <1.0 | <0.9 |
| Silver | 2.6 | <2 | <1.0 | <2 | <1.0 | <1 | <1.0 | <1 |
| Zinc | 7.1 | 790 | 82 | 160 | 158 | 270 | 564 | 350 |

Table A.2. Toxic Characteristic Leaching Procedure (TCLP) results for the sludge samples in mg/l.

UNION BLEACHERY
Toxic Characteristic
Leaching Procedure

| | SL-1 Landfill Sludge | | SL-2 Lagoon Sludge | | SL-3 Dye Range | | SL-4 Dye Range | |
|---|---|---|---|---|---|---|---|---|
| | 5/9/90 | 5/8/90 | 4/24/90 | 4/24/90 | 4/24/90 | 4/24/90 | 4/24/90 | 4/24/90 |
| PARAMETER | R&C | RMT | R&C | RMT | R&C | RMT | R&C | RMT |
| Arsenic | <0.01 | <0.003 | <0.01 | 0.005 | <0.01 | <0.003 | <0.01 | <0.003 |
| Barium | 0.56 | 0.72 | 0.59 | 0.77 | <0.01 | 0.05 | 0.68 | 1.3 |
| Cadmium | <0.01 | 0.008 | <0.01 | <0.005 | <0.01 | 0.01 | <0.01 | <0.005 |
| Chromium | 1.4 | 2.8 | 0.12 | 0.07 | 0.24 | 0.2 | <0.02 | 0.04 |
| Copper | 0.01 | <0.02 | <0.01 | <0.02 | 0.63 | <0.02 | 0.02 | 1.1 |
| Iron | 0.21 | 0.8 | 38 | 390 | 0.29 | 200 | 7.6 | <0.1 |
| Lead | <0.02 | <0.01 | <0.02 | <0.1 | 0.15 | 6 | <0.02 | <0.1 |
| Magnesium | 16 | 13 | 12 | 14 | 13 | 11 | 5.2 | 11 |
| Manganese | 1.1 | 1.1 | 4 | 19 | 0.63 | 6.2 | 11 | 0.55 |
| Mercury | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 |
| Selenium | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.006 | <0.01 | <0.003 |
| Silver | <0.01 | <0.01 | <0.01 | <10 | <0.01 | <10 | <0.01 | <10 |
| Zinc | 7.5 | 8.5 | 0.24 | 2.4 | 1 | 0.19 | 1.8 | 1.3 |

what wells are these?
W or USF series?

Table A.3. Groundwater sampling results from March 6, 1990 sampling episode in mg/l.

UNION BLEACHERY
MARCH 6, 1990

| PARAMETER | MW-1 R&C | MW-1 RMT | MW-2 R&C | MW-2 RMT | MW-3 R&C | MW-3 RMT | MW-4 R&C | MW-4 RMT | MW-5 R&C | MW-5 RMT |
|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | <0.01 | 0.006 | <0.01 | 0.004 | 0.242 | 0.21 | <0.01 | <0.003 | <0.01 | 0.003 |
| Barium | 0.47 | 0.42 | 0.03 | <0.05 | 0.02 | <0.05 | 0.19 | 0.18 | 0.29 | 0.3 |
| Cadmium | <0.01 | 0.0011 | <0.01 | 0.0004 | <0.01 | <0.0003 | <0.01 | <0.0003 | <0.01 | <0.0003 |
| Chromium | 0.08 | 0.061 | 100 | 110 | 0.07 | 0.039 | 0.04 | 0.017 | 0.11 | 0.12 |
| Lead | <0.01 | 0.1 | 0.017 | <0.003 | 0.038 | 0.008 | 0.013 | 0.009 | 0.045 | 0.046 |
| Mercury | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 |

| PARAMETER | MW-6 R&C | MW-6 RMT | MW-7 R&C | MW-7 RMT | MW-8 R&C | MW-8 RMT | MW-9 R&C | MW-9 RMT | MW-10 R&C | MW-10 RMT |
|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Barium | 0.04 | <0.05 | 0.48 | 0.5 | 0.05 | <0.05 | 0.05 | <0.05 | 0.05 | <0.05 |
| Cadmium | <0.01 | 0.0004 | <0.01 | 0.0004 | <0.01 | 0.0004 | <0.01 | <0.0003 | 0.01 | 0.0008 |
| Chromium | <0.02 | 0.008 | 0.09 | 0.098 | 0.02 | 0.006 | 135 | 140 | 42 | 41 |
| Lead | <0.01 | 0.004 | <0.01 | <0.003 | <0.01 | 0.004 | <0.01 | <0.003 | <0.01 | 0.007 |
| Mercury | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 |

| PARAMETER | MW-11 R&C | MW-11 RMT | MW-13 R&C | MW-13 RMT | MW-14 R&C | MW-14 RMT | MW-15 R&C | MW-15 RMT | MW-16 R&C | MW-16 RMT | MW-17 R&C | MW-17 RMT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | 0.013 | 0.025 | <0.01 | 0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Barium | 0.05 | <0.05 | 0.09 | 0.07 | 0.02 | <0.05 | 0.34 | 0.25 | 0.81 | 0.84 | 0.59 | 0.64 |
| Cadmium | <0.01 | <0.0003 | <0.01 | 0.002 | 0.01 | <0.0003 | <0.01 | <0.0003 | <0.01 | 0.0006 | <0.01 | <0.0003 |
| Chromium | 0.06 | 0.019 | 0.04 | 0.013 | 0.05 | 0.04 | 14 | 11 | 0.9 | 0.95 | 0.11 | 0.095 |
| Lead | 0.014 | <0.003 | 0.033 | 0.032 | 0.023 | 0.005 | 0.013 | 0.009 | <0.01 | 0.011 | <0.01 | 0.003 |
| Mercury | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 | <0.002 | <0.0002 |

Table A.4. Groundwater sampling results from June 20-21, 1990 sampling episode in mg/l.

UNION BLEACHERY
JUNE 20-21, 1990

| PARAMETER | MW-1 R&C | MW-1 RMT | MW-2 R&C | MW-2 RMT | MW-3 R&C | MW-3 RMT | MW-4 R&C | MW-4 RMT | MW-5 R&C | MW-5 RMT |
|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | 0.2 | <0.01 | <0.003 | <0.01 | <0.003 |
| Barium | 0.05 | <0.05 | 0.07 | 0.06 | 0.03 | <0.05 | 0.11 | 0.1 | 0.04 | <0.05 |
| Cadmium | <0.01 | <0.0003 | <0.01 | 0.0048 | <0.01 | <0.0003 | <0.01 | 0.0005 | <0.01 | 0.0008 |
| Chromium | <0.02 | <0.002 | 54 | 59 | <0.02 | 0.42 | 0.04 | <0.002 | 0.04 | 0.08 |
| Copper | <0.01 | 0.02 | <0.01 | 0.02 | <0.01 | <0.02 | 0.03 | <0.01 | 0.01 | <0.02 |
| Iron | 6.2 | 5.7 | 0.03 | <0.1 | 0.27 | 0.5 | <0.02 | <0.1 | 0.12 | 0.1 |
| Lead | <0.005 | <0.003 | <0.005 | <0.003 | <0.005 | 0.008 | <0.005 | <0.003 | <0.005 | 0.035 |
| Magnesium | 3.2 | 3.2 | 1.6 | 1.7 | 0.02 | <0.5 | 2.4 | 2.6 | 0.05 | <0.5 |
| Manganese | 0.14 | 0.13 | 0.39 | 0.4 | 0.02 | 0.005 | 0.01 | <0.005 | <0.01 | 0.014 |
| Mercury | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 |
| Selenium | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Silver | <0.01 | <0.001 | <0.01 | <0.001 | 0.02 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 |
| Zinc | <0.01 | 0.02 | 0.54 | 0.03 | 0.02 | 0.04 | 0.01 | 0.02 | 0.01 | 0.02 |

| PARAMETER | MW-6 R&C | MW-6 RMT | MW-7 R&C | MW-7 RMT | MW-8 R&C | MW-8 RMT | MW-9 R&C | MW-9 RMT | MW-10 R&C | MW-10 RMT |
|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Barium | 0.04 | <0.05 | 0.28 | 0.21 | 0.05 | <0.05 | 0.06 | <0.05 | 0.09 | <0.05 |
| Cadmium | <0.01 | 0.0008 | 0.37 | 0.0007 | <0.01 | <0.0003 | <0.01 | 0.0004 | <0.01 | 0.0034 |
| Chromium | <0.02 | 0.004 | 0.63 | 0.74 | <0.02 | <0.002 | 141 | 140 | 64 | 77 |
| Copper | <0.01 | <0.02 | 0.36 | <0.02 | <0.01 | <0.02 | 0.01 | <0.02 | <0.01 | 0.02 |
| Iron | <0.02 | 1 | <0.02 | <0.1 | 6.7 | 4.5 | <0.02 | <0.1 | 0.09 | <0.1 |
| Lead | <0.005 | 0.004 | <0.005 | 0.004 | <0.005 | <0.003 | <0.005 | <0.003 | <0.005 | <0.003 |
| Magnesium | 1.2 | 1.1 | 0.5 | <0.5 | 17 | 18 | 12 | 12 | 0.77 | 0.7 |
| Manganese | <0.01 | 0.76 | 0.45 | 0.21 | 0.1 | 0.059 | 0.16 | 0.17 | 0.02 | 0.022 |
| Mercury | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 |
| Selenium | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Silver | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 |
| Zinc | <0.01 | 0.02 | 0.37 | 0.04 | <0.01 | 0.02 | 0.09 | <0.02 | 0.91 | 0.95 |

Table A.4. Continued

UNION BLEACHERY
JUNE 20-21, 1990

| PARAMETER | MW-11 R&C | MW-11 RMT | MW-13 R&C | MW-13 RMT | MW-14 R&C | MW-14 RMT | MW-15 R&C | MW-15 RMT | MW-16 R&C | MW-16 RMT |
|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | 0.018 | <0.01 | <0.003 | <0.01 | <0.003 |
| Barium | 0.07 | <0.05 | 0.08 | <0.05 | 0.03 | <0.05 | 0.07 | <0.05 | 0.58 | 0.45 |
| Cadmium | <0.01 | <0.0003 | 0.02 | 0.0028 | <0.01 | 0.0013 | <0.01 | 0.0008 | <0.01 | 0.0007 |
| Chromium | <0.02 | 0.015 | <0.02 | 0.007 | <0.02 | 0.039 | 13 | 12 | 1.7 | 1.5 |
| Copper | <0.01 | <0.02 | 0.02 | <0.02 | 0.01 | 0.04 | <0.01 | <0.02 | <0.01 | <0.02 |
| Iron | <0.02 | <0.1 | <0.02 | <0.1 | 1 | 2.7 | 0.04 | <0.1 | <0.02 | <0.1 |
| Lead | <0.005 | <0.003 | <0.005 | <0.003 | <0.005 | 0.005 | <0.005 | <0.003 | <0.005 | 0.003 |
| Magnesium | 2.4 | 2.7 | 1.6 | 1.8 | 2.4 | 2.8 | 13 | 14 | 23 | 34 |
| Manganese | <0.01 | <0.005 | 0.02 | 0.013 | 0.02 | 0.013 | 0.08 | 0.054 | <0.01 | 0.005 |
| Mercury | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 |
| Selenium | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Silver | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 |
| Zinc | <0.01 | 0.05 | 0.08 | 0.09 | 0.01 | 0.04 | 0.12 | 0.04 | 0.02 | 0.04 |

| PARAMETER | MW-17 R&C | MW-17 RMT | RMT MW-1 R&C | RMT MW-1 RMT | RMT MW-2 R&C | RMT MW-2 RMT | RMT MW-2A R&C | RMT MW-2A RMT | RMT MW-4 R&C | RMT MW-4 RMT |
|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Barium | 0.28 | 0.22 | 0.07 | 0.06 | 0.07 | 0.06 | 0.04 | <0.05 | 0.08 | 0.07 |
| Cadmium | 0.02 | 0.0005 | <0.01 | 0.0007 | <0.01 | 0.0009 | <0.01 | 0.0005 | <0.01 | 0.0004 |
| Chromium | 44 | 0.59 | <0.02 | <0.002 | <0.02 | <0.002 | <0.02 | <0.002 | <0.02 | 0.003 |
| Copper | 0.02 | <0.02 | <0.01 | <0.02 | <0.01 | <0.02 | <0.01 | <0.02 | <0.01 | 0.03 |
| Iron | 0.13 | 0.1 | <0.02 | <0.1 | 0.03 | <0.1 | <0.02 | <0.1 | 1.1 | 1.2 |
| Lead | <0.005 | <0.003 | <0.005 | <0.003 | <0.005 | 0.007 | <0.005 | <0.003 | <0.005 | <0.003 |
| Magnesium | 16 | 18 | 0.36 | <0.5 | 1.7 | 1.7 | 2.4 | 2.3 | 0.47 | <0.5 |
| Manganese | 0.82 | 0.71 | 0.01 | 0.011 | 0.81 | 0.84 | 0.23 | 0.19 | 0.42 | 0.42 |
| Mercury | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | 0.0006 | <0.001 | <0.0002 | <0.001 | <0.0002 |
| Selenium | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Silver | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 |
| Zinc | 0.02 | 0.02 | 0.13 | 0.02 | 0.02 | 0.02 | <0.01 | 0.04 | <0.01 | 0.06 |

Table A.4. Continued

UNION BLEACHERY
JUNE 20-21, 1990

| PARAMETER | RMT MW-5 R&C | RMT MW-5 RMT | RMT MW-5A R&C | RMT MW-5A RMT | RMT MW-5B R&C | RMT MW-5B RMT | HP-5 R&C | HP-5 RMT |
|---|---|---|---|---|---|---|---|---|
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Barium | 0.07 | 0.06 | 0.78 | 0.75 | 0.44 | 0.42 | 0.07 | <0.05 |
| Cadmium | <0.01 | 0.0003 | <0.01 | 0.0008 | <0.01 | 0.0006 | <0.01 | 0.0004 |
| Chromium | 7.1 | 7.4 | <0.02 | <0.002 | 18 | 19 | <0.02 | <0.002 |
| Copper | <0.01 | <0.02 | <0.01 | <0.02 | <0.01 | <0.02 | <0.01 | <0.02 |
| Iron | <0.02 | <0.1 | 0.27 | 0.3 | <0.02 | <0.1 | <0.02 | 1.9 |
| Lead | <0.005 | 0.003 | <0.005 | <0.003 | <0.005 | <0.003 | <0.005 | 0.007 |
| Magnesium | 4.8 | 5.2 | 23 | 230 | 23 | 12 | 2.4 | 4.6 |
| Manganese | 0.05 | 0.05 | 0.84 | 0.85 | <0.01 | 0.17 | <0.01 | 2.1 |
| Mercury | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 |
| Selenium | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Silver | <0.01 | <0.001 | 0.02 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 |
| Zinc | 0.07 | <0.02 | <0.01 | 0.06 | 0.08 | 0.02 | <0.01 | 0.05 |

Table A.5. Groundwater sampling reusits from September 18, 1990 sampling episode in mg/l.

UNION BLEACHERY
SEPTEMBER 18, 1990

| | USF-1 | | USF-2 | | USF-3 | | RMT MW-2 | | RMT MW-2A | | RMT MW-4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | R&C | RMT | R&C | RMT | R&C | RMT | R&C | RMT | R&C | RMT | R&C | RMT |
| Arsenic | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | 0.007 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Barium | 0.15 | 0.14 | 0.32 | 0.41 | 0.31 | 0.39 | 1 | 0.73 | 0.27 | 0.26 | 0.21 | 0.13 |
| Cadmium | <0.01 | <0.0003 | <0.01 | <0.0003 | 0.01 | <0.0003 | 0.02 | <0.0003 | 0.01 | <0.0003 | 0.01 | 0.0004 |
| Calcium | 11 | 11 | 26 | 34 | 18 | 20 | 3.5 | 3.5 | 7.9 | 8 | 1.1 | 0.5 |
| Chloride | 7.1 | -- | 198 | -- | 22 | -- | -- | -- | -- | -- | -- | -- |
| Chromium | 0.03 | 0.023 | 0.02 | 0.011 | 0.13 | 0.17 | 0.06 | 0.14 | 0.03 | 0.047 | 0.04 | 0.029 |
| Hex Chrome | <0.01 | -- | <0.01 | -- | <0.01 | -- | <0.01 | -- | <0.01 | -- | <0.01 | -- |
| Copper | 0.02 | 0.02 | 0.02 | <0.02 | 0.03 | 0.03 | 0.06 | 0.05 | 0.03 | 0.03 | 0.02 | <0.02 |
| Iron | 13 | 13 | 4 | 2.5 | 47 | 60 | 80 | 140 | 44 | 53 | 24 | 14 |
| Lead | <0.005 | 0.024 | 0.0067 | 0.005 | <0.005 | 0.031 | <0.005 | 0.12 | 0.023 | 0.019 | 0.046 | 0.012 |
| Magnesium | 4.6 | 5.2 | 6.8 | 11 | 7.6 | 12 | 7.6 | 14 | 7.6 | 14 | 2.4 | 1.4 |
| Manganese | 0.24 | 0.26 | 0.3 | 0.37 | 0.9 | 1.1 | 3.3 | 3.4 | 0.56 | 0.64 | 0.3 | 0.26 |
| Mercury | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | <0.0002 | <0.001 | 0.0013 | <0.001 | <0.0002 | <0.001 | <0.0002 |
| Nitrate | 0.7 | -- | <0.02 | -- | 0.5 | -- | -- | -- | -- | -- | -- | -- |
| Potassium | 3.4 | 3.7 | 3.2 | 3.8 | 4.6 | 5.2 | 13 | 12 | 13 | 17 | 3.2 | 2.2 |
| Selenium | <0.01 | <0.003 | <0.01 | 0.014 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 | <0.01 | <0.003 |
| Silver | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 | <0.01 | <0.001 | 0.14 | <0.001 | 0.03 | <0.001 |
| Sodium | 7.6 | 6.6 | 83 | 110 | 30 | 37 | 7.4 | 8 | 6.6 | 6 | 305 | 410 |
| Sulfate | 9.8 | -- | 57 | -- | 34 | -- | -- | -- | -- | -- | -- | -- |
| Zinc | -- | 0.09 | -- | 0.03 | -- | 0.11 | -- | 0.14 | -- | 0.09 | -- | <0.02 |

APPENDIX B - CHROMIUM CONCENTRATION WITH TIME PLOTS, LOG SCALE

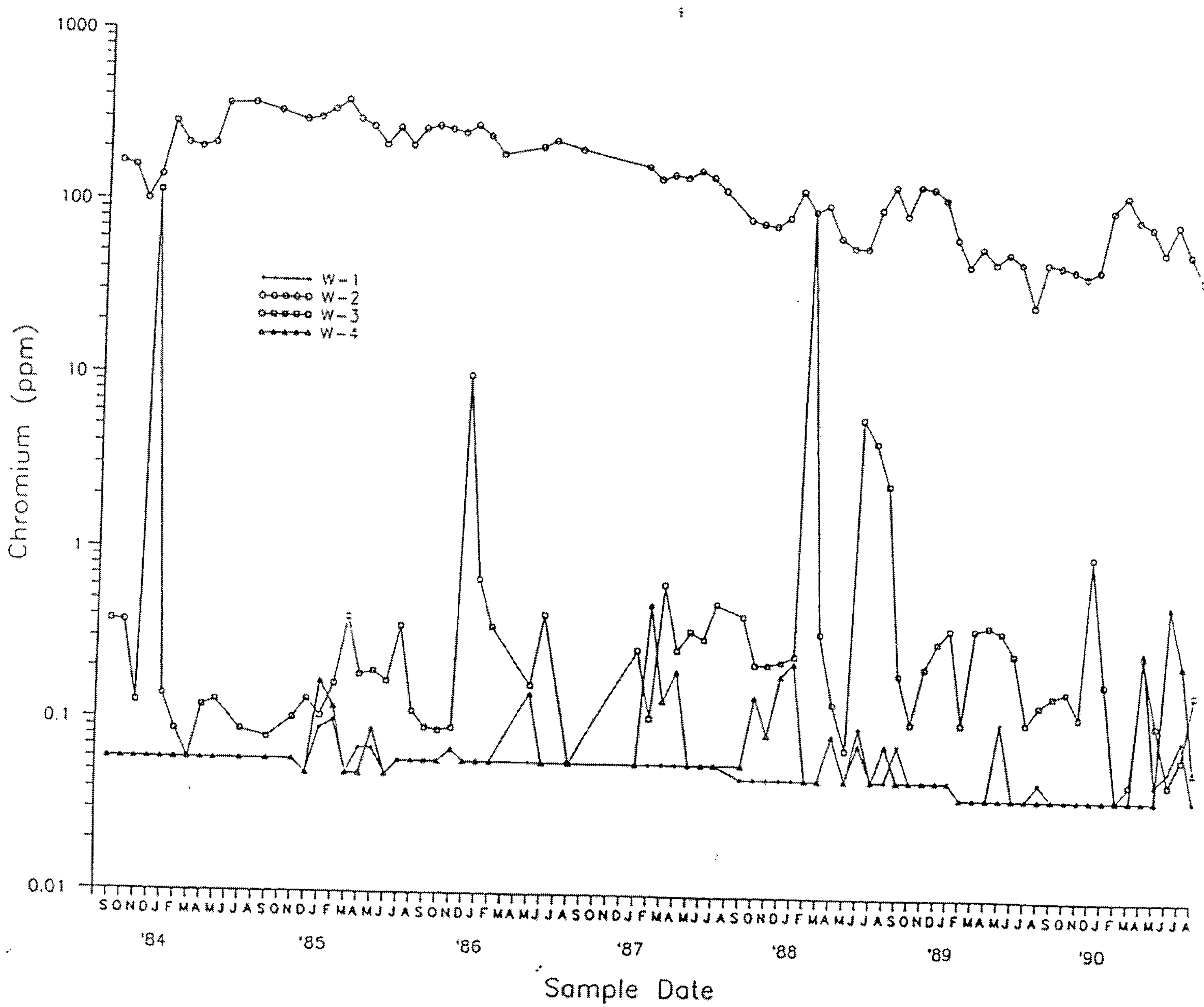



Figure B1. Chromium concentration versus time for Cone monitor wells.

GeoTrans, inc.

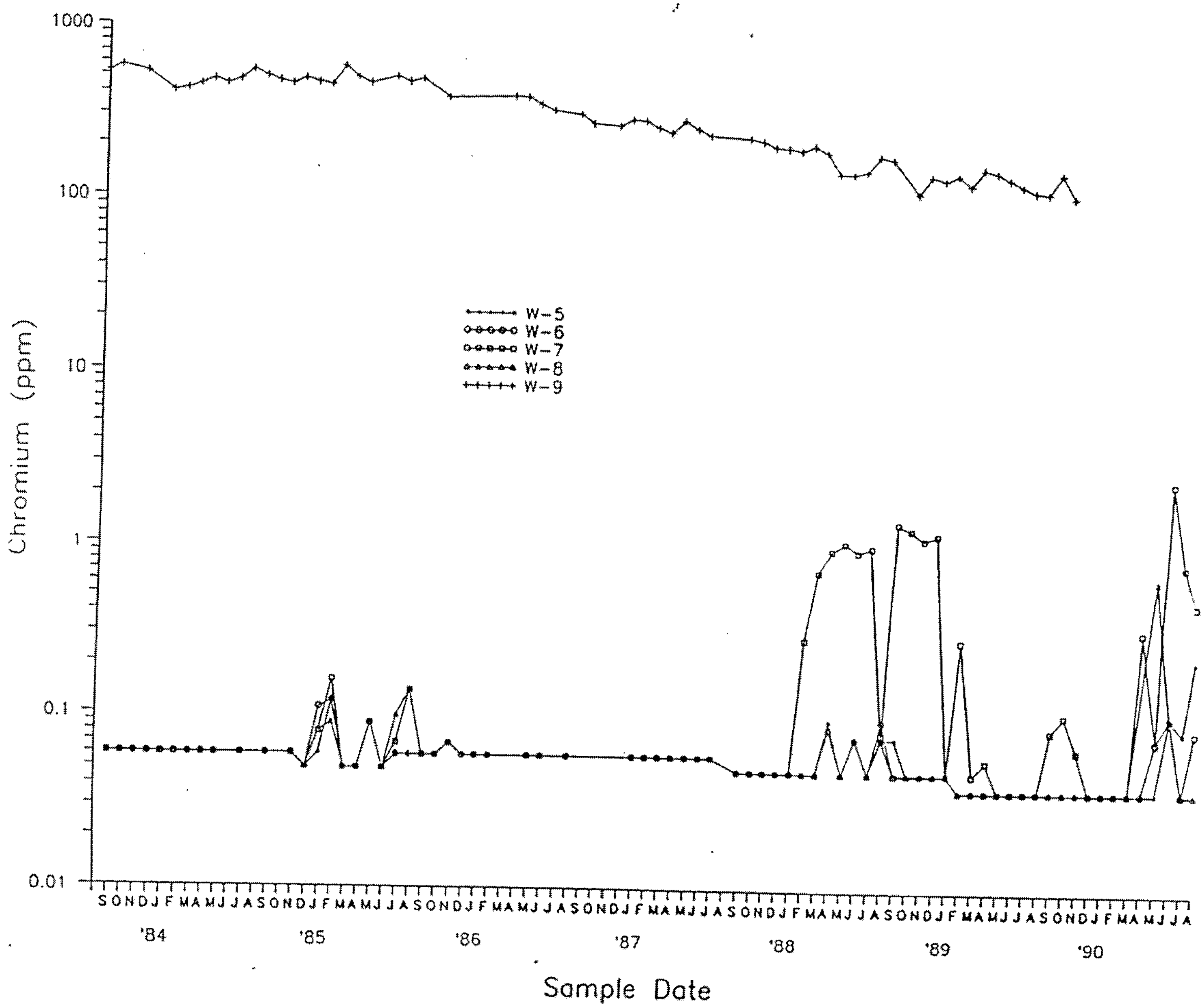



Figure B2. Chromium concentration versus time for Cone monitor wells.

GeoTrans, inc.

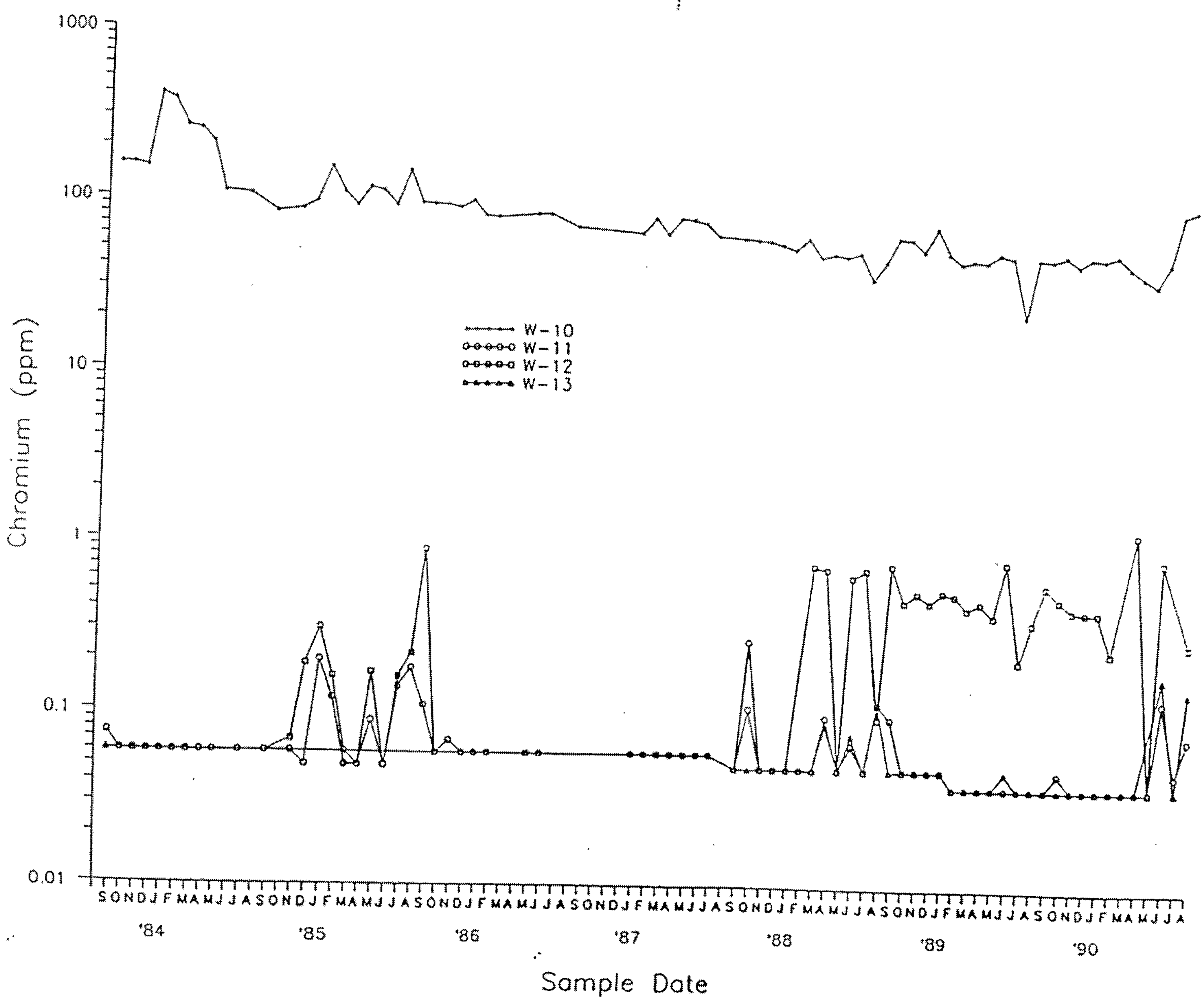



Figure B3. Chromium concentration versus time for Cone monitor wells.

GeoTrans, inc.

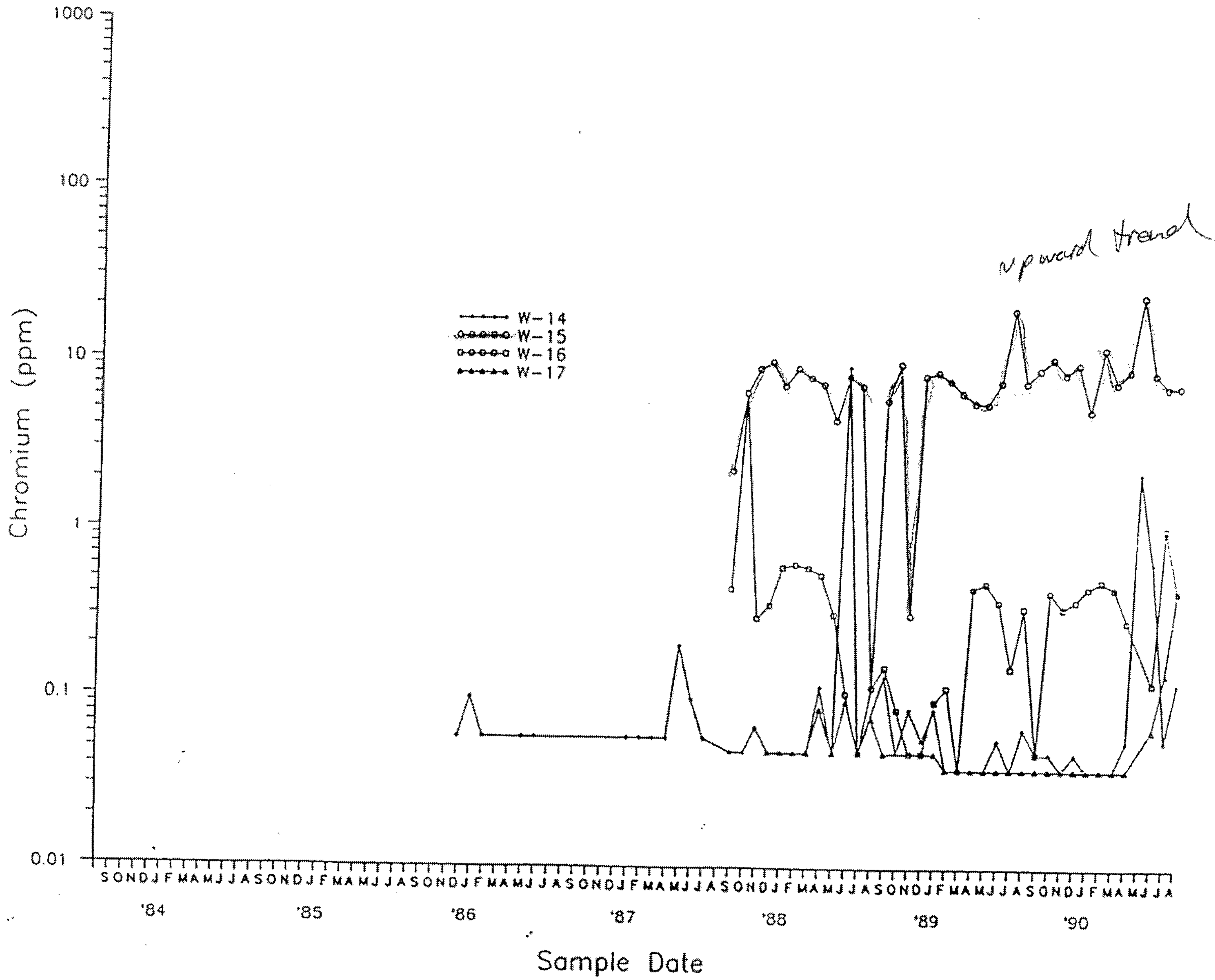


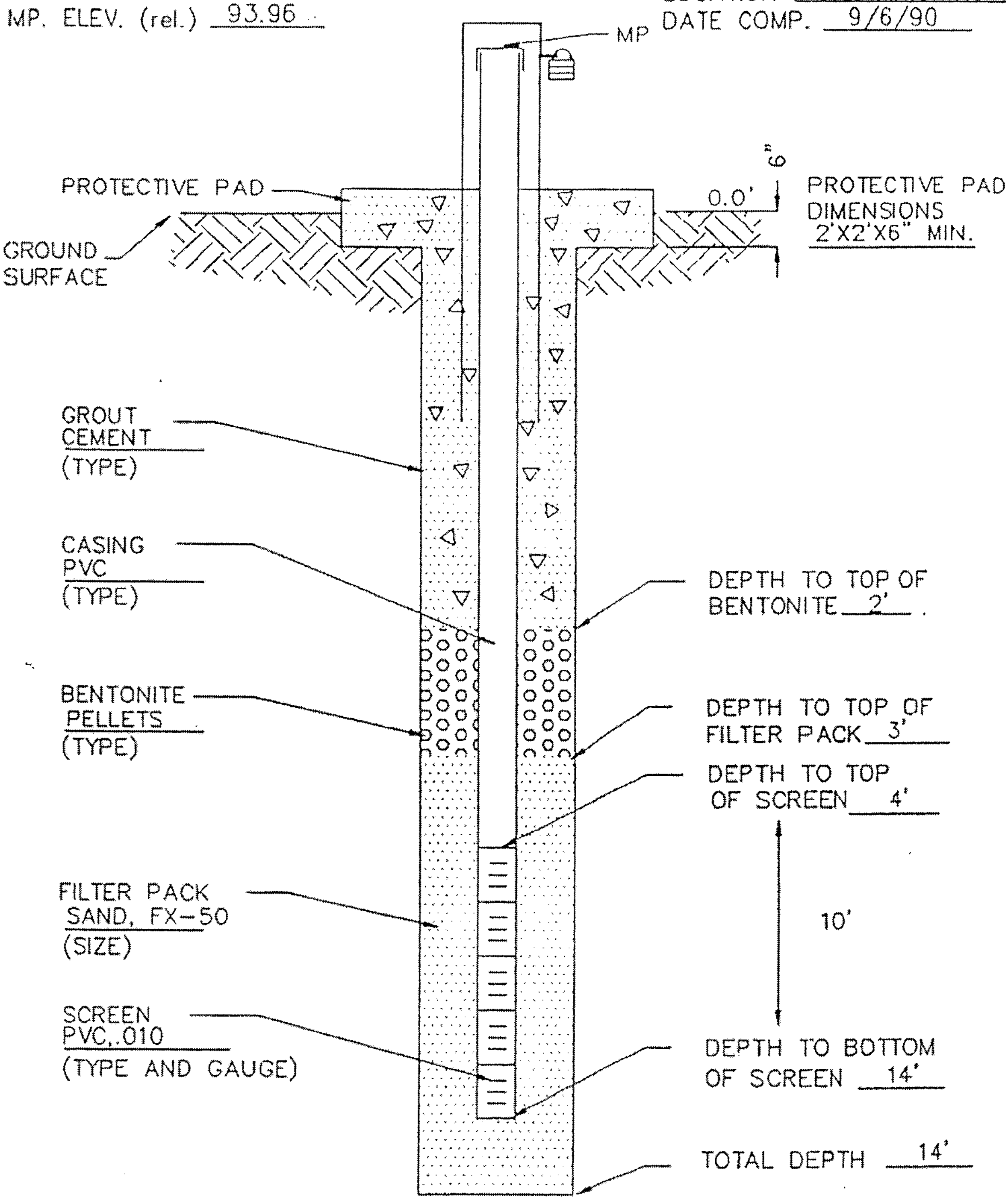

Figure B4. Chromium concentration versus time for Cone monitor wells.

GeoTrans, inc.

APPENDIX C - WELL LOGS

D. CASING 2"
D. BOREHOLE 10"
MP. ELEV. (rel.) 93.96

WELL NO. USF-1
LOCATION U.S. FINISHING
DATE COMP. 9/6/90




NOTE: DEPTHS REFERENCED FROM GROUND SURFACE

90-75-MW

| | |
|---|---|
| AS BUILT<br>U.S. FINISHING WELL 1 (USF-1) | J.L. Rogers & Callcott Engineers, Inc.<br>Greenville South Carolina |

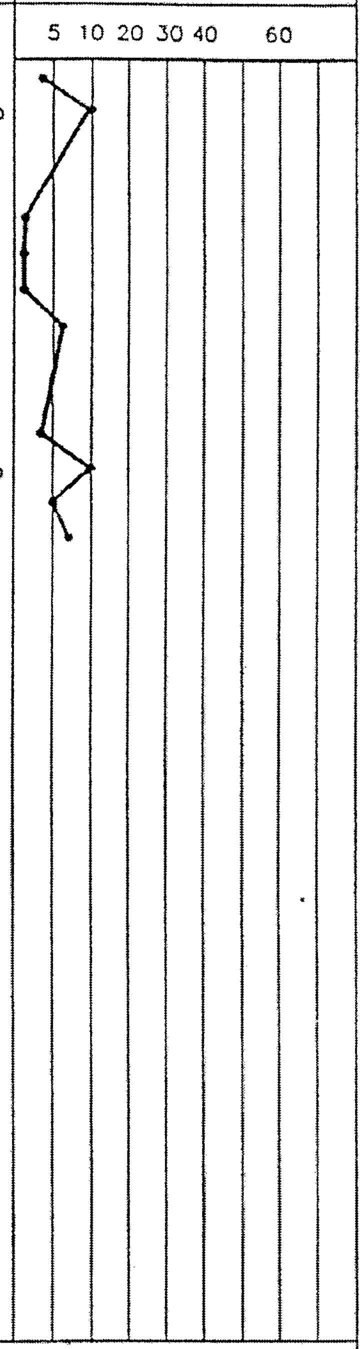
90-75-LL

# LITHOLOGY LOG



| REL. ELEV. | DEPTH (FEET) | DESCRIPTION | N |
|---|---|---|---|
| 93.96 | MP | | |
| | 0 | Clay; silty, red-brown; black ash-like material at 1.5' | 4<br>10 |
| | | No Recovery | |
| ▽ | -5 | Ash; black with dark grey clay damp | 2<br>2 |
| | | No Recovery, wet | 2<br>6 |
| | | Sand; silty, tan-med. grey, very coarse grained. | |
| | -10 | Same as above | 4<br>10 |
| | | Same as above | 5<br>7 |
| | T.D. 14' | | |
| | -15 | 24 Hr. Water Level 7.14' below MP | |
| | -20 | | |
| | -25 | | |
| | -30 | | |
| | -35 | | |

PENETRATION BLOWS PER FT. (N)




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

⊠ UNCONSOLIDATED SAMPLE
▧ UNDISTURBED SAMPLE
■ CORED INTERVAL

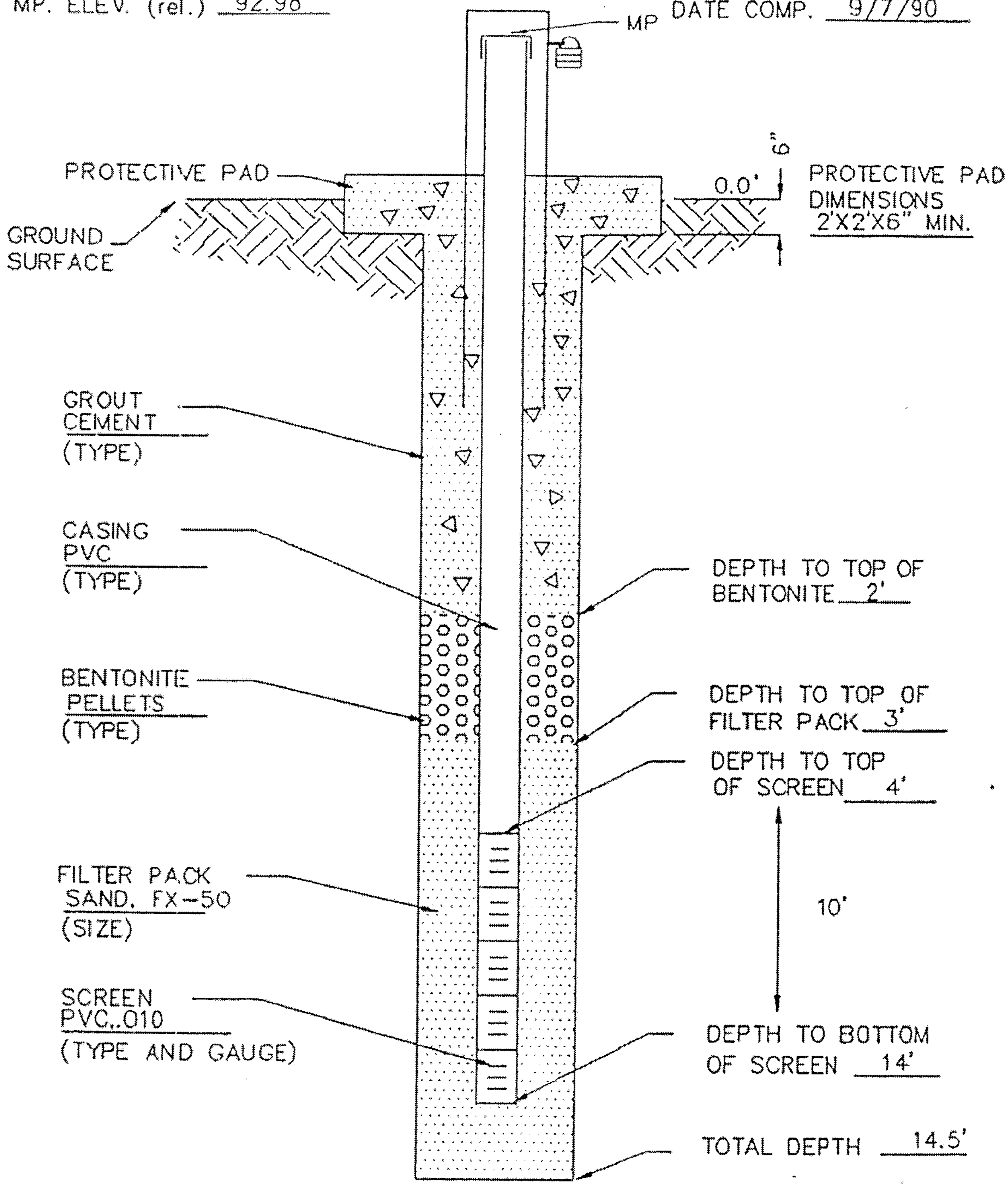
▽ WATER TABLE, 1 HR.
▽ WATER TABLE, 24 HR.
⊕ HYDROPUNCH SAMPLE

J. L. Rogers & Callcott Engineers, Inc.
Greenville South Carolina

WELL NO. USF-1
LOCATION J.S. FINISHING
DATE DRILLED 9/6/90
LOGGED BY KWW

D. CASING 2"
D. BOREHOLE 10"
MP. ELEV. (rel.) 92.98

WELL NO. USF-2
LOCATION U.S. FINISHING
DATE COMP. 9/7/90




NOTE: DEPTHS REFERENCED FROM GROUND SURFACE

90-75-MW

| | |
|---|---|
| AS BUILT<br>U.S. FINISHING WELL 2 (USF-2) | J.L. Rogers & Callcott<br>Engineers, Inc.<br>Greenville South Carolina |

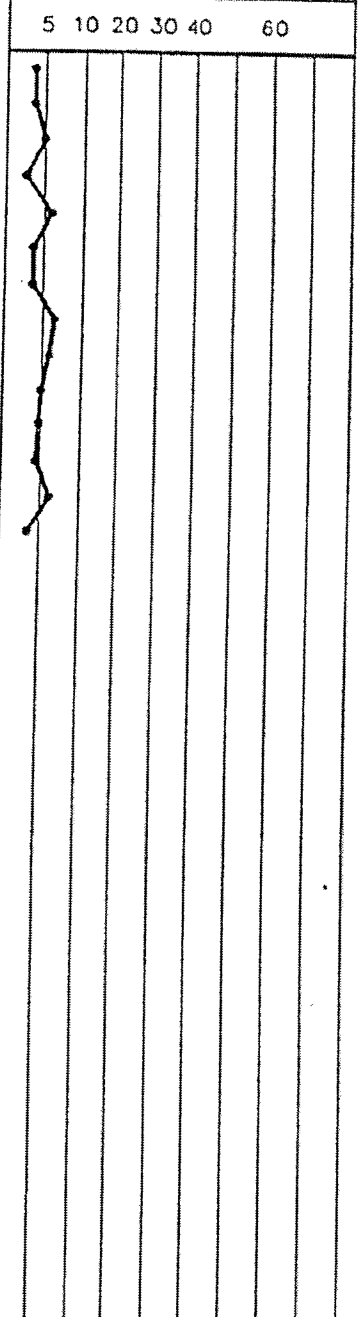
80-76-LL

# LITHOLOGY LOG



| REL. ELEV. | DEPTH (FEET) | DESCRIPTION | N |
| --- | --- | --- | --- |
| 92.98 | MP | | |
| | 0 | Ash; dark brown, damp | 4 |
| | | | 4 |
| | | Ash; dark brown with dark brown clay | 5 |
| ▼ | | | 3 |
| | -5 | Same as above | 6 |
| | | | 4 |
| | | Clay; greenish brown, stiff, wet | 4 |
| | | | 7 |
| | | Same as above | 6 |
| | -10 | | 5 |
| | | Same as above | 5 |
| | | | 5 |
| | | Same as above | 6 |
| | | | 4 |
| | T.D. 14.5' | | |
| | -15 | | |
| | | 24 Hr. Water Level 5.7' below M.P. | |
| | -20 | | |
| | -25 | | |
| | -30 | | |
| | -35 | | |

PENETRATION BLOWS PER FT. (N)



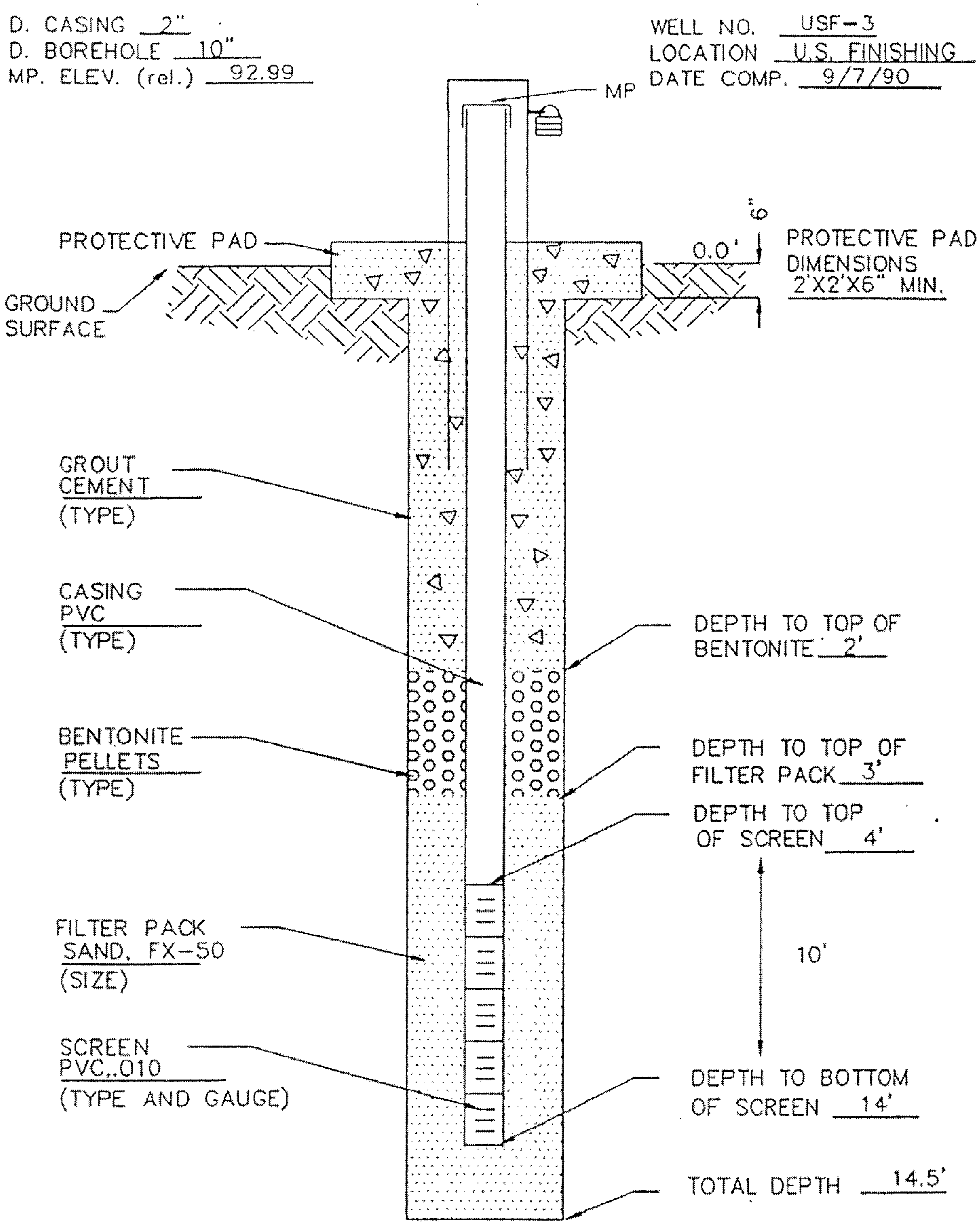

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

⊠ UNCONSOLIDATED SAMPLE
▧ UNDISTURBED SAMPLE
■ CORED INTERVAL

▽ WATER TABLE, 1 HR.
▼ WATER TABLE, 24 HR.
⊗ HYDROPUNCH SAMPLE

J.L. Rogers & Callcott Engineers, Inc.
Greenville South Carolina

WELL NO. USF-2
LOCATION U.S. FINISHING
DATE DRILLED 9-7-90
LOGGED BY KWW




NOTE: DEPTHS REFERENCED FROM GROUND SURFACE

90-75-MW

| | |
|---|---|
| AS BUILT<br>U.S. FINISHING WELL 3 (USF-3) | J.L. Rogers & Callcott<br>Engineers, Inc.<br>Greenville South Carolina |

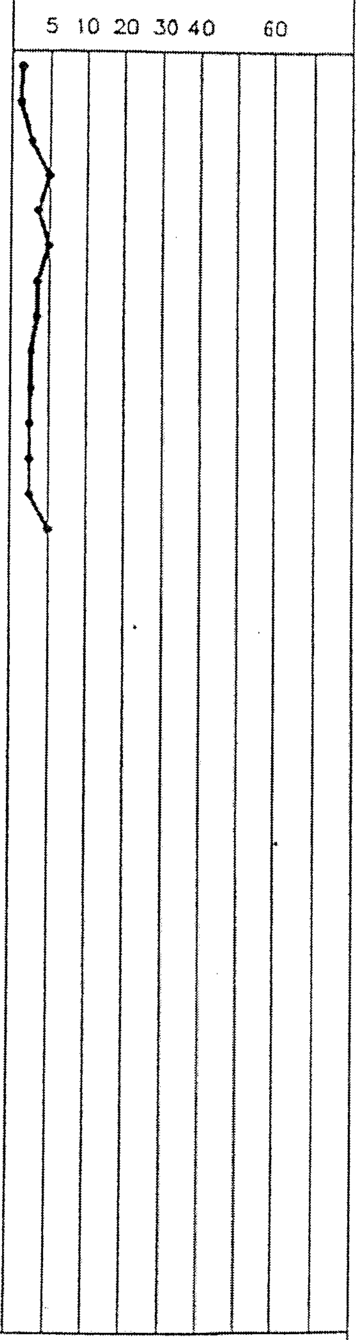
90-75-LL

# LITHOLOGY LOG



| REL ELEV. | DEPTH (FEET) | DESCRIPTION | N |
|---|---|---|---|
| 92.99 | MP | | |
| | 0 | Ash, black, with silt | 2 |
| | | | 2 |
| | | Same as above | 3 |
| | | | 5 |
| ▽ (24 HR.) | -5 | Same as above | 4 |
| | | | 5 |
| | | Same as above, wet | 4 |
| | | | 4 |
| | | Clay, greenish brown | 3 |
| | -10 | | 3 |
| | | Same as above | 3 |
| | | | 3 |
| | | Same as above | 3 |
| | | | 5 |
| | T.D. 14.5' -15 | 24 Hr. Water Level 6.80' below MP | |
| | -20 | | |
| | -25 | | |
| | -30 | | |
| | -35 | | |

PENETRATION BLOWS PER FT. (N)




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

⊠ UNCONSOLIDATED SAMPLE
▧ UNDISTURBED SAMPLE
■ CORED INTERVAL

▽ WATER TABLE, 1 HR.
▽ WATER TABLE, 24 HR.
⊕ HYDROPUNCH SAMPLE

J.L. Rogers & Callcott Engineers, Inc.
Greenville South Carolina

WELL NO. USF-3
LOCATION U.S. FINISHING
DATE DRILLED 9-7-90
LOGGED BY KWW

ROGERS & CALLCOTT ENGINEERS, INC.

P.O. BOX 5655, GREENVILLE, SOUTH CAROLINA 29606
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

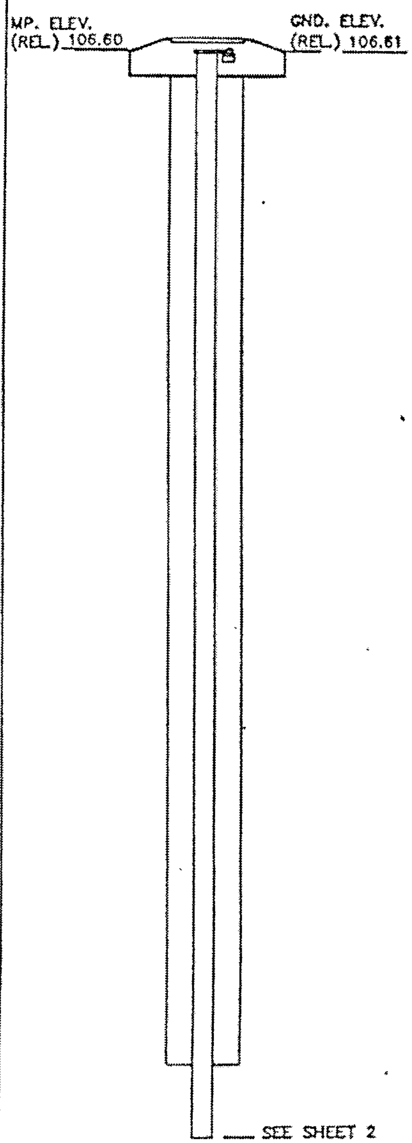
# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-4 |
| CLIENT | U.S. FINISHING | DATE STARTED | 1-9-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 1-15-91 |
| LOGGED BY | KWW, RR | DRILLER CONTRACTOR | E D & S |
| LATITUDE | 34° 53' 00" | DRILLER'S NAME | M. JACKSON |
| LONGITUDE | 82° 25' 36" | DRILLER'S CERT. # | 807 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | | | |
| -10 | | | |
| -15 | | | |
| -20 | | | |
| -25 | | | |
| -28 to -30 | 12<br>15 | (sampled) | Silt, very micaceous; medium silvery-brown; no odor (SAPROLITE) |
| -30 | | | |

**WELL SCHEMATIC**

D. CASING 10" TO 28' D. BOREHOLE 12" TO 28
D. CASING 2" TO 50' D. BOREHOLE 10" TO 50




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

ROGERS & CALLCOTT ENGINEERS, INC.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

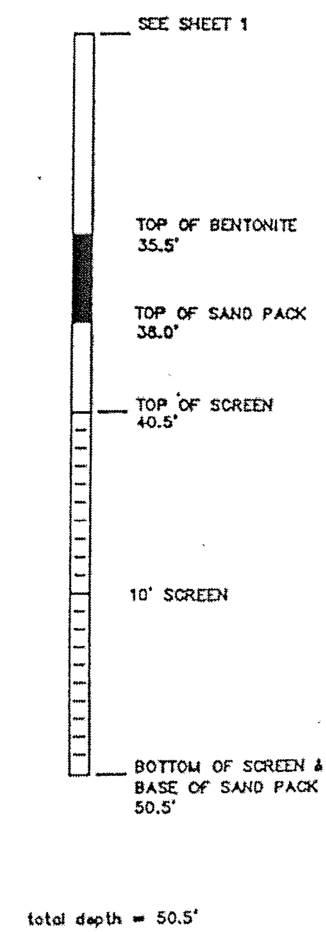
# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-4 |
| CLIENT | U.S. FINISHING | DATE STARTED | 1-9-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 1-15-91 |
| LOGGED BY | KWW, RR | DRILLER CONTRACTOR | E D & S |
| LATITUDE | 34° 53' 00" | DRILLER'S NAME | M. JACKSON |
| LONGITUDE | 82° 25' 36" | DRILLER'S CERT. # | 807 |

| DEPTH (FEET) | BLOWS PER FT. (N) | LITHOLOGY |
|---|---|---|
| -30 | | |
| | 17 | Silt, sandy, very micaceous; medium silver-brown with a 1/4" lense of coarse grained quartz; no odor (SAPROLITE) |
| | 22 | Silt, sandy, micaceous; medium brown with three 1/4" layers of white sand |
| | 21 | |
| | 35 | |
| -35 | 22 | Same as above |
| | 28 | Silt, sandy, micaceous; dark medium brown with white quartz nodes instead of layers |
| | 27 | |
| | 39 | |
| | 51 | Same as above but with some minor orange staining |
| -40 | 46 | |
| | 41 | Sand very fine grained, very silty, micaceous with two white layers of very fine grained sand |
| | 50 | Same as above except grading to sand very coarse and very fine grained, micaceous with white and black gneiss at the base of sample |
| | 36 | |
| | 90 | Sand very fine grained, silty, micaceous; medium; with a few white coarse grained quartz lenses ≈ 1" thick |
| -45 | 26 | |
| | 29 | |
| | 27 | Same as above with weathered garnet schist |
| | 54 | |
| | 43 | Sand fine to coarse grained, silty, micaceous with sharp contact with very coarse grained quartz at ≈ 49' |
| -50 | 50/4" 34/6" 75/0" | Same as above except coarse grained biotite gneiss (SPOON AND AUGER REFUSAL AT 50.5') |
| -55 | | |
| -60 | | |

## WELL SCHEMATIC

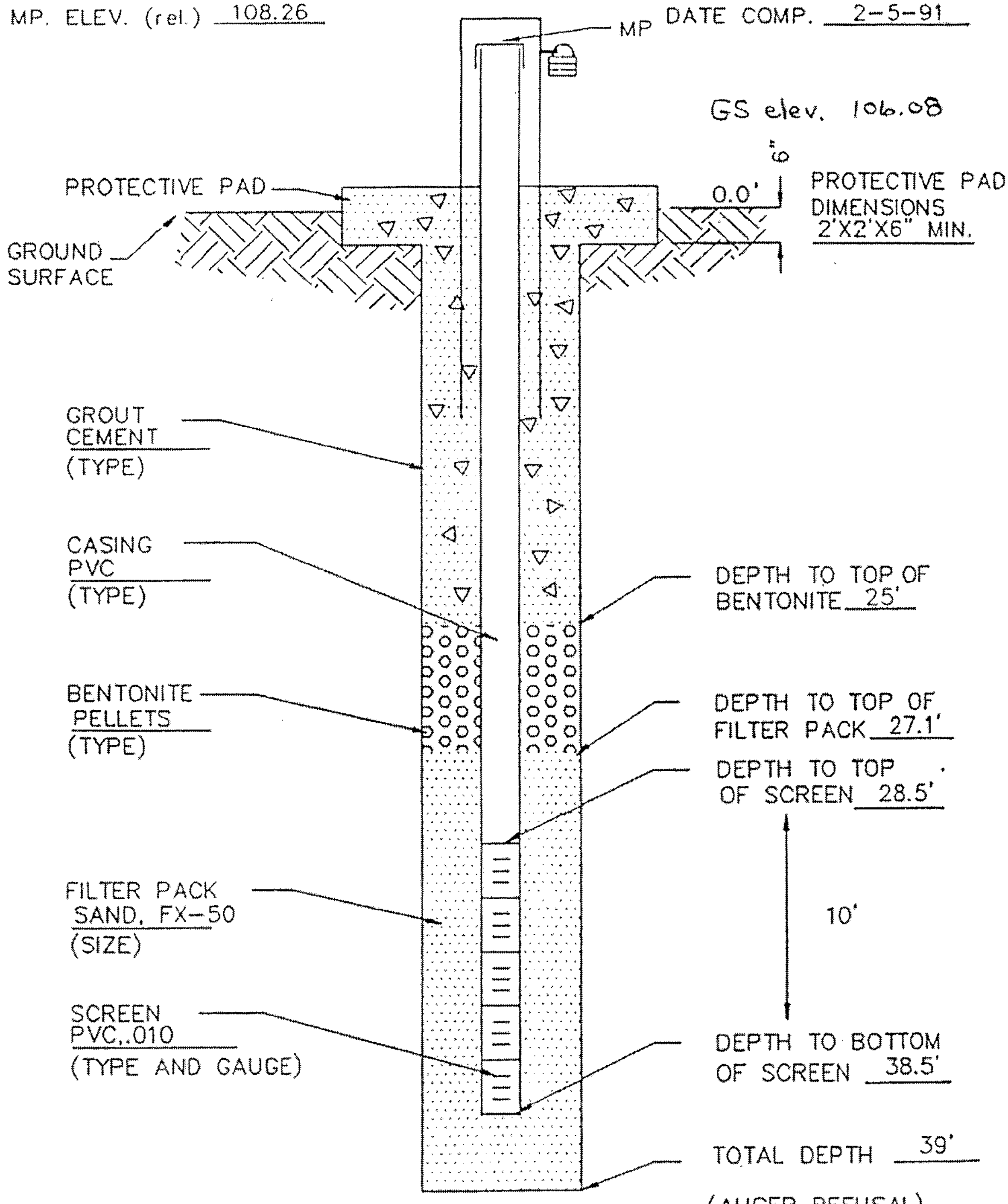
D. CASING 2" D. BOREHOLE 10"




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

D. CASING 2"
D. BOREHOLE 10"
MP. ELEV. (rel.) 108.26

WELL NO. USF-5
LOCATION U.S. FINISHING
DATE COMP. 2-5-91




NOTE: DEPTHS REFERENCED FROM GROUND SURFACE

90-75-MW

| | |
|---|---|
| AS BUILT<br>U.S. FINISHING WELL 5 (USF-5) | J.L. Rogers & Callcott<br>Engineers, Inc.<br>Greenville South Carolina |

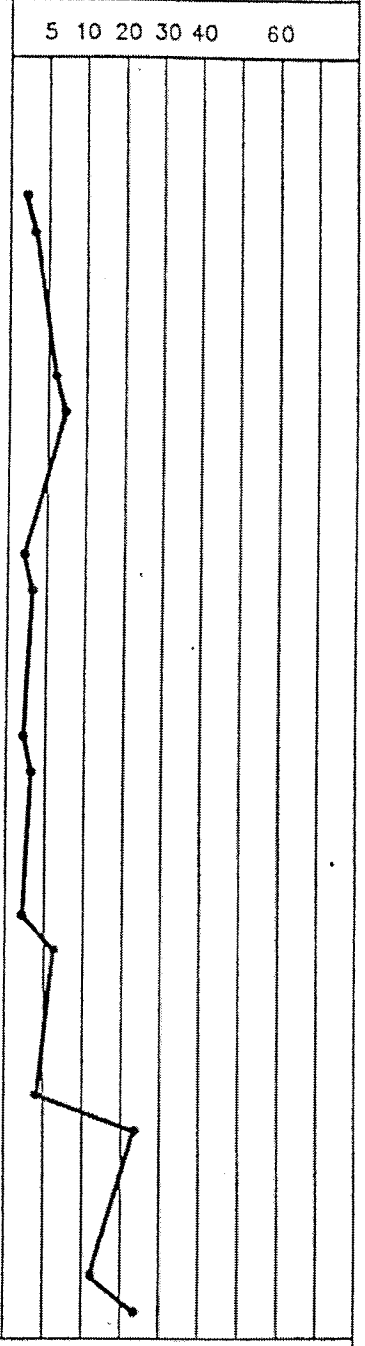
90-75-LL

# LITHOLOGY LOG



| REL. ELEV. | DEPTH (FEET) | DESCRIPTION | N |
|---|---|---|---|
| 108.26 | MP | | |
| 106.08 | 0 | Silt and cinders; black<br>No split spoon | |
| | -5 | Silt, clayey; dark brown to black; wet | 2<br>3 |
| | | Hard at ≈ 6' | |
| | -10 | Clay, sandy; medium grey; very stiff; damp | 6<br>7 |
| | -15 | Clay, micaceous, silty; medium brown grading to silt, clayey; orange-brown at 13.5' (SAPROLITE) | 2<br>3 |
| | -20 | Silt, micaceous, sandy, clayey; medium orange-brown; dripping wet | 2<br>3 |
| | -25 | Same as above except slightly sandier with less clay; very wet ⊗~ 24'-25' | 2<br>6 |
| | -30 | Same as above with 4 quartz veinlets | 4<br>23 |
| | -35 | Silt, micaceous, sandy; medium brown; mixed with weathered biotite gneiss; black and white; very wet | 12<br>33 |

PENETRATION
BLOWS PER FT. (N)




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

LATITUDE 34° 53' 01"
LONGITUDE 82° 25' 35"
DRILLED BY E D & S
DRILLER M. JACKSON
DRILLER'S CERT. 807

⊠ UNCONSOLIDATED SAMPLE
▧ UNDISTURBED SAMPLE
■ CORED INTERVAL

▽ WATER TABLE, 1 HR.
▼ WATER TABLE, 24 HR.
⊛ HYDROPUNCH SAMPLE

J.L. Rogers & Callcott Engineers, Inc.
Greenville South Carolina

WELL NO. USF-5
LOCATION U.S. FINISHING
DATE DRILLED 2-4-91
LOGGED BY KWW

USF5-1

90-75-LL

# LITHOLOGY LOG



| REL. ELEV. | DEPTH (FEET) | | DESCRIPTION | N | PENETRATION BLOWS PER FT. (N) 5 10 20 30 40 60 |
|---|---|---|---|---|---|
| | MP | | | | |
| | -35 | | | | |
| | | | Silt; sand; black and white; (weathered biotite gneiss); very hard; auger refusal @ ≈ 39' | 67 | |
| | -40 | | | | |
| | | | TOTAL DEPTH = 39' | | |
| | -45 | | | | |

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

LATITUDE 34° 53' 01"
LONGITUDE 82° 25' 35"
DRILLED BY E D & S
DRILLER M. JACKSON
DRILLER'S CERT. 807

⊠ UNCONSOLIDATED SAMPLE
▨ UNDISTURBED SAMPLE
■ CORED INTERVAL

▽ WATER TABLE, 1 HR.
▼ WATER TABLE, 24 HR.
⊗ HYDROPUNCH SAMPLE

J.L. Rogers & Callcott Engineers, Inc.
Greenville South Carolina

WELL NO. USF-5
LOCATION U.S. FINISHING
DATE DRILLED 2-4-91
LOGGED BY KWW

USF5-2

SHEET 1 OF 2

ROGERS & CALLCOTT ENGINEERS, INC.

P.O. BOX 5655, GREENVILLE, SOUTH CAROLINA 29606
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

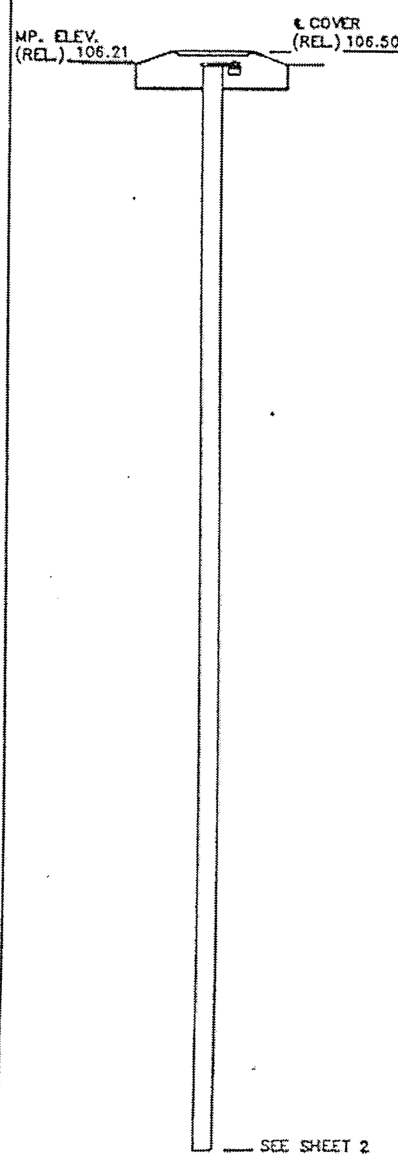
# WELL LOG

| | |
|---|---|
| PROJECT: U.S. FINISHING | WELL NO. OR BORING NO.: USF-6 |
| CLIENT: U.S. FINISHING | DATE STARTED: 2-5-91 |
| LOCATION: GREENVILLE SC. | DATE FINISHED: 2-6-91 |
| LOGGED BY: KWW | DRILLER CONTRACTOR: E D & S |
| LATITUDE: 34° 53' 01" | DRILLER'S NAME: M. JACKSON |
| LONGITUDE: 82° 25' 37" | DRILLER'S CERT. #: 807 |

| DEPTH (FEET) | BLOWS PER FT. (N) | LITHOLOGY |
|---|---|---|
| 0 | | |
| | 12 | Silt, cinders; black; top 4" grading to clay, slightly sandy, micaceous; orange-brown; stiff |
| | 11 | |
| | 2 | Same as above |
| -5 | 4 | |
| | 5 | Clay, silty, sandy, mottled orange yellow-brown and some black; stiff; slight hydrocarbon smell |
| | 6 | |
| | 5 | Clay, silty, micaceous; some grey staining; odor |
| | 8 | |
| -10 | 5 | Clay, silty, micaceous; greenish brown; less odor |
| | 7 | Silt, little clay, very micaceous; orange-brown; dripping wet; strong odor at 11', not much odor at 13' |
| | 4 | |
| | 7 | |
| | 5 | Silt, very micaceous; medium brown to orange-brown; no odor |
| -15 | 5 | |
| | 4 | Silt, very micaceous; orange-brown; no odor |
| | 4 | |
| -20 | | |
| | 4 | Same as above except for some weathered hornblende (?) crystals |
| | 6 | |
| -25 | | |
| | 2 | Silt, very micaceous; orange-brown; with a 1/2" vein of quartz and black accessory minerals at 25.5' and a silt, sandy; medium brown; 1" thick at 26.5' |
| | 5 | |
| -30 | | |

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

ROGERS & CALLCOTT
ENGINEERS, INC.

P.O. BOX 5655, GREENVILLE, SOUTH CAROLINA 29606
715 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

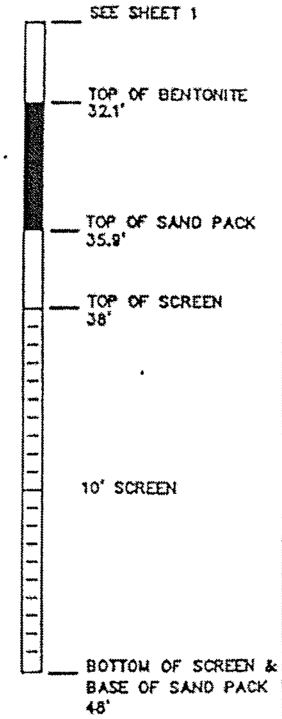
# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-6 |
| CLIENT | U.S. FINISHING | DATE STARTED | 2-5-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 2-6-91 |
| LOGGED BY | KWW | DRILLER CONTRACTOR | E D & S |
| LATITUDE | 34° 53' 01" | DRILLER'S NAME | M. JACKSON |
| LONGITUDE | 82° 25' 37" | DRILLER'S CERT. # | 807 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 to -32 | 2<br>2 | ▨ | Silt, very micaceous; orange-brown; with two medium-brown micaceous silt zones |
| | | | Very slow drilling to 35' |
| -35 to -37 | 42/1' | ▨ | Same as above except with a 1" silty sand layer at ~ 36' |
| -40 to -42 | 2<br>2 | ▨ | Same as above |
| -45 to -47 | 10<br>70/6" | ▨ | Same as above except sharp contact at 46' with sand very coarse grained; black and white with biotite and quartz grains (WEATHERED GRANITE OR BOTITE GNEISS) |
| -47 to -47.5 | 27<br>50/0" | ▨ | Same as above |
| | | | (SPOON AND AUGER REFUSAL AT 48') |

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




TOTAL DEPTH = 48'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING [illegible] REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

ROGERS & CALLCOTT
ENGINEERS, INC.

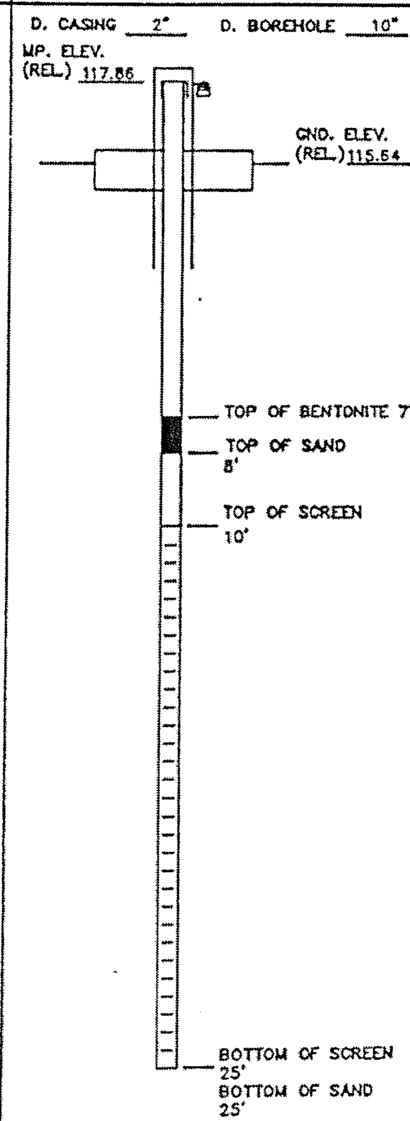
P.O. BOX 5000, GREENVILLE, SOUTH CAROLINA 29606
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-7 (CDLB-1) |
| CLIENT | U.S. FINISHING | DATE STARTED | 1-16-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 1-18-91 |
| LOGGED BY | KWW / RR | DRILLER CONTRACTOR | E D & S |
| LATITUDE | 34° 53' 00" | DRILLER'S NAME | M. JACKSON |
| LONGITUDE | 82° 25' 38" | DRILLER'S CERT. # | 807 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| | | ▨ | Clay, silty, red-brown |
| -5 | | | |
| | | ▨ | Same as above, slightly micaceous |
| | | ▨ | Same as above, very micaceous |
| -10 | | | |
| | | ▨ | Silt, red-brown, very micaceous, slight hydrocarbon odor |
| -15 | | ▨ | Silt, greenish-brown, very micaceous, strong hydrocarbon odor |
| | | ▨ | Same as above |
| | | ▨ | Same as above, no odor |
| -20 | | | |
| -25 | | | |
| -30 | | | |

## WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

ROGERS & CALLCOTT
ENGINEERS, INC.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
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FAX (803) 233-9058

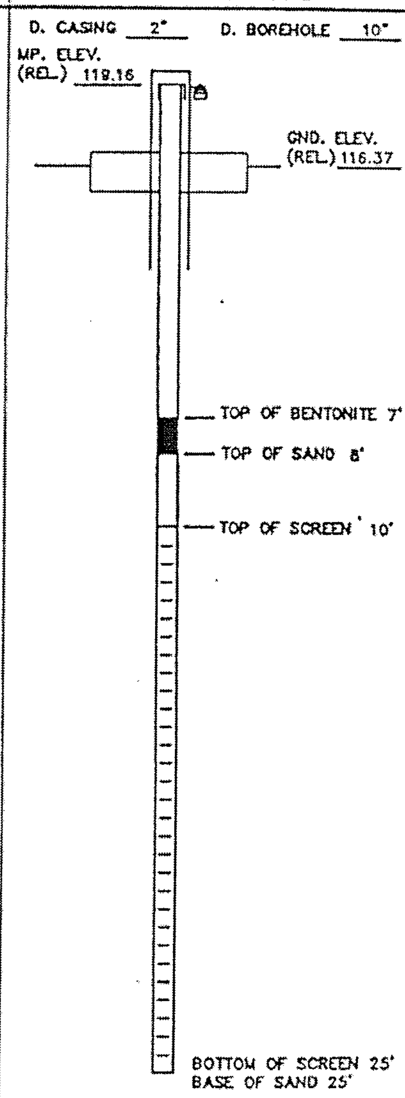
# WELL LOG

PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY RR,KWW
LATITUDE 34° 53' 01"
LONGITUDE 82° 25' 37"

WELL NO. OR BORING NO. USF-8 (CDLB-14+2)
DATE STARTED 1-16-91
DATE FINISHED 1-18-91
DRILLER CONTRACTOR E D & S
DRILLER'S NAME M. JACKSON
DRILLER'S CERT. # 807

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| | | ▨ | Silt, cinders and gravel, very dark brown |
| -5 | | ▨ | Clay, med. brown, very stiff |
| | | ▨ | Same as above, very micaceous |
| -10 | | ▨ | Clay, med. brown, silty, very micaceous |
| | | ▨ | Silt, med. brown, clayey, very micaceous |
| -15 | | ▨ | Same as above |
| | | ▨ | Silt, greenish-brown, very micaceous |
| | | ▨ | Silt, med. brown, very micaceous, wet |
| -20 | | | |
| -25 | | | |
| -30 | | | |

## WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

SHEET 1 OF 1

# ROGERS & CALLCOTT ENGINEERS, INC.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

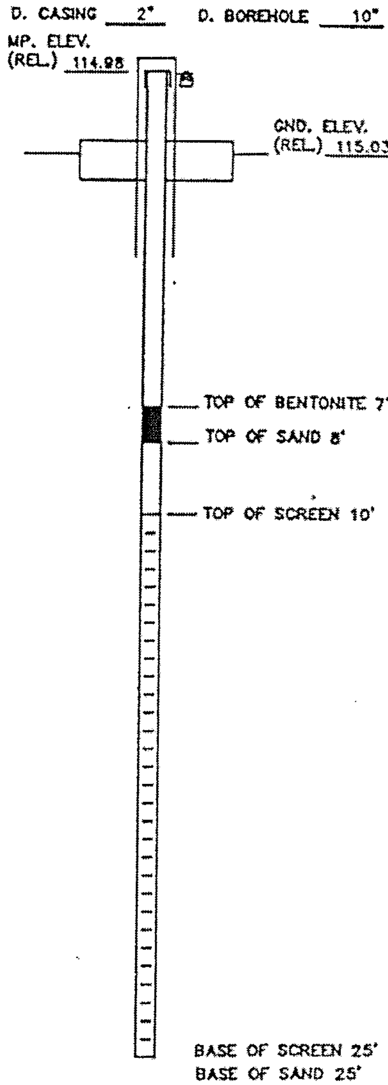
## WELL LOG

PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY RR,KWW
LATITUDE 34° 53' 02"
LONGITUDE 82° 25' 37"

WELL NO. OR BORING NO. USF-9 (CDLB-20+3.7)
DATE STARTED 1-17-91
DATE FINISHED 1-18-91
DRILLER CONTRACTOR E D & S
DRILLER'S NAME M. JACKSON
DRILLER'S CERT. # 807

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| | | sampled | Clay, red-brown, silty |
| -5 | | sampled | Same as above |
| | | sampled | Same as above |
| -10 | | | |
| | | sampled | Same as above, very micaceous |
| | | sampled | Silt, red-brown, clayey, very micaceous |
| -15 | | sampled | Same as above |
| | | sampled | Silt, greenish-brown, clayey, very micaceous |
| | | sampled | Same as above, grading to med. brown |
| -20 | | | |
| -25 | | | |
| -30 | | | |

WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

# ROGERS & CALLCOTT ENGINEERS, INC.

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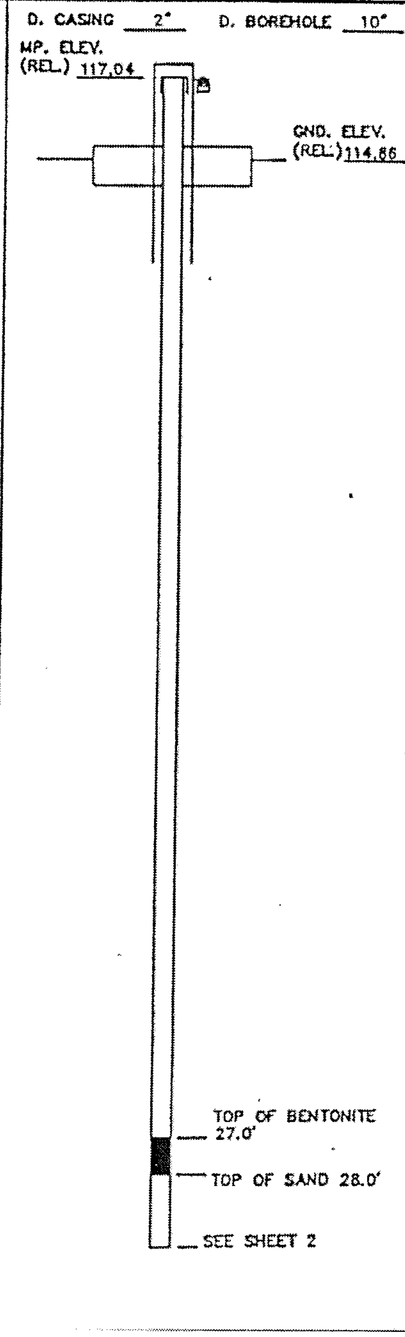
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

## WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-9A |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-19-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-21-91 |
| LOGGED BY | DT (GEOTRANS) | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 53' 02" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 36" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | No samples collected | Coal; Fill |
| | | | Sand, dark brown, clayey, moist |
| -5 | | | |
| -10 | | | Clay, red brown, silty and sandy, very moist |
| -15 | | | (SAPROLITE) |
| -20 | | | |
| -25 | | | |
| -30 | | | |

### WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

SHEET 2 OF 2

# ROGERS & CALLCOTT ENGINEERS, INC.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

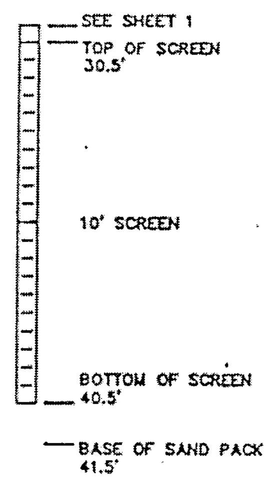
## WELL LOG

| | |
|---|---|
| PROJECT U.S. FINISHING | WELL NO. OR BORING NO. USF-9A |
| CLIENT U.S. FINISHING | DATE STARTED 3-19-91 |
| LOCATION GREENVILLE SC. | DATE FINISHED 3-21-91 |
| LOGGED BY DT (GEOTRANS) | DRILLER CONTRACTOR A T & E |
| LATITUDE 34° 53' 02" | DRILLER'S NAME T. BURNETTE |
| LONGITUDE 82° 25' 36" | DRILLER'S CERT. # 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 | | No samples collected | |
| -35 | | | |
| -40 | | | |
| | 31/6" | | AUGER REFUSAL AT 41' |
| | 50/3" | | |
| -45 | | | |
| -50 | | | |
| -55 | | | |
| -60 | | | |

WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"

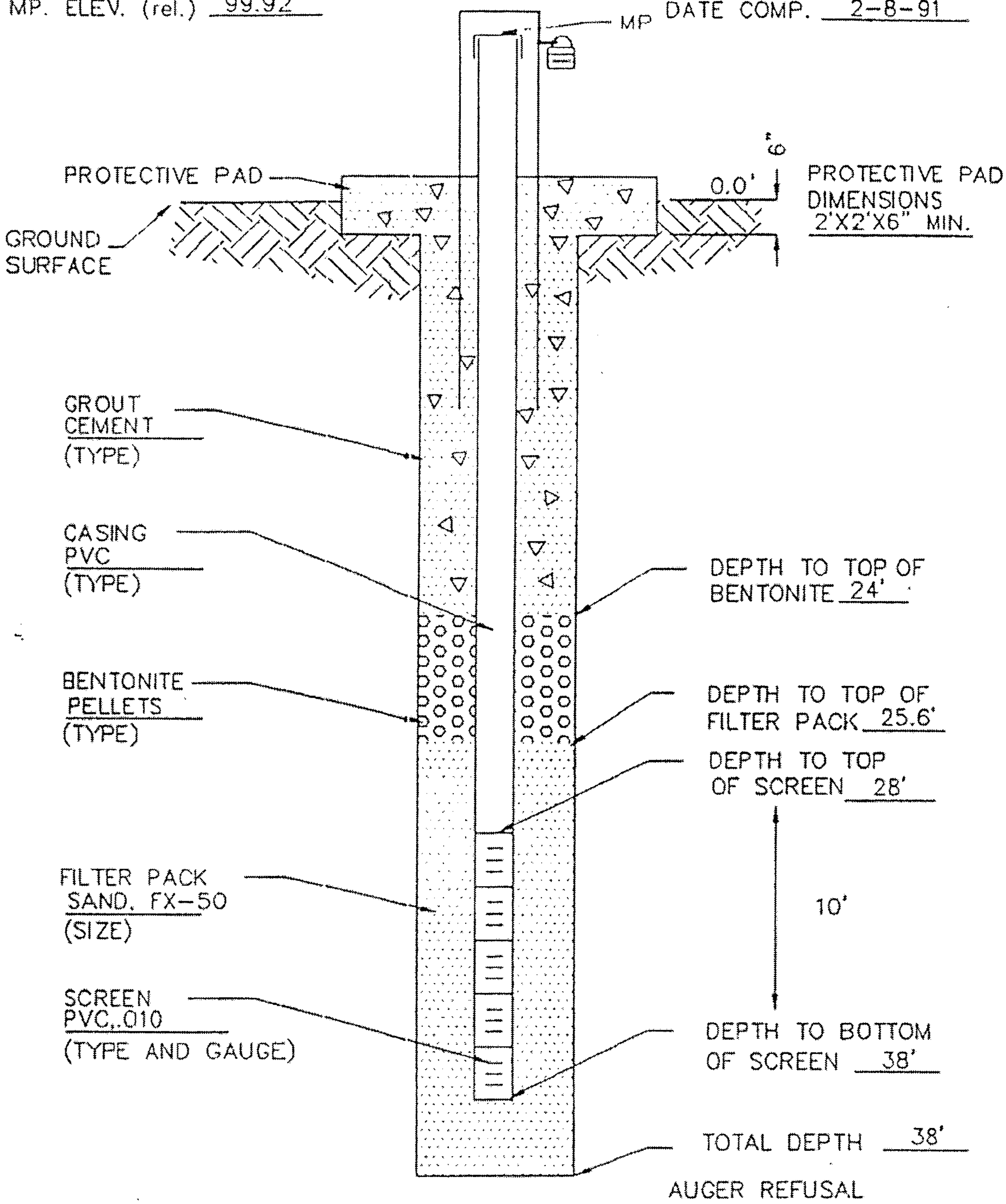



TOTAL DEPTH = 41.5'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

D. CASING 2"
D. BOREHOLE 10"
MP. ELEV. (rel.) 99.92

WELL NO. USF-10
LOCATION U.S. FINISHING
DATE COMP. 2-8-91




NOTE: DEPTHS REFERENCED FROM GROUND SURFACE

90-75-MW

| | |
|---|---|
| AS BUILT<br>U.S. FINISHING WELL 10 (USF-10) | J.L. Rogers & Callcott<br>Engineers, Inc.<br>Greenville South Carolina |

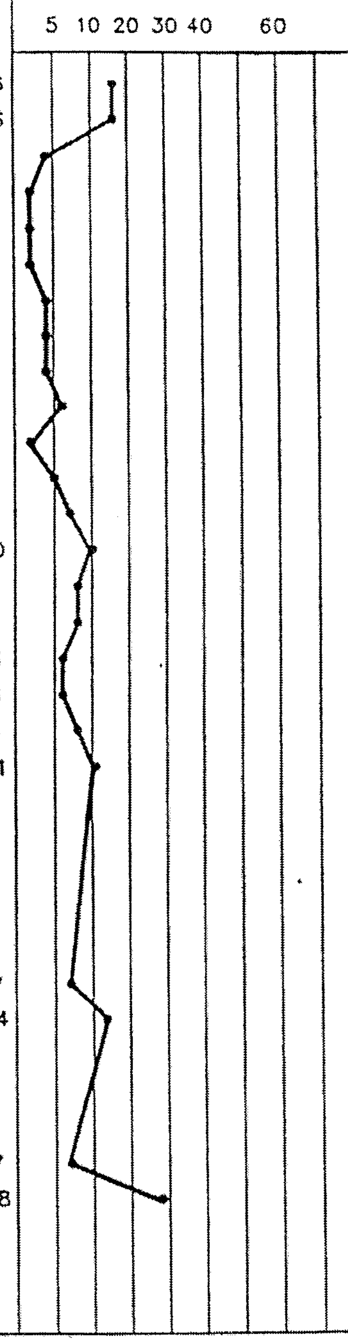
90-75-LL

# LITHOLOGY LOG



| REL. ELEV. | DEPTH (FEET) | DESCRIPTION | N |
|---|---|---|---|
| 99.92 | MP | | |
| 98.25 | 0 | Silt and cinders; black | 16 |
| | | Silt and cinders; black; grading to clay, micaceous; grey and red-brown; damp; at ≈ 2.5' | 16<br>4<br>2 |
| | -5 | Clay, sandy; mottled grey and medium brown; stiff; damp | 2<br>2 |
| | | Same as above except more sand and more grey color; wet | 4<br>4 |
| | | Same as above | 4 |
| | -10 | Silt, micaceous; silvery grey; to 11'. 1" lense of silt, sandy, micaceous; grey and white. Silt, micaceous; (SAPROLITE) orange-brown with black accessory minerals | 6<br>2<br>5 |
| | | Silt; micaceous; (SAPROLITE); orange-brown with black accessory minerals | 7<br>10 |
| | -15 | Same as above except wet | 8 |
| | | Same as above except with 1" silt, micaceous, sandy; medium brown at base | 8<br>6<br>6 |
| | | Silt; orange-brown; grading to silt, sandy micaceous; medium brown and white | 8 |
| | -20 | | 11 |
| | -25 | Silt, sandy, micaceous; medium brown and white grading to silt, very micaceous; orange brown | 7<br>14 |
| | -30 | Sand (fine to coarse grained), silty; medium orange-brown and white | 7<br>28 |
| | -35 | | |

PENETRATION BLOWS PER FT. (N)




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

LATITUDE 34° 52' 59"
LONGITUDE 82° 25' 32"
DRILLED BY E D & S
DRILLER H. JACKSON
DRILLER'S CERT. 807

⊠ UNCONSOLIDATED SAMPLE
▧ UNDISTURBED SAMPLE
■ CORED INTERVAL

▽ WATER TABLE, 1 HR.
▽ WATER TABLE, 24 HR.
⊕ HYDROPUNCH SAMPLE

J.L. Rogers & Callcott Engineers, Inc.
Greenville South Carolina

WELL NO. USF-10
LOCATION U.S. FINISHING
DATE DRILLED 2/8/91
LOGGED BY KWW

USF10-1

# LITHOLOGY LOG

90-75-LL



| REL. ELEV. | DEPTH (FEET) | | DESCRIPTION | N | PENETRATION BLOWS PER FT. (N) |
|---|---|---|---|---|---|
| | MP | | | | 5 10 20 30 40 60 120 |
| | -35 | | Sand; micaceous; orange-brown; grading to silt; very micaceous; dark brown | | BLOW COUNT 50 PER 1" |
| | | | Silt; very micaceous, sandy, orange-brown; sharp contact at 38' with 6" weathered biotite gneiss; fine and coarse grained quartz with biotite; black and white | | |
| | -40 | | | | |
| | -45 | | (AUGER REFUSAL AT 38') | | |

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

LATITUDE 34° 52' 59"
LONGITUDE 82° 25' 32"
DRILLED BY E D & S
DRILLER M. JACKSON
DRILLER'S CERT. 807

J.L. Rogers & Callcott Engineers, Inc.
Greenville South Carolina

☒ UNCONSOLIDATED SAMPLE
▧ UNDISTURBED SAMPLE
■ CORED INTERVAL

▽ WATER TABLE, 1 HR.
▽ WATER TABLE, 24 HR.
⊕ HYDROPUNCH SAMPLE

WELL NO. USF-10
LOCATION U.S. FINISHING
DATE DRILLED 2/8/91
LOGGED BY KWW

ROGERS & CALLCOTT ENGINEERS, INC.

P.O. BOX 5655, GREENVILLE, SOUTH CAROLINA 29606
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9068

# WELL LOG

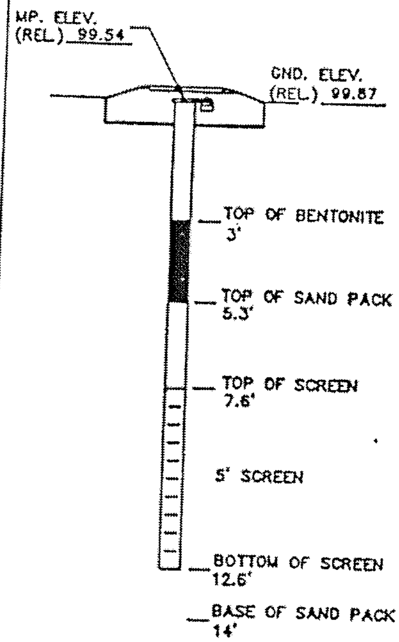
PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY KWW
LATITUDE 34° 52' 57"
LONGITUDE 82° 25' 34"

WELL NO. OR BORING NO. USF-11
DATE STARTED 1-22-91
DATE FINISHED 1-22-91
DRILLER CONTRACTOR E D & S
DRILLER'S NAME M. JACKSON
DRILLER'S CERT. # 807

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | 25, 27 | ▨ | Ash, cinders; black; with gravel |
| | 6, 7 | ▨ | Clay, sandy, slightly micaceous; medium brown |
| −5 | 2, 2 | ▨ | Clay, sandy; medium grey |
| | 2, 2 | ▨ | Clay, sandy; medium grey grading to clay, sandy; orange—brown |
| −10 | 2, 2 | ▨ | Sand, slightly micaceous, silty, clayey; medium to dark brown |
| | 2, 2 | ▨ | Clay, sandy; medium grey; very wet |
| | 2, 2 | ▨ | Clay, sandy; medium grey grading to sand fine grained, micaceous, silty; medium to dark brown |
| −15 | | | |
| −20 | | | |
| −25 | | | |
| −30 | | | |

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




TOTAL DEPTH = 14'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

SHEET 1 OF 1

# ROGERS & CALLCOTT ENGINEERS, INC.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
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FAX (803) 233-9058

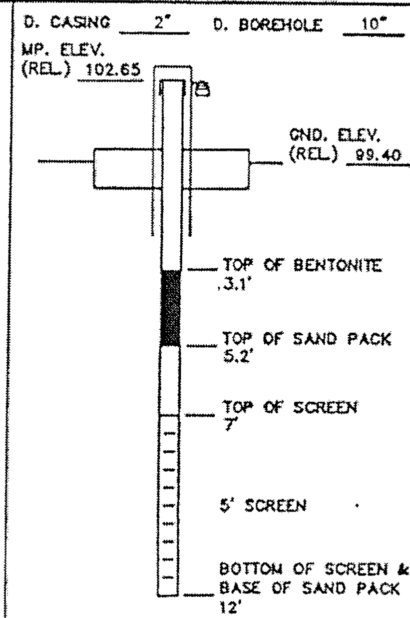
## WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-12 |
| CLIENT | U.S. FINISHING | DATE STARTED | 1-22-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 1-22-91 |
| LOGGED BY | KWW | DRILLER CONTRACTOR | E D & S |
| LATITUDE | 34° 52' 58" | DRILLER'S NAME | M. JACKSON |
| LONGITUDE | 82° 25' 33" | DRILLER'S CERT. # | 807 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 to -1 | 4 | sampled | Clay; medium brown; with gravel |
| -1 to -2 | 10 | sampled | |
| -2 to -3 | 4 | sampled | Clay; orange grading to clay, sandy; medium brown; damp |
| -3 to -4 | 4 | sampled | |
| -4 to -5 | 2 | sampled | Clay, sandy; medium grey; wet |
| -5 to -6 | 2 | sampled | |
| -6 to -7 | 2 | sampled | Clay, sandy; medium grey grading to sand, clayey; light grey with some gravel; wet |
| -7 to -8 | 2 | sampled | |
| -8 to -9 | 2 | sampled | Silty, micaceous, some clay and fine to coarse grained sand; medium grey; very wet |
| -9 to -10 | 4 | sampled | |
| -10 to -11 | 7 | sampled | Same as above except sharp contact sand, silty; yellow to orange with black accessory mineralS (SAPROLITE) |
| -11 to -12 | 15 | sampled | |

Depth scale: 0, -5, -10, -15, -20, -25, -30

## WELL SCHEMATIC




TOTAL DEPTH = 12'

PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB.
HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

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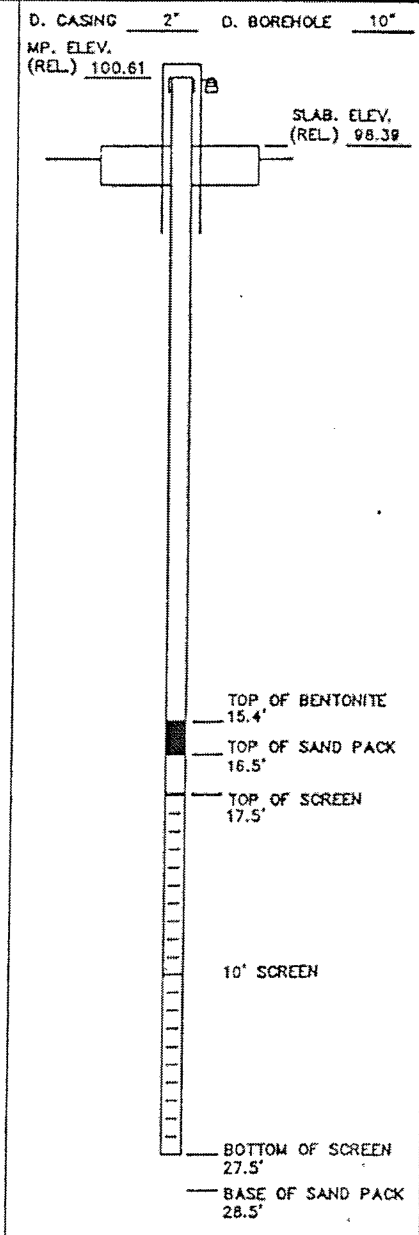
FAX (803) 233-9058

# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-13 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-18-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-19-91 |
| LOGGED BY | EB | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 53' 01" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 31" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | | | |
| -10 | | | |
| -15 | | | |
| -20 | | | |
| | 34 | (sample ~-21.5 to -22.5) | Sand, silty; foliated red-brown "salt and pepper" appearance with black accessory minerals; weathered gneiss appearance |
| | | | (AUGER REFUSAL AT 28.8') |
| -25 | | | |
| -30 | | | |

## WELL SCHEMATIC




TOTAL DEPTH = 28.5'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

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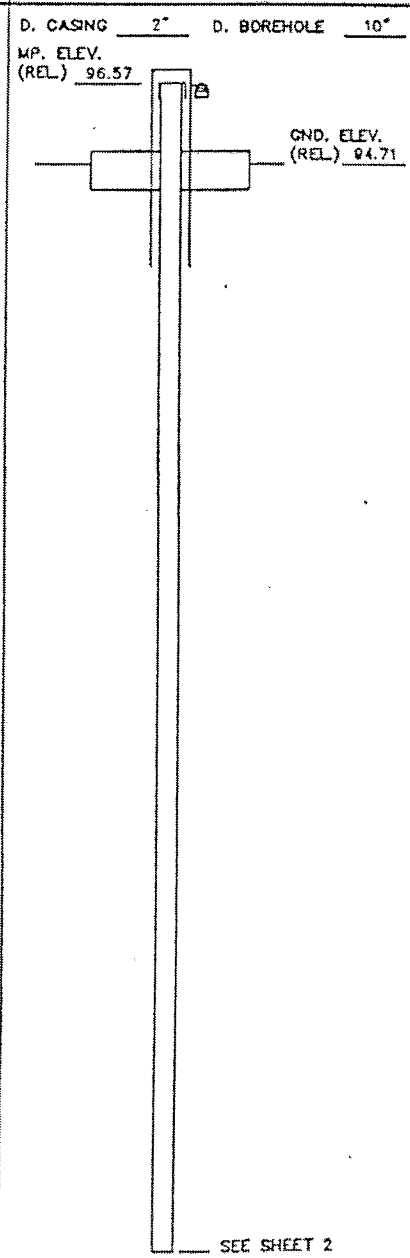
FAX (803) 233-9058

# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-14 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-19-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-19-91 |
| LOGGED BY | KWW | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 56" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 32" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | 2<br>1 | -5 to -7 | No recovery; wet at 5' |
| -10 | 2<br>2 | -9 to -11 | Clay, sandy, silty; medium brown with vegetation fragments (ALLUVIUM) |
| -15 | 3<br>9 | -14 to -16 | Sand medium to coarse grained, silty, slightly micaceous with a few pebble sized quartz fragments; (ALLUVIUM) |
| -20 | | | |
| -25 | 3<br>25 | -24 to -26 | Sand fine to coarse grained with black biotite; very weathered biotite gneiss appearance (SAPROLITE) |
| -30 | | | |

WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

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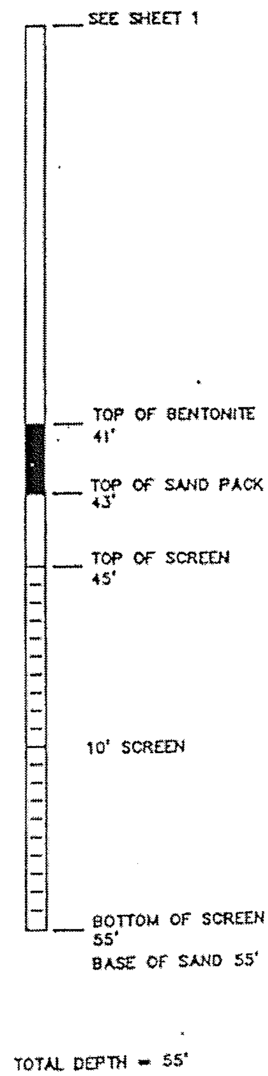
# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-14 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-19-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-19-91 |
| LOGGED BY | KWW | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 56" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 32" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 | | | |
| -35 | | | |
| -40 | | | |
| -45 | | | |
| -50 | | | |
| -55 | 50/4" | | Black very fine grained gneiss (SPOON AND AUGER REFUSAL) |
| -60 | | | |

## WELL SCHEMATIC

D. CASING 2"   D. BOREHOLE 10"




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
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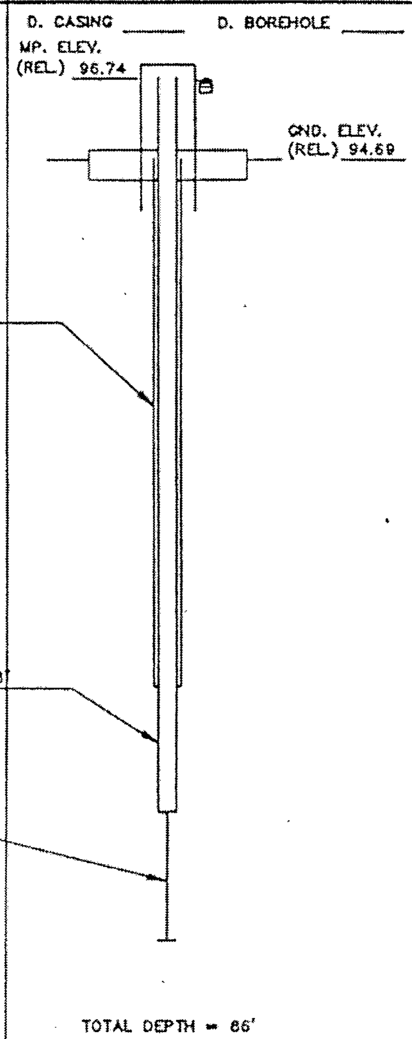
FAX (803) 233-9058

# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-14A |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-26-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 4-1-91 |
| LOGGED BY | EB(R/C) & DT(GEOTRANS) | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 56" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 31" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY | WELL SCHEMATIC |
|---|---|---|---|---|
| -0 | | | | |
| -20 | | | DIA. OF MUD ROTARY BOREHOLE FROM 0' TO 59' = 12"<br>DIA. OF PVC CASING FROM 0' TO 59' = 6" | |
| -40 | | | | |
| -60 | | | DIA. OF AIR ROTARY BOREHOLE FROM 59' TO 72' = 7 7/8"<br>DIA. OF PVC CASING FROM 0' TO 72' = 4" | |
| | | | HQ CORE FROM 71' TO 86' | |
| -80 | | | CORE DESCRIPTION: Dark grey granite biotite gneiss with iron staining at 76' and at 76.5'; orange and green stained fracture at 84' | |
| -100 | | | | |
| -120 | | | | |




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.



USF14A

SHEET 1 OF 1

ROGERS & CALLCOTT ENGINEERS, INC.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
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FAX (803) 233-9058

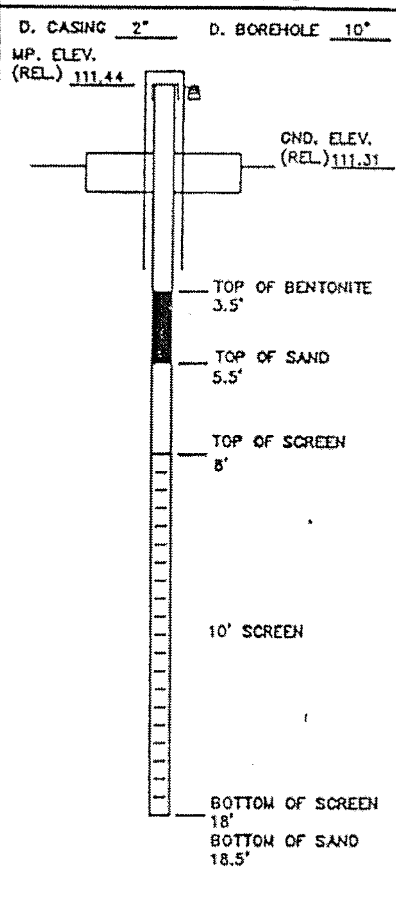
# WELL LOG

PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY DT (GEOTRANS)
LATITUDE 34° 53' 03"
LONGITUDE 82° 25' 36"

WELL NO. OR BORING NO. USF-15
DATE STARTED 3-21-91
DATE FINISHED 3-21-91
DRILLER CONTRACTOR A T & E
DRILLER'S NAME R. POWELL
DRILLER'S CERT. # 927

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | Asphalt |
| | | No samples collected | Clay, silty to sandy, med-brown, very moist (3') |
| -5 | | | |
| -10 | | | |
| -15 | | | |
| -20 | | | |
| -25 | | | |
| -30 | | | |

## WELL SCHEMATIC




TOTAL DEPTH = 18.5'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

SHEET 1 OF 1


# ROGERS & CALLCOTT ENGINEERS, INC.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058


## WELL LOG

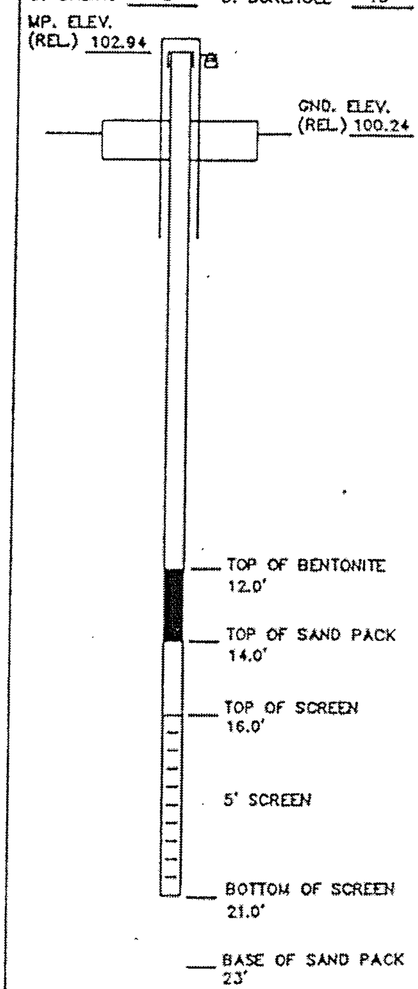
| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-16 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-25-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-25-91 |
| LOGGED BY | EB | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 56" | DRILLER'S NAME | R. POWELL |
| LONGITUDE | 82° 25' 37" | DRILLER'S CERT. # | 927 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 to -2 | 6, 6 | sampled | Clay; red-brown mixed with black solid slag and a light green pumice-like slag grading to clay, micaceous, silty; blue-grey |
| -2 to -4 | 1, 2 | sampled | Clay; red-brown; stiff |
| -4 to -6 | 2, 2 | | No return |
| -6 to -8 | 2, 2 | sampled | Clay; yellow-brown with saprolite and gravel grading to clay, micaceous, silty; red-brown with black gravel; wet; (BACKFILL) |
| -8 to -10 | 2, 2 | sampled | Clay, micaceous, silty; red-brown with small to large black gravel grading to clay, silt; mottled dark brown (BACKFILL) |
| -10 to -12 | 3, 5 | sampled | Clay, micaceous, silty; red-brown with black flakes and very coarse grain sand (BACKFILL) |
| -12 to -14 | 2, 3 | sampled | Clay; light grey with roots grading to sand (very coarse grain), silty; light grey |
| -14 to -16 | 2, 2 | sampled | Silt, sandy (fine to coarse grain), micaceous supported by a matrix of silt, micaceous; grey |
| -16 to -18 | 2, 2 | sampled | Same as above except with 1/4" to 1/2" interlayers of sand (fine to coarse grain) and gravel (>2mm) |
| -18 to -20 | 1, 1 | sampled | Same as above except with a 1" layer mica flakes (SAPROLITE) |
| -20 to -22 | 1, 5 | sampled | Same as baove except grading to silt, very micaceous; laminated and interfoliated; greenish-grey, grey, dark grey with some sand (very coarse grain); orange-white |

Depth scale: 0, -5, -10, -15, -20, -25, -30

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




TOTAL DEPTH 23'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

SHEET 1 OF 2


# ROGERS & CALLCOTT ENGINEERS, INC.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9068


## WELL LOG

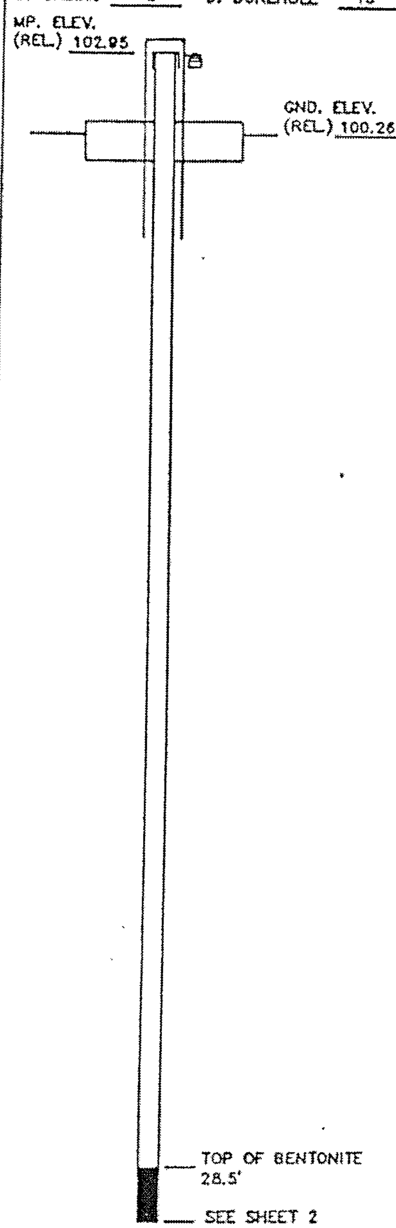
PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY JEC
LATITUDE 34° 52' 56"
LONGITUDE 82° 25' 38"

WELL NO. OR BORING NO. USF-16A
DATE STARTED 3-27-91
DATE FINISHED 3-27-91
DRILLER CONTRACTOR A T & E
DRILLER'S NAME R. POWELL
DRILLER'S CERT. # 927

| DEPTH (FEET) | BLOWS PER FT. (N) | LITHOLOGY |
|---|---|---|
| | | NOTE: LITHOLOGY FOR 0' TO 22' ARE FROM USF-16 BY EB (ROGERS AND CALLCOTT) |
| 0 | | |
| | 6 | Clay; red-brown mixed with black solid slag and a light green pumice-like slag grading to clay, micaceous, silty; blue-grey |
| | 6 | |
| | 1 | Clay; red-brown; stiff |
| | 2 | |
| -5 | 2 | No return |
| | 2 | |
| | 2 | Clay; yellow-brown with saprolite and gravel grading to clay, micaceous, silty; red-brown with black gravel; wet; (BACKFILL) |
| | 2 | |
| | 2 | Clay, micaceous, silty; red-brown with small to large black gravel grading to clay, silt; mottled dark brown (BACKFILL) |
| -10 | 2 | |
| | 3 | Clay, micaceous, silty; red-brown with black flakes and very coarse grain sand (BACKFILL) |
| | 5 | |
| | 2 | Clay, light grey with roots grading to sand (very coarse grain), silty; light grey |
| | 3 | |
| -15 | 2 | Silt, sandy (fine to coarse grain), micaceous supported by a matrix of silt, micaceous; grey |
| | 2 | |
| | 2 | Same as above except with 1/4" to 1/2" interlayers of sand (fine to coarse grain) and gravel (>2mm) |
| | 2 | |
| | 1 | Same as above except with a 1" layer mica flakes (SAPROLITE) |
| -20 | 1 | |
| | 1 | Same as boove except grading to silt, very micaceous; laminated and interfoliated; greenish-grey, grey, dark grey with some sand (very coarse grain); orange-white |
| | 5 | |
| | 2 | Silt, very micaceous; silver; soft and wet grading to silt, micaceous, clay; orange-brown with black and white accessory minerals; wet |
| -25 | 3 | |
| -30 | 2 | Clay, silty; orange-brown with white and black accessory minerals; damp; (SAPROLITE) |

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

SHEET 2 OF 2

ROGERS & CALLCOTT ENGINEERS, INC.

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718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
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FAX (803) 233-9058

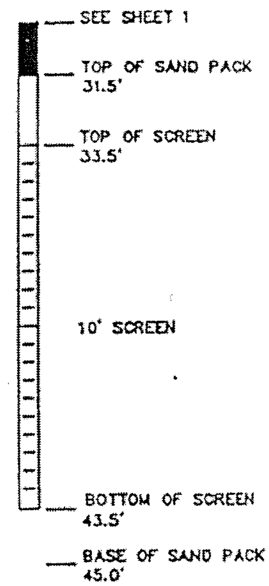
# WELL LOG

| | |
|---|---|
| PROJECT U.S. FINISHING | WELL NO. OR BORING NO. USF-16A |
| CLIENT U.S. FINISHING | DATE STARTED 3-27-91 |
| LOCATION GREENVILLE SC. | DATE FINISHED 3-27-91 |
| LOGGED BY JEC | DRILLER CONTRACTOR A T & E |
| LATITUDE 34° 52' 56" | DRILLER'S NAME R. POWELL |
| LONGITUDE 82° 25' 38" | DRILLER'S CERT. # 927 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 | 2 | | SEE SHEET 1 FOR LITHOLOGY OF SPLIT SPOON |
| -35 | 3<br>3 | | Sand (fine to coarse grain), micaceous, clay; pale orange with white and black accessory minerals; damp (SAPROLITE) |
| -40 | 3<br>6 | | Sand (coarse grain), white with orange tint grading to clay, micaceous, sandy; orange with black accessory minerals grading to silt, micaceous, clay foliated with white and black accessory minerals; damp (SAPROLITE) |
| | 50/6" | | Sand, micaceous; white and grey bands (foliated) with black accessory minerals (SAPROLITE) |
| -45 | 50/6" | | Same as above except large quartz crystals (up to 3/4") (REFUSAL) |
| -50 | | | |
| -55 | | | |
| -60 | | | |

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




TOTAL DEPTH -45.5'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

ROGERS & CALLCOTT
ENGINEERS, INC.

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FAX (803) 233-9058

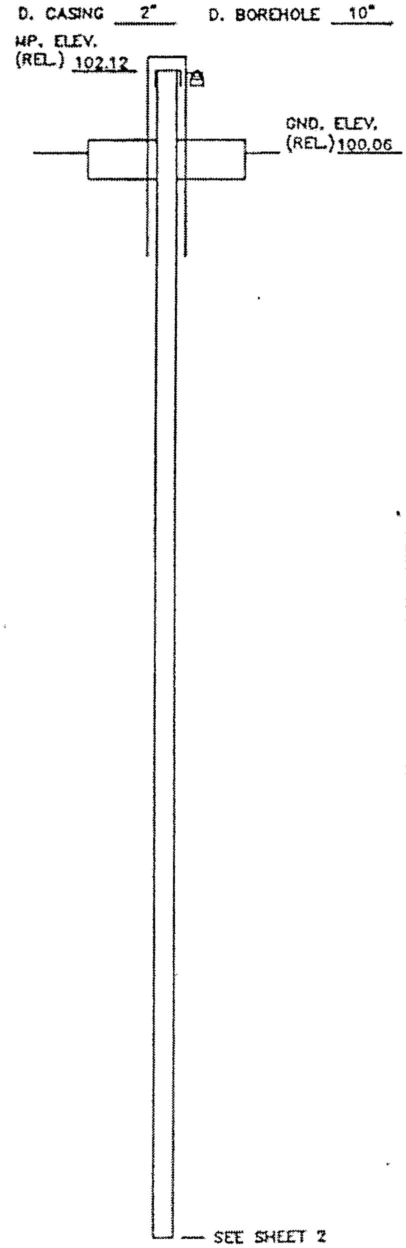
# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-17 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-22-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-22-91 |
| LOGGED BY | DT (GEOTRANS) | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 58" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 35" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | Concrete |
| | | | Clay, sandy to silty, moist from 2' |
| -5 | | | |
| -10 | | | Clay, light brown, with vermiculite |
| | | | Sand, fine grained and silty (12') |
| -15 | | | |
| -20 | | | |
| -25 | | | |
| -30 | | | |

WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




SEE SHEET 2

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

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TELEPHONE (803) 232-1556
FAX (803) 233-9058

# WELL LOG

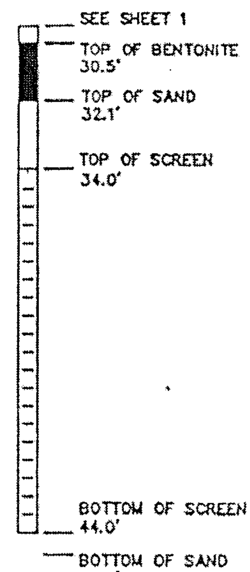
PROJECT: U.S. FINISHING
CLIENT: U.S. FINISHING
LOCATION: GREENVILLE SC.
LOGGED BY: DT (GEOTRANS)
LATITUDE: 34° 52' 58"
LONGITUDE: 82° 25' 35"

WELL NO. OR BORING NO.: USF-17
DATE STARTED: 3-22-91
DATE FINISHED: 3-22-91
DRILLER CONTRACTOR: A T & E
DRILLER'S NAME: T. BURNETTE
DRILLER'S CERT. #: 384

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 | 9<br>18 | sample | Sand, silty, grey, micaceous, damp (weathered gueiss) |
| -35 | 26<br>29 | sample | Weathered gueiss |
| -40 | 23<br>49 | sample | Weathered gueiss |
| -45 | 13<br>50/4" | sample | |
| -50 | | | |
| -55 | | | |
| -60 | | | |

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




TOTAL DEPTH = 44.5'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT

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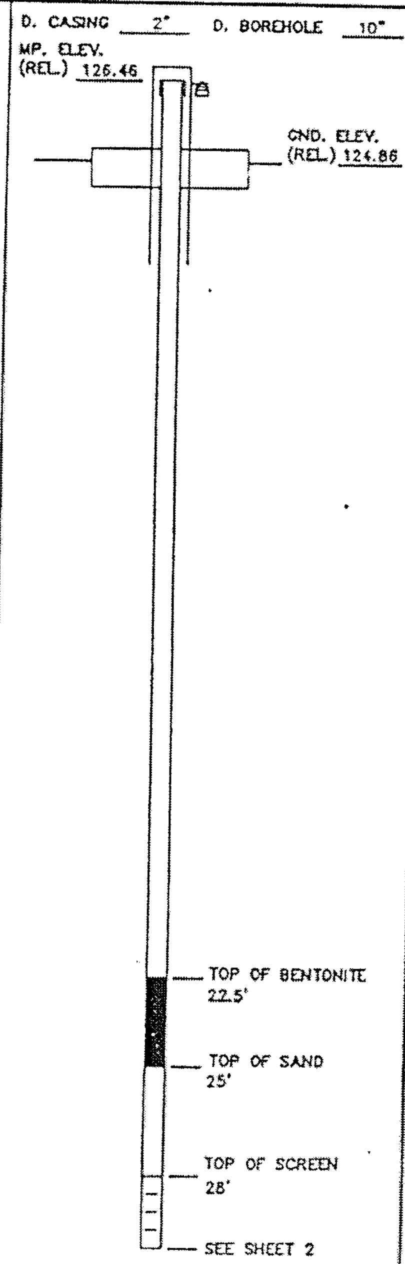
# WELL LOG

PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY JEC
LATITUDE 34° 52' 56"
LONGITUDE 82° 25' 55"

WELL NO. OR BORING NO. USF-18
DATE STARTED 3-28-91
DATE FINISHED 3-28-91
DRILLER CONTRACTOR A T & E
DRILLER'S NAME R. POWELL
DRILLER'S CERT. # 927

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | 4 | | Clay, micaceous; red |
| | 8 | | |
| | 6 | | Clay, micaceous; red-brown with some white accessory minerals. |
| | 14 | | |
| | 8 | | Clay, micaceous; red-brown grading to clay, micaceous; orange-brown with white bands (SAPROLITE) |
| -10 | 10 | | |
| | 9 | | Clay, micaceous; orange-brown foliated layers of orange and tan with black and white accessory minerals. (SAPROLITE) |
| | 12 | | |
| -15 | | | NO EVIDENCE OF SLUDGE IN ANY SPLIT SPOON SAMPLES, NO SPLIT SPOONS COLLECTED AFTER 11.5'. |
| -20 | | | |
| | | | SLOW DRILLING BETWEEN 20' AND 30' |
| -25 | | | |
| -30 | | | |

## WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

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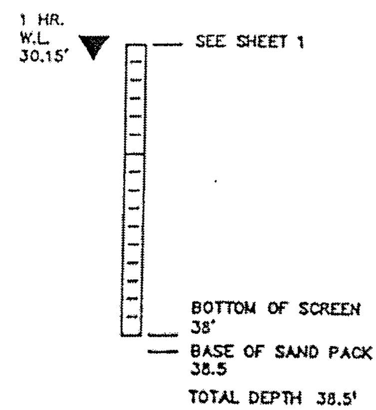
FAX (803) 233-9058

## WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-18 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-28-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-28-91 |
| LOGGED BY | JEC | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 56" | DRILLER'S NAME | R. POWELL |
| LONGITUDE | 82° 25' 55" | DRILLER'S CERT. # | 927 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY | WELL SCHEMATIC |
|---|---|---|---|---|
| 0 | | | | |
| -5 | | | NO SPLIT SPOONS COLLECTED PAST 11.5' | |
| -10 | | | | |
| -15 | | | | |
| -20 | | | | |
| -25 | | | | |
| -30 | | | | |

D. CASING 2" D. BOREHOLE 10"




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

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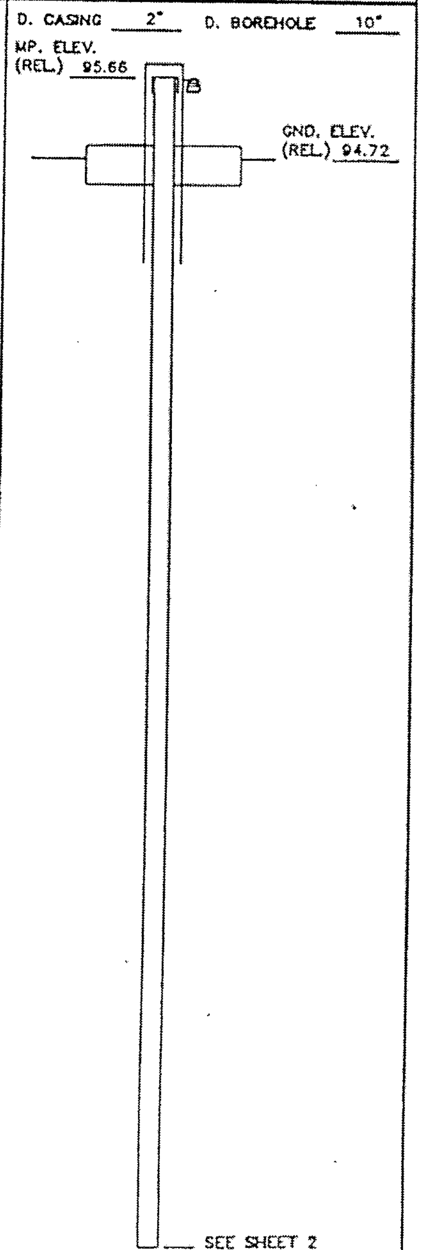
# WELL LOG

PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY EB
LATITUDE 34° 52' 58"
LONGITUDE 82° 25' 30"

WELL NO. OR BORING NO. USF-19
DATE STARTED 3-20-91
DATE FINISHED 3-20-91
DRILLER CONTRACTOR A T & E
DRILLER'S NAME T. BURNETTE
DRILLER'S CERT. # 384

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | | | NO SPLIT SPOONS COLLECTED BETWEEN 0'-14' |
| -10 | | | |
| -15 | 4<br>5 | ▨ | Sand very coarse grained; white with a large amount of black accessory minerals; wet |
| -20 | 3<br>2 | ▨ | Same as above except grading to silt, clayey, very micaceous; brown |
| -25 | 1<br>1 | ▨ | Silt, clayey, micaceous; foliated red-brown, brown and black |
| -30 | | | |

WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQ[illegible] DRIVE A 1.4 IN. I.D.

SHEET 2 OF 2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FAX (803) 233-9058


# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-19 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-20-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-20-91 |
| LOGGED BY | EB | DRILLER CONTRACTOR | AT & E |
| LATITUDE | 34° 52' 58" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 30" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 | | | |
| -35 | | | |
| -40 | | | No split spoons attempted until 59' |
| -45 | | | |
| -50 | | | |
| -55 | | | |
| -59 | 50/1" | | No recovery at 59' with split spoon. (SPOON AND AUGER REFUSAL) |
| -60 | | | |

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"


PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

TOTAL DEPTH =59.0'

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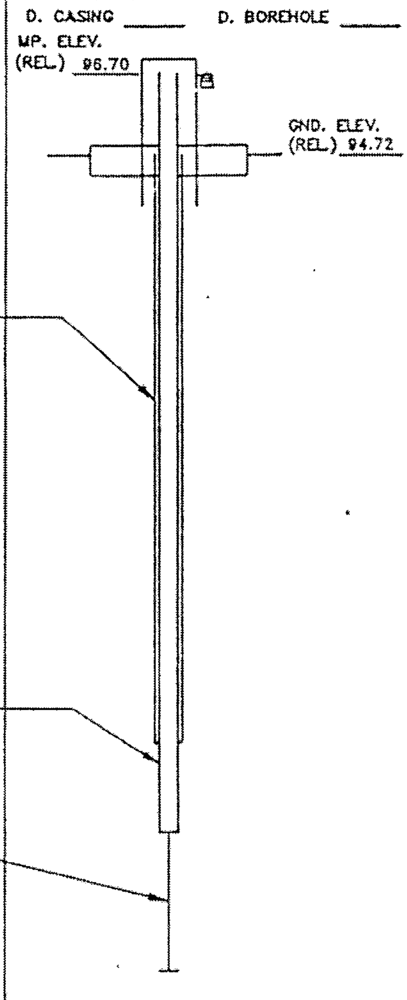
FAX (803) 233-9058

# WELL LOG

| | |
|---|---|
| PROJECT U.S. FINISHING | WELL NO. OR BORING NO. USF-19A |
| CLIENT U.S. FINISHING | DATE STARTED 3-27-91 |
| LOCATION GREENVILLE SC. | DATE FINISHED 4-1-91 |
| LOGGED BY EB(R/C) & DT(GEOTRANS) | DRILLER CONTRACTOR A T & E |
| LATITUDE 34° 52' 57" | DRILLER'S NAME T. BURNETTE |
| LONGITUDE 82° 25' 30" | DRILLER'S CERT. # 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY | WELL SCHEMATIC |
|---|---|---|---|---|
| -0 | | | | |
| -20 | | | DIA. OF MUD ROTARY BOREHOLE FROM 0' TO 65' = 12 "<br>DIA. OF PVC CASING FROM 0' TO 65' = 8" | |
| -40 | | | | |
| -60 | | | DIA. OF AIR ROTARY BOREHOLE FROM 65' TO 75.5' = 7 7/8"<br>DIA. OF PVC CASING FROM 0' TO 75.5' = 4" | |
| -80 | | | HQ CORE FROM 75.5' TO 90.5'<br>CORE DESCRIPTION: Light grey granite biotite gneiss, very hard with weathered zones at 80.5', 85.5' and 87.5' | |
| -100 | | | | |
| -120 | | | | |




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

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FAX (803) 233-9058

# WELL LOG

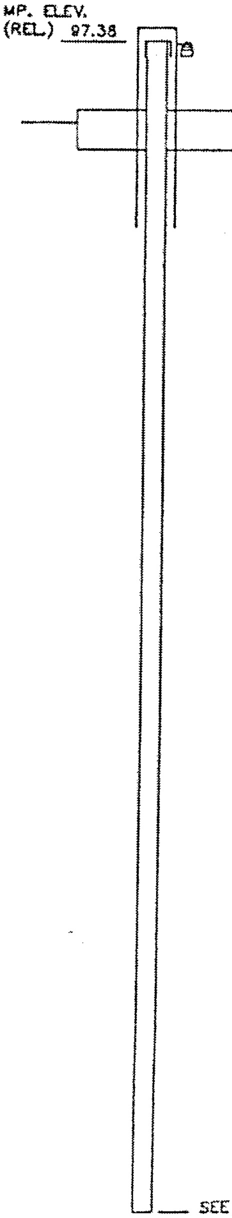
PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY KWW
LATITUDE 34° 52' 55"
LONGITUDE 82° 25' 29"

WELL NO. OR BORING NO. USF-20
DATE STARTED 3-21-91
DATE FINISHED 3-21-91
DRILLER CONTRACTOR A T & E
DRILLER'S NAME T. BURNETTE
DRILLER'S CERT. # 384

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 to -14 | | | NO SPLIT SPOONS COLLECTED BETWEEN 0'-14' |
| -15 | 5<br>11 | sampled | Sand, medium to coarse grained, micaceous, some annular quartz pebbles; tan |
| -20 | 9<br>14 | sampled | Sand less coarse grained with sharp contact at 20' with clay, micaceous; dark brown; very stiff. Sharp contact at 20.4' with sand, medium and coarse grained, biotite mica; slightly orange-tan with black accessory minerals |

WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"
MP. ELEV. (REL.) 97.38
GND. ELEV. (REL.) 94.49



SEE SHEET 2

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT

SHEET 2 OF 2

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FAX (803) 233-9058

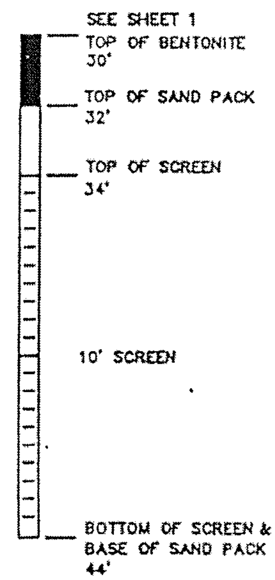
# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-20 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-21-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-21-91 |
| LOGGED BY | KWW | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 55" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 29" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 | | | |
| -35 | | | |
| -40 | | | |
| ~-42 | 50/5" | ▨ | Very weathered biotite gneiss (SPOON REFUSAL) |
| -44 | 50/<1" | | No recovery at 44' with split spoon (SPOON AND AUGER REFUSAL) |
| -45 | | | |
| -50 | | | |
| -55 | | | |
| -60 | | | |

## WELL SCHEMATIC

D. CASING 2"  D. BOREHOLE 10"




TOTAL DEPTH = 44'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

ROGERS & CALLCOTT ENGINEERS, INC.

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FAX (803) 233-9058

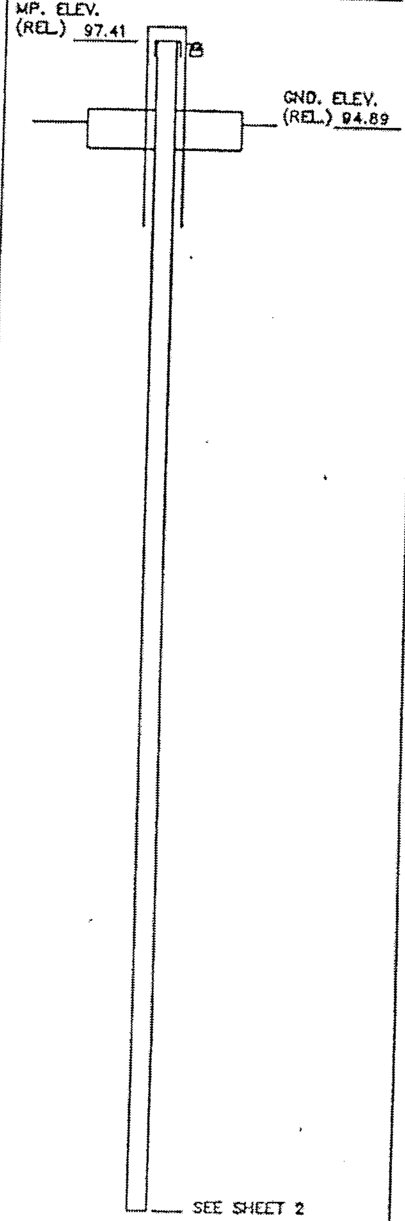
# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-21 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-22-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-22-91 |
| LOGGED BY | EB | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 58" | DRILLER'S NAME | R. POWELL |
| LONGITUDE | 82° 25' 27" | DRILLER'S CERT. # | 927 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 to -19 | | | NO SPLIT SPOONS COLLECTED BETWEEN 0'-19' |
| -20 | 0<br>0 | ▨ | Clay; red-brown; organic material present<br>No blow count- sank 2' due to weight of the spoon. |
| -25 | 10<br>10 | ▨ | Silt, micaceous, clayey; foliated red-brown, brown and black |
| -30 | | | |

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




SEE SHEET 2

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. R[EQUIRED] TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT

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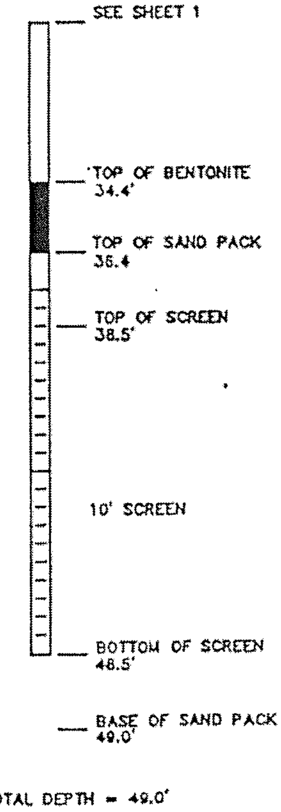
# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-21 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-22-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-22-91 |
| LOGGED BY | EB | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 58" | DRILLER'S NAME | R. POWELL |
| LONGITUDE | 82° 25' 27" | DRILLER'S CERT. # | 927 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY | WELL SCHEMATIC |
|---|---|---|---|---|
| | | | | D. CASING 2" D. BOREHOLE 10" |
| -30 | | | | |
| -35 | | | | |
| -40 | | | | |
| -45 | | | | |
| | | | No recovery at 49' with split spoon. (SPOON AND AUGER REFUSAL) | |
| -50 | | | | |
| -55 | | | | |
| -60 | | | | |




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. R[illegible] TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

SHEET 1 OF 2

# ROGERS & CALLCOTT ENGINEERS, INC.

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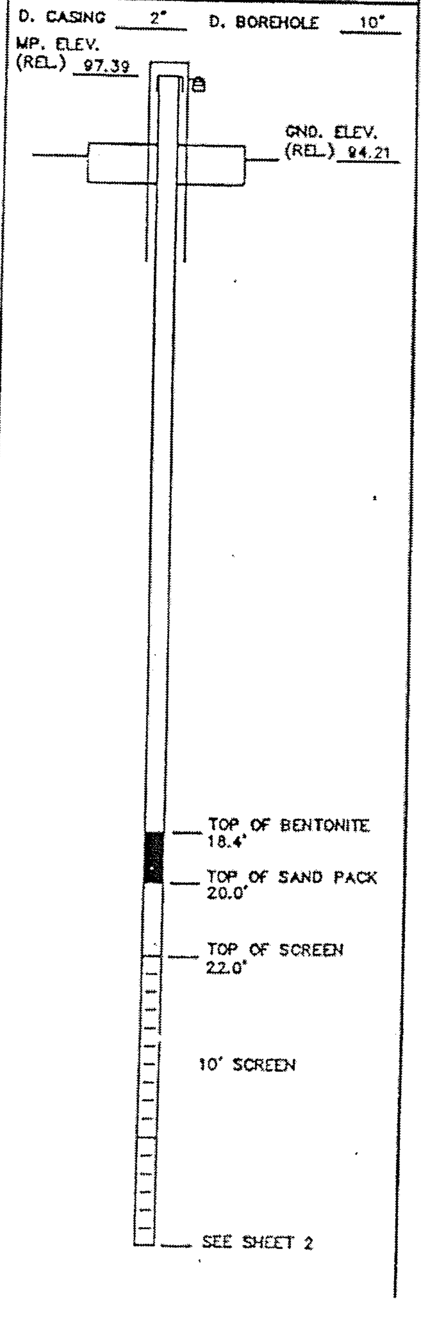
## WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-22 |
| CLIENT | U.S. FINISHING | DATE STARTED | 3-25-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 3-25-91 |
| LOGGED BY | EB | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 52' 53" | DRILLER'S NAME | R. POWELL |
| LONGITUDE | 82° 25' 35" | DRILLER'S CERT. # | 927 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | | | |
| -10 | | | |
| -15 | 7<br>6 | (sampled) | Clay, micaceous; black grading to sand, very coarse grained, micaceous grading finally to gravel, quartz and feldspar; wet (ALLUVIUM) |
| -20 | 7<br>9 | (sampled) | Silt, clayey, micaceous; foliated orange-brown with black accessory minerals (SAPROLITE) |
| -25 | | | |
| -30 | | | |

### WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

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# WELL LOG

PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY EB
LATITUDE 34° 52' 53"
LONGITUDE 82° 25' 35"

WELL NO. OR BORING NO. USF-22
DATE STARTED 3-25-91
DATE FINISHED 3-25-91
DRILLER CONTRACTOR A T & E
DRILLER'S NAME R. POWELL
DRILLER'S CERT. # 927

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 | | | |
| | 50/4" | (hatched) | 2" recovery of granite biotite gneiss (SPOON AND AUGER REFUSAL) |
| -35 | | | No recovery at 49' with split spoon. (SPOON AND AUGER REFUSAL) |
| -40 | | | |
| -45 | | | |
| -50 | | | |
| -55 | | | |
| -60 | | | |

WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"

- SEE SHEET 1
- BOTTOM OF SCREEN & BASE OF SAND PACK 32.0'
- TOTAL DEPTH 32'

PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. ...

SHEET 1 OF 1

ROGERS & CALLCOTT ENGINEERS, INC.

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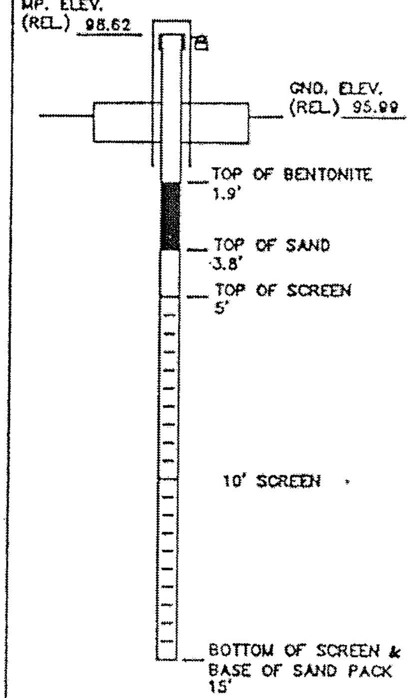
# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | USF-23 |
| CLIENT | U.S. FINISHING | DATE STARTED | 4-3-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 4-3-91 |
| LOGGED BY | EB | DRILLER CONTRACTOR | A T & E |
| LATITUDE | 34° 53' 00" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 29" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | | | |
| -10 | NO BLOW COUNT | | Sand very coarse grained, gravel with some wood (ALLUVIUM) |
| -15 | NO BLOW COUNT | | Sand medium grained; "salt and pepper" appearance; hard |
| | 50/1" | | (SPOON REFUSAL AT 15') |
| -20 | | | |
| -25 | | | |
| -30 | | | |

## WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




TOTAL DEPTH = 15'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

SHEET 1 OF 1

# ROGERS & CALLCOTT ENGINEERS, INC.

P.O. BOX 5655, GREENVILLE, SOUTH CAROLINA 29606
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

## WELL LOG

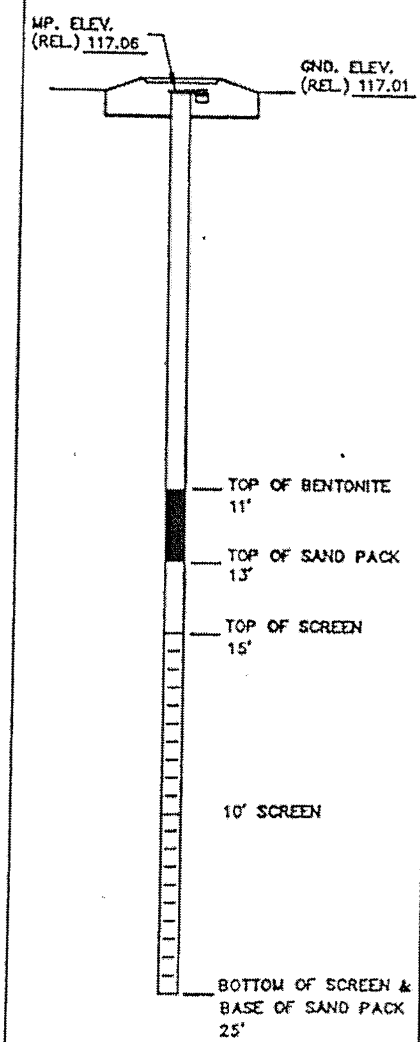
PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY KWW
LATITUDE 34° 53' 02"
LONGITUDE 82° 25' 37"

WELL NO. OR BORING NO. USF-24
DATE STARTED 4-4-91
DATE FINISHED 4-4-91
DRILLER CONTRACTOR AT & E
DRILLER'S NAME T. BURNETTE
DRILLER'S CERT. # 384

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 to -5 | | NO SAMPLES | Clay, silty, micaceous; red-brown |
| -5 to -10 | | | Clay, silty, very micaceous; medium brown<br>Damp at 15'<br>Wet at 17' |
| -15 to -20 | | NO SAMPLES | TOTAL DEPTH = 25' |
| -25 to -30 | | | |

### WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"




TOTAL DEPTH = 25

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

ROGERS & CALLCOTT
ENGINEERS, INC.

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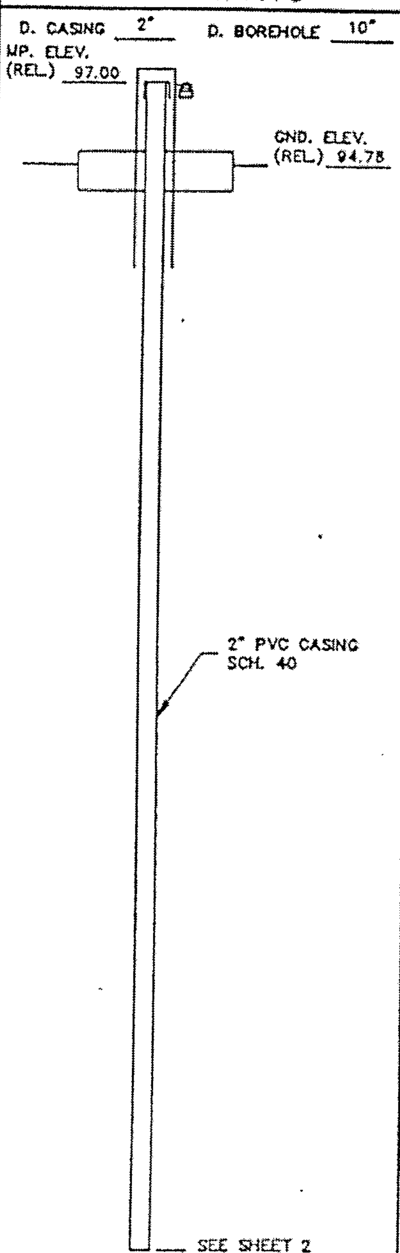
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

# WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | PZ-1 |
| CLIENT | U.S. FINISHING | DATE STARTED | 4-4-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 4-8-91 |
| LOGGED BY | EB | DRILLER CONTRACTOR | AT&E |
| LATITUDE | 34° 52' 57" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 31" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | | | |
| -10 | | | |
| -15 | NO BLOW COUNT | (sampled) | Silt, micaceous; silvery grading to a silt, clayey, micaceous with root material |
| -20 | NO BLOW COUNT | (sampled) | Sand fine to coarse grained, micaceous, silty; foliated black, tan, white and grey-brown (SAPROLITE) |
| -25 | | | |
| -30 | | | |

WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

ROGERS & CALLCOTT
ENGINEERS, INC.

P.O. BOX 5655, GREENVILLE, SOUTH CAROLINA 29606
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

# WELL LOG

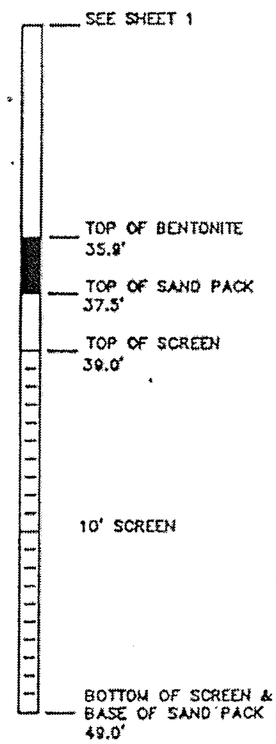
PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY EB
LATITUDE 34° 52' 57"
LONGITUDE 82° 25' 31"

WELL NO. OR BORING NO. PZ-1
DATE STARTED 4-4-91
DATE FINISHED 4-8-91
DRILLER CONTRACTOR AT&E
DRILLER'S NAME T. BURNETTE
DRILLER'S CERT. # 384

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 | | | |
| -35 | | | |
| -40 | | | |
| -45 | | | |
| | 50/2" | ▨ | 2" Recovery of friable granite biotite gneiss (SPOON AND AUGER REFUSAL) |
| -50 | | | |
| -55 | | | |
| -60 | | | |

## WELL SCHEMATIC

D. CASING 2"    D. BOREHOLE 10"




TOTAL DEPTH = 49.0'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

SHEET 1 OF 1

# ROGERS & CALLCOTT ENGINEERS, INC.

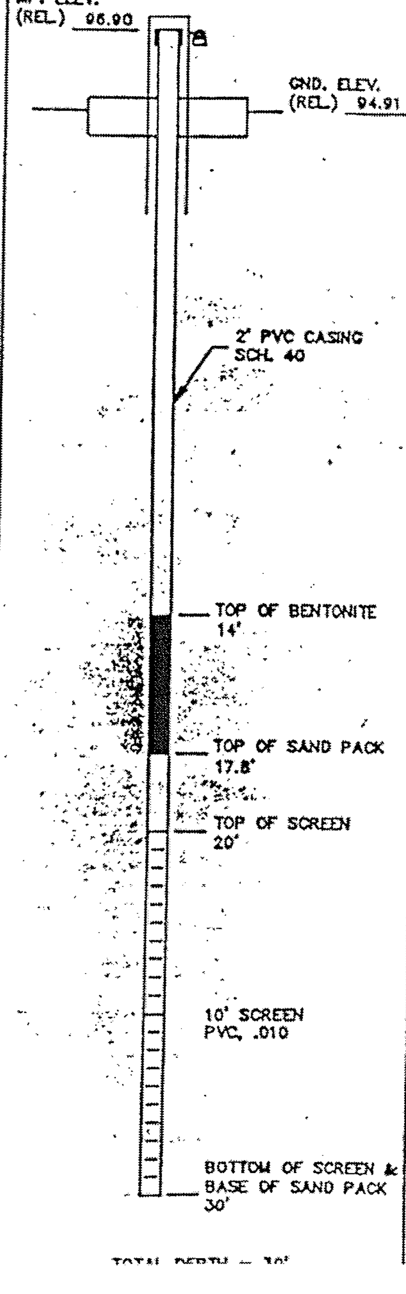
P.O. BOX 5655, GREENVILLE, SOUTH CAROLINA 29606
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

## WELL LOG

| | | | |
|---|---|---|---|
| PROJECT | U.S. FINISHING | WELL NO. OR BORING NO. | PZ-2 |
| CLIENT | U.S. FINISHING | DATE STARTED | 4-8-91 |
| LOCATION | GREENVILLE SC. | DATE FINISHED | 4-8-91 |
| LOGGED BY | EB | DRILLER CONTRACTOR | AT&E |
| LATITUDE | 34° 52' 58" | DRILLER'S NAME | T. BURNETTE |
| LONGITUDE | 82° 25' 30" | DRILLER'S CERT. # | 384 |

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | | | |
| -10 | | | |
| -15 | NO BLOW COUNT | (sampled) | No recovery, traces of sand |
| -20 | NO BLOW COUNT | (sampled) | Silt, clayey, micaceous with black weathered "garnets" |
| -25 | | | |
| -30 | 50/2" | (sampled) | No recovery at 30' |

### WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D.

ROGERS & CALLCOTT ENGINEERS, INC.
P.O. BOX 5655, GREENVILLE, SOUTH CAROLINA 29606
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

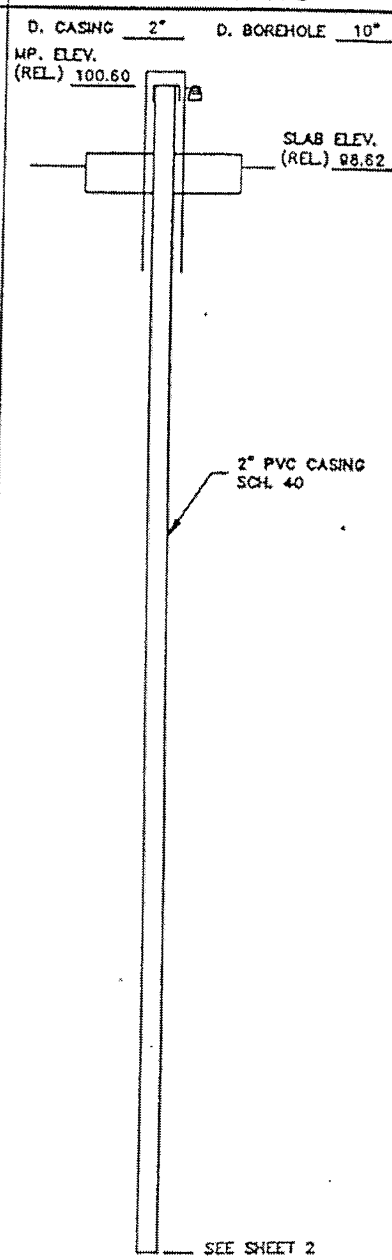
# WELL LOG

PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY EB
LATITUDE 34° 52' 58"
LONGITUDE 82° 25' 32"

WELL NO. OR BORING NO. PZ-3
DATE STARTED 4-9-91
DATE FINISHED 4-9-91
DRILLER CONTRACTOR AT&E
DRILLER'S NAME T. BURNETTE
DRILLER'S CERT. # 384

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| 0 | | | |
| -5 | | | |
| -10 | NO BLOW COUNT | (sample) | Clay, silty, charcoal grey, abundant root material present (ALLUVIUM) |
| -15 | NO BLOW COUNT | (sample) | Silt, clayey, very micaceous; red to orange-brown (SAPROLITE) |
| -20 | NO BLOW COUNT | (sample) | Sand, gravelly, biotite; interfoliated black and white with dark colored accessory minerals (SAPROLITE) |
| -25 | | | |
| -30 | | | |

WELL SCHEMATIC




PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

ROGERS & CALLCOTT ENGINEERS, INC.

P.O. BOX 5655, GREENVILLE, SOUTH CAROLINA 29606
718 LOWNDES HILL RD., GREENVILLE, SOUTH CAROLINA
TELEPHONE (803) 232-1556
FAX (803) 233-9058

# WELL LOG

PROJECT U.S. FINISHING
CLIENT U.S. FINISHING
LOCATION GREENVILLE SC.
LOGGED BY EB
LATITUDE 34° 52' 58"
LONGITUDE 82° 25' 32"

WELL NO. OR BORING NO. PZ-3
DATE STARTED 4-9-91
DATE FINISHED 4-9-91
DRILLER CONTRACTOR AT&E
DRILLER'S NAME T. BURNETTE
DRILLER'S CERT. # 384

| DEPTH (FEET) | BLOWS PER FT. (N) | SAMPLE INTERVAL | LITHOLOGY |
|---|---|---|---|
| -30 | | | |
| -35 | | | |
| -40 | | | |
| -45 | 50/2" | ▨ | No recovery |
| -50 | | | |
| -55 | | | |
| -60 | | | |

WELL SCHEMATIC

D. CASING 2" D. BOREHOLE 10"

SEE SHEET 1
TOP OF BENTONITE 31.5'
TOP OF SAND PACK 33.5'
TOP OF SCREEN 35.5'
10' SCREEN
BOTTOM OF SCREEN & BASE OF SAND PACK 45.5'

TOTAL DEPTH = 45.5'

PENETRATION IS THE NUMBER (N) OF BLOWS OF A 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE A 1.4 IN. I.D. SAMPLER 1 FT.

APPENDIX D - AERATION BASIN SLUDGE REMOVAL STATUS REPORT 6/12/91

ROGERS & CALLCOTT
ENGINEERS, INC.
P.O. Box 5655, Greenville, SC 29606
Phone (803) 232-1556 • FAX (803) 233-9058

J. L. Rogers, P.E.
F. D. Callcott, P.E.
S. W. Avery, Jr.,
Laboratory Director

June 12, 1991

Mr. E.C. McCall
Leatherwood, Walker, Todd and Mann
P.O. Box 87
Greenville, S.C. 29602

Subject: U.S. Finishing
Aeration Basin Sludge Removal

Dear Gene:

In response to your request and in response to discussion with Rich Rabold, we have summarized our findings in the enclosed report regarding sludge removal from the aeration basin.

Yours very truly,

J. L. ROGERS AND CALLCOTT ENGINEERS, INC.

Frank D. Callcott

FDC/dc

cc: Mr. Rich Rabold

Enclosure

U.S. FINISHING/AMERICAN FAST PRINT

AERATION BASIN SLUDGE REMOVAL STUDY

STATUS REPORT

JUNE 10, 1991

The aeration basin at U.S. Finishing was investigated to determine the feasibility of cleaning the basin to remove accumulated sludge.

Analyses of sludge in the aeration basin provide the following data.

AERATION BASIN SLUDGE

| DATE<br>SAMPLE<br>LOCATION | 3/16/88<br>53645<br>LAGOON SLUDGE<br>mg/kg | 4/24/90<br>77135<br>SL-2<br>mg/kg | 4/24/90<br>49785 (RMT)<br>SL-2<br>mg/kg | 3/20/91<br>90314<br>DRIED SLUDGE<br>mg/kg |
|---|---|---|---|---|
| As | 7.3 | <1.0 | 5.4 | 6.7 |
| Sb | <25 | ---- | ---- | ---- |
| Ba | 215 | 123 | 210 | 34 |
| Cd | 1.0 | 2.6 | <0.8 | <1.0 |
| Cr | 3200 | 1750 | 1900 | ~~380~~ 398 |
| Co | 8 | ---- | ---- | ---- |
| Cu | 650 | 46 | 53 | 80 |
| Fe | ---- | 35,000 | 53,000 | ---- |
| Pb | 70 | <2.0 | 30 | 7.1 |
| Hg | 0.23 | <0.2 | <0.1 | <0.2 |
| Mg | ---- | 1050 | 1500 | ---- |
| Mn | ---- | 342 | 590 | ---- |
| Ni | 91 | ---- | ---- | ---- |
| Se | ---- | <1.0 | <1.0 | <5.0 |
| Ag | 1.0 | <1.0 | <2 | <1.0 |
| Tl | <12 | ---- | ---- | ---- |
| Sn | 90 | ---- | ---- | ---- |
| Zn | 1000 | 82 | 160 | 143 |
| Phenol | 1.5 | ---- | ---- | ---- |

The preliminary concept of work was to remove the basin from operation, allow suspended solids to settle in the basin, pump supernatant to the existing sewer, dewater and/or stabilize remaining sludge and dispose of dewatered sludge off-site or on site. An alternate concept is to remove bottom sludge by a small dredge while the basin remains in service. To remove the basin from operation requires that influent to the aeration basin be discharged directly to the Western Carolina Regional Sewer Authority (WCRSA) sewer system.

Several 24-hr. composite samples of influent to the aeration basin were obtained and analyzed to determine if discharge directly to WCRSA is acceptable.

AERATION BASIN INFLUENT

| DATE<br>SAMPLE | 2/7/91<br>88643 | 3/21/91<br>90443 | 3/22/91<br>90482 | 4/18/91<br>91503 | 5/2/91<br>91933 |
|---|---|---|---|---|---|
| pH, units | 11.7 | 11.9 | 12.0 | 12.1 | 12.6 |
| Temp. °C. | 39 | 41 | 43 | 44 | 46 |
| BOD, mg/l | 840 | 540 | 638 | 705 | 870 |
| TSS, mg/l | 91 | 304 | 128 | 144 | 129 |
| COD, mg/l | 2920 | 2200 | 1910 | 2160 | 2490 |
| Cr, mg/l | <.02 | .06 | .02 | <.02 | .03 |
| Cu, mg/l | .04 | .06 | .05 | .04 | .06 |
| Ni, mg/l | <.02 | .03 | .02 | .06 | .03 |
| Zn, mg/l | .12 | .90 | 1.9 | <.01 | .14 |

These results indicate high pH, high temperatures and high BOD in the aeration basin influent; however, temperature should dissipate in the long-sewer lines prior to the treatment plant, WCRSA has been accepting high pH in some instances and BOD in this range may be acceptable for a limited time at additional surcharge. No contact has been made with WCRSA.

Aeration basin volume was calculated by field survey of the water surface and by using a typical bank slope and water depth. Calculated volume is 9.37 million gallons.

Suspended and settled sludge was sampled on February 5, 1991 at approximately 30 locations in the basin. Samples were taken with a long clear plastic sampler ("sludge judge") which provided a cross section of the entire liquid and sludge depth at the sample point. During this sampling, settled sludge was noted at 1 inch to 3 inches in the basin. These samples were composited as taken into four 5-gallon containers. A mixed sample of each container was analyzed for total suspended solids and total volatile suspended solids, with the following results.

AERATION BASIN SOLIDS

| SAMPLE | TSS, mg/l | TVSS, mg/l |
|---|---|---|
| 88513 | 2420 | 300 |
| 88514 | 4460 | 700 |
| 88515 | 2280 | 860 |
| 88516 | 2080 | 620 |
| Average | 2810 | 620 |

Calculated total solids in the basin is 9.37(8.34)2810 = 219,590 pounds, say 220,000 pounds. Most of these solids are kept in suspension by the aerators. Less than this amount would be removed if the basin were cleaned.

Suspended sludge from the 5-gallon samples was dewatered by filtration. Fifteen gallons of sample was filtered through a pilot filter of approximately 6 inches of sand with effective size of 0.92 to 0.99 mm. Solids retained on the filter were allowed to air dry for 10 days. No stabilizer was blended with the sludge. The sludge cake was 46% solids after 10 days. Analyses of the sludge and a TCLP test resulted in the following data.

FILTERED AND DRIED SLUDGE

| PARAMETER SAMPLE | SLUDGE, mg/kg 90314 | TCLP, mg/l 89500 |
|---|---|---|
| Arsenic | 6.7 | <0.05 |
| Barium | 34 | 0.84 |
| Cadmium | <1.0 | <0.01 |
| Chromium | 380 | 0.04 |
| Copper | 80 | ---- |
| Lead | 7.1 | <0.02 |
| Mercury | <0.2 | <0.001 |
| Selenium | <5.0 | <0.05 |
| Silver | <1.0 | 0.02 |
| Zinc | 143 | ---- |

This indicates that the sludge should be non-hazardous and may be acceptable to various landfills.

Two contractors were invited to visit the site and provide conceptual proposals and budget costs for the work. These proposals are attached.

APPENDIX E - AZIMUTH, INC. ASBESTOS SAMPLING REPORT 6/25/91

azimuth
INCORPORATED

*Consultants in Environmental &
Occupational Health*

July 22, 1991

Mr. Richard Rabold
Geotrans, Inc.
4350 Brownboro Road
Suite 239
Louisville, KY 40207

Dear Mr. Rabold:

We are pleased to provide you with the results of the asbestos air monitoring as requested by you for the U.S. Finishing Property in Greenville, South Carolina.

If we can be of any service to you in the future, please don't hesitate to call.

Sincerely,

Jeffrey A. Massey
Manager, Greenville Operations

JAM:alt
2249

Enclosures (3)

Corporate:

9229 University Boulevard
Charleston, SC 29418
(803) 553-9456
(800) 537-0336 toll-free
(803) 569-3282 fax

Atlanta:

5500 Oakbrook Parkway, Suite 200
Norcross, GA 30093
(404) 840-7223
(404) 662-8532 fax

Columbia:

111 Executive Center Drive, Suite 200
Columbia, SC 29210
(803) 798-2343
(800) 882-3101 toll-free
(803) 731-3489 fax

U.S. Finishing Property

Geotrans, Incorporated

Report of Findings

## Introduction

Samples were collected to measure airborne asbestos fibers on the U.S. Finishing Property identified on the attached site drawing. These samples were collected on June 16, 1991 and analyzed using Transmission Electron Microscopy (TEM) as per the Asbestos Hazard Emergency Response Act (AHERA), 40 CFR Part 763.

Initial inspection of the site indicated that at least three major areas were contaminated with tile suspected of containing asbestos. This debris was classified as Category I, non-friable asbestos tile, as per the National Emission Standard for Hazardous Air Pollutants (NESHAP), and is a regulated material.

One TEM sample was collected in each contaminated area. TEM was the analysis method used as it is capable of quantifying asbestos fibers.

## Sample Locations

| Sample No. | Location |
|---|---|
| 01 | Hill area with tiles |
| 02 | Road area with tiles |
| 03 | Railroad track area with tiles |

## Results

No asbestos was detected in the air in any of the areas. Actual sample results are attached. This material should not release significant asbestos fibers unless the material is handled or moved. Air and water erosion may result in minor fiber release over time.

Sample Collection Methodology

Samples were collected for TEM analysis on 0.45 micrometer pore size mixed cellulose filters. Air was drawn through the filter media using battery-operated air sampling pumps calibrated to collect a known volume of air. The pumps are calibrated using a precision rotometer traceable to a primary standard. The samples are sealed immediately after shipping and transported to the laboratory for analysis.

The sample locations were selected at random in close proximity to the three known contaminated areas. The actual sample media was positioned downward and approximately five feet from the ground. Aggressive walking and thrashing about was performed during the sampling in the areas to simulate human activity.

azimuth INCORPORATED

*Consultants in Environmental & Occupational Health*



Received: 06/18/91

Azimuth, Inc. REPORT 06/20/91 16:51:46

Work Order # 91-06-138

REPORT TO: GEOTRANS, Incorporated
4350 Brownboro Road
Suite 239
Louisville, Kentucky 40207

ATTEN: Richard Rabold

PREPARED BY: Azimuth, Inc.
9229 University Blvd.
Charleston, SC 29418

ATTEN: Laboratory Services

PHONE:

APPROVED BY: [signature]

CONTACT: EVIE

CLIENT: GEOTRANS INC SAMPLES 3

COMPANY: GEOTRANS, Incorporated

FACILITY:

Director of Laboratories
Harriotte A. Hurley, CIH

WORK ID: TEM Samples

TAKEN:

TRANS: Federal Express

TYPE: TEM

P.O. #:

INVOICE: under separate cover

SAMPLE IDENTIFICATION

| | |
|---|---|
| 1 | 01 |
| 02 | 02 |
| 03 | 03 |

TEST CODES and NAMES used on this workorder

TEM 5 TEM Asbestos Analysis

Corporate:

9229 University Boulevard
Charleston, SC 29418
(803) 553-9456
(800) 537-0336 toll-free
(803) 569-3282 fax

Atlanta:

5500 Oakbrook Parkway, Suite 200
Norcross, GA 30093
(404) 840-7223
(404) 662-8532 fax

Columbia:

111 Executive Center Drive, Suite 200
Columbia, SC 29210
(803) 798-2343
(800) 882-3101 toll-free
(803) 731-3489 fax

azimuth INCORPORATED

*Consultants in Environmental & Occupational Health*

Date: June 20, 1991

Client: GEOTRANS INC.

Subject: TEM Analysis Report # 91-06-138
Azimuth Project # 91-8016

The attached TEM asbestos analysis data includes a detailed report of the asbestos fiber content for each sample analyzed. The results for all samples analyzed are summarized on a separate form. At least one Elemental Analysis Spectrum representative of each fiber type encountered in the analysis is included with this report. Film negatives of any Electron Diffraction patterns are recorded and kept on file in the laboratory.

The samples were prepared and analyzed using procedures in compliance with the Asbestos Hazard Emergency Response Act (AHERA) as per the Environmental Protection Agency Federal Register, 40 CFR Part 763, Final Rule Notice. The sample fiber analysis was performed with an Hitachi H-7000 Scanning/Transmission Electron Microscope equipped with a KEVEX Energy Dispersive X-ray Microanalyzer.

Azimuth, Inc. is accredited for Airborne Asbestos Fiber Analysis by the National Institute of Standards and Technology under the National Voluntary Laboratory Accreditation Program (NVLAP Lab Code 1050). This report relates only to the items tested and must not be used to claim product endorsement by NVLAP or any agency of the U.S. Government.

Should you have any questions regarding this report, please contact me at (803) 792-2704.

Sincerely,

Bradley A. Schulte /lhh

Bradley A. Schulte, Ph.D.
Director
Electron Microscopy Services

BAS/lhh

9229 University Blvd.
Charleston, SC 29418
(803) 553-9456

TEM ASBESTOS ANALYSIS REPORT

TEM Report #91-06-138

| | |
|---|---|
| Client: GEOTRANS INC.<br>Project:<br>Client Sample #: 01<br>EM lab sample #: 01A<br>Sample type: Air<br>Sample volume: 1140 Liters | Date received: 06-18-91<br>Date analyzed: 06-18-91<br>Filter type: MCE<br>Filter deposit area: 385 mm$^2$<br>Preparer: [signature]<br>Analyst: William B. Greene |

Average grid opening area: 0.0104 mm$^2$
# of grid openings analyzed: 7
Area of filter analyzed: 0.0728 mm$^2$

Detection Sensitivity: < 0.0046 s/cc

Total Nonasbestos Structures Detected: 0
Total Asbestos Structures Detected: 0

Chrysotile: 0
Anthophyllite: 0
Amosite: 0
Crocidolite: 0
Actinolite: 0
Tremolite: 0

| Break-down of Asbestos Structures | # of Structures | | Structures per cc | |
|---|---|---|---|---|
| | < 5µm | ≥ 5µm | < 5µm | ≥ 5µm |
| Total Chrysotile fibers | 0 | 0 | 0.000 | 0.000 |
| bundles | 0 | 0 | 0.000 | 0.000 |
| clusters | 0 | 0 | 0.000 | 0.000 |
| matrices | 0 | 0 | 0.000 | 0.000 |
| Total Amphibole fibers | 0 | 0 | 0.000 | 0.000 |
| bundles | 0 | 0 | 0.000 | 0.000 |
| clusters | 0 | 0 | 0.000 | 0.000 |
| matrices | 0 | 0 | 0.000 | 0.000 |

General Comments: Only fibers ≥ 0.5µm in length were counted in accordance with current EPA protocol.

TOTAL NUMBER OF ASBESTOS STRUCTURES: < 13.7 s/mm$^2$ < 0.0046 s/cc

TEM ASBESTOS ANALYSIS REPORT

TEM Report #91-06-138

Client: GEOTRANS INC.
Project:
Client Sample #: 03
EM lab sample #: 03A
Sample type: Air
Sample volume: 1140 Liters

Date received: 06-18-91
Date analyzed: 06-18-91
Filter type: MCE
Filter deposit area: 385 mm$^2$
Preparer: Anne D Greene
Analyst: William B Greene

Average grid opening area: 0.0104 mm$^2$
# of grid openings analyzed: 7
Area of filter analyzed: 0.0728 mm$^2$

Detection Sensitivity: < 0.0046 s/cc

Total Nonasbestos Structures Detected: 0
Total Asbestos Structures Detected: 0

Chrysotile: 0
Anthophyllite: 0
Amosite: 0
Crocidolite: 0
Actinolite: 0
Tremolite: 0

| Break-down of Asbestos Structures | # of Structures | | Structures per cc | |
|---|---|---|---|---|
| | < 5µm | ≥ 5µm | < 5µm | ≥ 5µm |
| Total Chrysotile fibers | 0 | 0 | 0.000 | 0.000 |
| bundles | 0 | 0 | 0.000 | 0.000 |
| clusters | 0 | 0 | 0.000 | 0.000 |
| matrices | 0 | 0 | 0.000 | 0.000 |
| Total Amphibole fibers | 0 | 0 | 0.000 | 0.000 |
| bundles | 0 | 0 | 0.000 | 0.000 |
| clusters | 0 | 0 | 0.000 | 0.000 |
| matrices | 0 | 0 | 0.000 | 0.000 |

General Comments: Only fibers ≥ 0.5µm in length were counted in accordance with current EPA protocol.

TOTAL NUMBER OF ASBESTOS STRUCTURES: < 13.7 s/mm$^2$ < 0.0046 s/cc

Date: 06-20-91

TEM ASBESTOS ANALYSIS LABORATORY
SUMMARY REPORT # 91-06-138
AZIMUTH PROJECT # 91-8016

CLIENT: GEOTRANS INC.

PROJECT:

| Client Sample # | TEM Lab # | Liters Filtered | Filter Concentration (asbestos s/mm$^2$) | Air Concentration (asbestos s/cc) |
|---|---|---|---|---|
| 01 | 01A | 1140 | < 13.7 | < 0.0046 |
| 02 | 02A | 1140 | < 13.7 | < 0.0046 |
| 03 | 03A | 1140 | < 13.7 | < 0.0046 |

APPENDIX F - NORMANDEAU, INC. RBP III REPORT 6/91

Rapid Bioassessment Protocal III
(RBP III) of Langston Creek and
the Reedy River, Greenville County,
South Carolina

Prepared for Geotrans, Inc.

by

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Normandeau Associates, Inc.
P.O. Box 1393
Aiken, SC 29802

June 1991

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## 1.0 INTRODUCTION

Normandeau Associates, Inc. (NAI) was contracted by Geotrans through J. L. Rogers and Callcott Engineers, Inc. to evaluate the macroinvertebrate community from three sites on the Reedy River and three sites on Langston Creek in Greenville, South Carolina. Procedures developed by the US EPA (EPA 1989) were used to perform this study. Known as the Rapid Bioassessment Protocol III (RBI III), these procedures are designed to provide a quick, cost-effective biological assessment of rivers and streams. The method evaluates physical factors influencing the structure of the macroinvertebrate community and ranks the pollution tolerance of important members of the community. The overall biotic "health" of a reach of river is determined on a weight of evidence basis; all factors are summarized to calculate a final rank that determines the degree to which a site is impacted if impact has occurred.

## 2.0 SITE DESCRIPTION

Three sites physically similar in habitat on the Reedy River and three physically similar sites on Langston Creek were pre-selected by J.L. Rogers and Callcott Engineers, Inc. personnel (Figure 2-1). Both study areas on the Reedy River and on Langston Creek in the study area can be characterized as generally shallow (0.5-1.5 m), slow moving, sandy bottom streams. Few riffle areas were noted in the vicinity of the areas studied on either stream.

The upstream control site on the Reedy River was located at the gauging station near the Highway 253 bridge. This site was accessed by walking approximately 850 m upstream along the railroad tracks from the Highway 253 bridge and taking a path marked by Rogers and Callcott personnel with blue flagging tape to the river. The midstream Reedy River site was located at the pumphouse approximately 200 m upstream from the Highway 253 bridge. The downstream site was located in the vicinity of the Highway 253 bridge (Figure 2-1). The upstream Langston Creek site was located at the Old Buncombe Road bridge. The midstream site was located immediately below the dam on US Finishing Company property, behind the facility. The downstream Langston Creek site was located at the Brooks Avenue bridge.

The water level at all sites on the Reedy River was above normal pool. The water level at all Langston Creek sites, except Langston Midstream, was above normal. Flood stage conditions were present in both waterbodies the week prior to sampling.

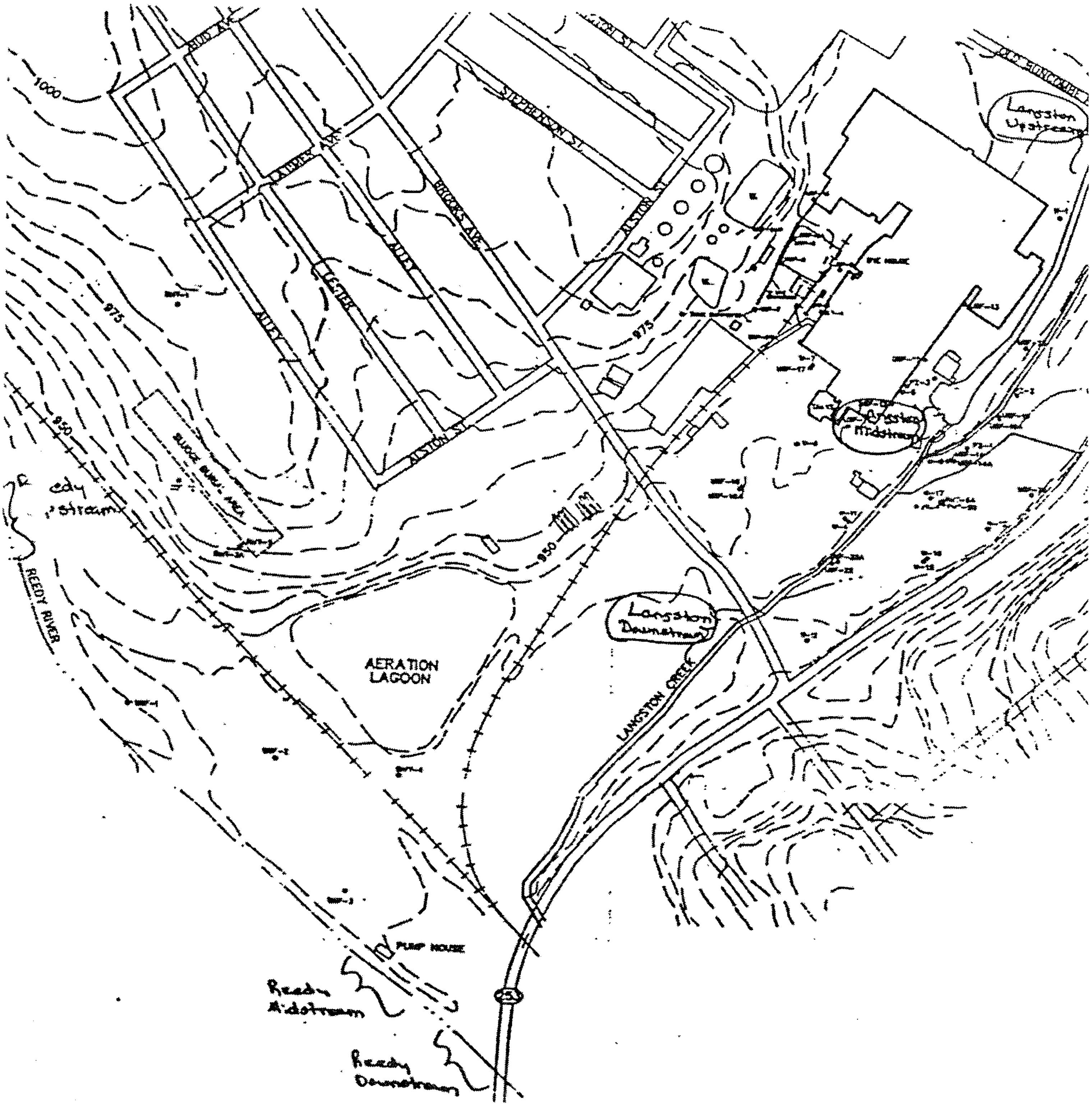


Figure 2-1. Map of area around U.S. Finishing Co. indicating macroinvertebrate bioassessment sampling sites. May 2, 1991.

# 3.0 METHODS AND MATERIALS

## 3.1 FIELD PROCEDURES

Each site was defined by a transect that ran perpendicular to the flow of each waterbody. Comparable areas (e.g., 50-60 m upstream from the transect) at all three sites on each waterbody were sampled on May 2, 1991, for 30 man-minutes with a dipnet sampler. The frame of the sampler was placed securely against the substrate with the opening facing upstream. The substrate directly in front of the sampler's opening was disturbed so that macroinvertebrates dislodged from the substrate would drift into the collecting net. Other submerged structures such as boulders, logs and tree trunks, undercut banks, and root masses were also sampled. The samples were rinsed into labeled 1-liter plastic jars, preserved in buffered formalin, and returned to the laboratory for processing and identification.

In addition to the dipnet sample, a coarse particulate organic matter (CPOM) sample was collected at each site. The CPOM sample represents a food source for shredders, an important macroinvertebrate functional feeding group. This sample provides data on the relative abundance of this functional group. The CPOM sample consisted of collecting several handfuls of organic material (leaves, needles, twigs, leaf packs, debris accumulations, etc.) and washing over a sieve (US Standard No. 30). These samples were rinsed into labeled 1-liter plastic jars, preserved with buffered formalin, and returned to the laboratory for processing and separation. The CPOM samples were processed and analyzed separately from the dipnet samples. A habitat assessment was also performed to evaluate habitat quality on the basis of key parameters (e.g., sediment type, stream velocity, etc.) of the waterbody and surrounding land. Water quality parameters were also recorded at each station.

## 3.2 LABORATORY PROCEDURES

All samples were rinsed over a US Standard No. 30 (0.6mm mesh) sieve. Organisms were sorted from the debris with the aid of a dissecting microscope and placed in vials containing 70% ethanol. Macroinvertebrates collected from the dipnet samples were identified to the lowest practical taxon, enumerated, and assigned to the appropriate functional feeding group according to classifications by Merritt and Cummins (1984; Table 3-1).

Macroinvertebrates from the CPOM samples were counted to obtain a ratio of shredders, a functional feeding group, to the total number of organisms in the sample.

## 3.3 DATA ANALYSIS

Eight different metrics (described for the RBP III in US EPA 444/4-89-001) were used to evaluate the macroinvertebrate data. The RBP III is based on comparing study sites to a reference site, therefore each metric is given a score based on percent comparability to the reference station metric score. Scores from individual metrics for each station are totalled and a biological "Condition Category" is assigned based on the % comparability to the upstream reference station score in each waterbody (Figure 3-1). Each metric is described as follows:

### 3.3.1 Metric 1: Species Richness

Species richness is the total number of unique macroinvertebrate taxa collected at each site. This index reflects the health of the community through a measurement of the variety of taxa. Species richness generally increases with increasing water quality and habitat diversity and/or suitability.

Table 3-1. Macroinvertebrate functional groups and their modes of feeding (Merritt and Cummins 1984).

| Functional Group | Feeding Mode |
|---|---|
| Scrapers | Shear off attached aufwuchs film (periphyton, fungi, bacteria, protoza, etc.) from underwater substrates. |
| Collector-gatherers | "Vacuum" sedimented organic deposits from the substrates. |
| Collector-filterers | Filter suspended particulate organic matter from the water column. |
| Shredders | Skeletonize whole leaves and leaf fragments or mine or bore into wood. |
| Piercer-herbivores | Pierce plant tissues or cells and suck fluids. |
| Piercer-carnivores | Attack animal prey and pierce tissues and cells and suck fluids. |
| Engulfer-predators | Capture and ingest animals. |

Site-Specific Study

Sampling & Analysis

| Metric | Biological Condition Scoring Criteria: 6 | 4 | 2 | 0 |
|---|---|---|---|---|
| 1. Taxa Richness[a] | >80% | 60–80% | 40–60% | <40% |
| 2. Hilsenhoff Biotic Index (modified)[b] | >85% | 70–85% | 50–70% | <50% |
| 3. Ratio of Scrapers/Filt. Collectors[a,c] | >50% | 35–50% | 20–35% | <20% |
| 4. Ratio of EPT and Chironomid Abundances[a] | >75% | 50–75% | 25–50% | <25% |
| 5. % Contribution of Dominant Taxon[d] | <20% | 20–30% | 30–40% | >40% |
| 6. EPT Index[a] | >90% | 80–90% | 70–80% | <70% |
| 7. Community Loss Index[e] | <0.5 | 0.5–1.5 | 1.5–4.0 | >4.0 |
| 8. Ratio of Shredders/Total[a,c] | >50% | 35–50% | 20–35% | <20% |

(a) Score is a ratio of study site to reference site × 100.
(b) Score is a ratio of reference site to study site × 100.
(c) Determination of Functional Feeding Group is independent of taxonomic grouping.
(d) Scoring criteria evaluate actual percent contribution, not percent comparability to the reference station.
(e) Range of values obtained. A comparison to the reference station is incorporated in these indices.

BIOASSESSMENT

| % Comp. to Ref. Score[a] | Biological Condition Category | Attributes |
|---|---|---|
| >83% | Nonimpaired | Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality. |
| 54–79% | Slightly impaired | Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases. |
| 21–50% | Moderately impaired | Fewer species due to loss of most intolerant forms. Reduction in EPT index. |
| <17% | Severely impaired. | Few species present. If high densities of organisms, then dominated by one or two taxa. |

(a) Percentage values obtained that are intermediate to the above ranges will require subjective judgement as to the correct placement. Use of the habitat assessment and physiochemical data may be necessary to aid in the decision process.

Recommendations

Figure 3-1. Flowchart of bioassessment approach advocated for Rapid Bioassessment Protocol III.

### 3.3.2 Metric 2: Biotic Index

This index evaluates the macroinvertebrate community based on the finding that certain taxa of aquatic organisms are more tolerant to pollution than others. This index was developed as a means of detecting organic pollution, use of this index in selecting non-organic pollution effects has not been thoroughly evaluated. Tolerance values range from 0 to 5, increasing as water quality decreases. The index used here was originally developed by Hilsenhoff (1987), and later modified by the North Carolina Division of Environmental Management, for use in streams of North and South Carolina to summarize overall pollution tolerance of the benthic macroinvertebrate community with a single value. The formula for calculating the Biotic Index (BI) is:

$$BI = \frac{\Sigma x_1 t_1}{n}$$

where

$x_1$=number of individuals within each species or genus.

$t_1$=tolerance value of a species or genus

n =total number of organisms in the sample

| BI | Water Quality | State of the stream |
|---|---|---|
| <1.75 | Excellent | Clean undisturbed |
| 1.75 - 2.25 | Good | Some enrichment or disturbance |
| 2.25 - 3.0 | Fair | Moderate enrichment or disturbance |
| 3.00 - 3.75 | Poor | Significant enrichment or disturbance |
| >3.75 | Very Poor | Gross enrichment or disturbance |

### 3.3.3 Metric 3: Ratio of Scrapers and Collector-Filterers Functional Feeding Groups

This index is important because predominance of a particular functional feeding type may indicate an unbalanced community responding to an overabundance of a particular food source (EPA 1989). See Table 3-1 for a summary of functional feeding group descriptions.

### 3.3.4 Metric 4: Ratio of EPT and Chironomidae Abundances

The ratio of the abundance of members of the insect orders EPT (Ephemeroptera, Plecoptera, Trichoptera) to members of the insect family Chironomidae serves as a measure of community balance. As indicated in the BI (Appendix Table 1), the Chironomidae are generally more tolerant of pollution than the insect orders grouped together as EPT. Certain species of some genera, such as Cricotopus, are highly pollution tolerant (Lenat 1983, Mount et al. 1984). Chironomids tend to become increasingly dominant in terms of percent composition along a gradient of increasing enrichment or heavy metals concentration (Ferrington 1987). A dominance of the more tolerant Chironomidae reduces the value of this index indicating pollution.

### 3.3.5 Metric 5: Percent Contribution of Dominant Taxon

When conditions of environmental stress are present, a benthic community is usually dominated by relatively few species. This index determines the percentage of the total number of organisms in the sample comprised by the most dominant taxon of that sample.

### 3.3.6 Metric 6: EPT Index

The EPT Index is derived by counting the total number of distinct macroinvertebrate taxa representing the orders Ephemeroptera, Plecoptera, and Trichoptera collected at each site. Due to the pollution tolerant characteristics of these genera, the numeric value of this index generally increases with increasing water quality.

### 3.3.7 Metric 7: Community Loss Index

This index measures the loss of benthic species between a control site and the downstream site of comparison. The value of this index increases as the degree of dissimilarity in the community composition of the reference and downstream site increases. Index values range from 0 to infinity.

### 3.3.8 Metric 8: Ratio of Shredders/Total Number of Organisms

This index is derived from the CPOM sample. The shredders functional feeding group feed upon coarse particulate organic matter (CPOM). Abundance of this functional group in relation to all other functional feeding groups allows evaluation of potential impairment. Shredders are sensitive to riparian zone (vegetation along the bank) impacts and are good indicators of toxic effects when the toxicants involved are readily absorbed to the CPOM and either affect the microbial communities colonizing the CPOM or the shredders directly (Cummins 1987).

## 4.0 RESULTS AND DISCUSSION

A total of 59 unique macroinvertebrate taxa were collected from the Reedy River and 67 unique macroinvertebrate taxa were collected from Langston Creek. A list of taxa collected at each site is presented in Table 4-1. Water quality and habitat characterization data are presented in Table 4-2.

The values assigned to each of the eight RBP III metrics at each study location are presented in Table 4-3.

### 4.1 REEDY RIVER

The highest number of unique taxa (43) were found at the upstream control site, as compared to 30 unique macroinvertebrate taxa at both the midstream and downstream sites. The Biotic Index was lowest (0.59) at the upstream control site. The midstream site exhibited the highest BI value (1.30). The downstream site BI value was slightly lower (1.22) than the midstream site. These BI values are indicative of excellent water quality at all three sites on the Reedy River. However, the absence of assigned tolerance values, due to the inability to identify particularly abundant organisms to species or genus level (eg., Oligochaeta, Baetidae, Pelecypoda, Sphaeriidae), makes this index very misleading. If these numerically predominant organisms had been assigned tolerance values, the BI would increase significantly indicating possible disturbance.

The ratio of EPT organisms to Chironomids increased downstream from the upstream reference site, as did the ratio of shredders to total organisms (Table 4-4). A large number (208) of pollution tolerant Oligochaeta were collected at

Table 4-1. Macroinvertebrates collected from the Reedy River and Langston Creek. May 2, 1991.

| Taxon | Functional group | Reedy River Upstream | Reedy River Midstream | Reedy river Downstream | Langston Cr. Upstream | Langston Cr. Mistream | Langston Cr. Downstream |
|---|---|---|---|---|---|---|---|
| | | number of organisms found | | | | | |
| Class Turbellaria | 4 | | | | | | 1 |
| Phylum Nematoda | 1 | 2 | | | 3 | 2 | 1 |
| Class Hirudinea | 4 | | | | | | 1 |
| Class Oligochaeta | 1 | 208 | 14 | 1 | 114 | 106 | 156 |
| Family Enchytraeidae | 1 | | | | 3 | | 2 |
| Family Naididae | 1 | | | | | | |
| Chaetogaster langi | 4 | | | | | 1 | |
| Dero digitata | 1 | | | | 1 | | |
| Nais communis | 1 | | | 1 | | 8 | |
| Pristina sp. | 1 | | | | 2 | 2 | 1 |
| Pristina plumaseta | 1 | 2 | 5 | | | | |
| Slavina appendiculata | 1 | | | | 2 | | |
| Vejdovskyella comata | 1 | | | | | 1 | |
| Family Tubificidae | 1 | | | | | | 1 |
| Limnodrilus hoffmeisteri | 1 | 11 | 2 | 2 | 9 | 11 | 23 |
| Peloscolex sp. | 1 | | | | 1 | | |
| Order Gastropoda | 3 | | | | 6 | 3 | 1 |
| Family Ancylidae | 3 | | | | 4 | | |
| Physella heterostropha | 3 | | 1 | 4 | 4 | 5 | 12 |
| Menetus dilatatus | 3 | | | | 1 | | |
| Order Pelecypoda | 2 | 75 | 3 | 3 | 27 | 4 | 5 |
| Family Sphaeriidae | 2 | 26 | | 5 | 31 | 1 | 4 |
| Order Hydracarina | 7 | 1 | | | | | 2 |
| Order Isopoda | 1 | | | | | | |
| Asellus | 1 | | | | | 3 | 3 |
| Procambarus | 6 | | | 1 | | | |
| Order Collembola | 1 | | | | | 1 | |
| Order Ephemeroptera | 1 | | | | | | |
| Family Baetidae | 1 | 46 | 20 | 30 | 9 | 16 | 110 |
| Beatis sp. | 1 | 1 | 2 | 1 | | | 1 |
| Caenis sp. | 1 | 2 | 2 | | | 1 | 1 |
| Family Ephemerellidae | 1 | 2 | | 1 | | | |
| Ephemerella sp. | 1 | 1 | 1 | | | | |
| Eurylophella sp. | 1 | | | | 1 | 1 | |
| Eurylophella temporalis | 1 | | | 2 | | | |
| Family Heptageniidae | 1 | | | 2 | 1 | | |
| Stenonema sp. | 1 | | 1 | | | | 1 |
| Family Oligoneuridae | 2 | | 1 | | | | |
| Isonychia sp. | 2 | | 1 | | | | |
| Suborder Anisoptera | 4 | 8 | | 3 | | 1 | 3 |
| Family Aeshnidae | 4 | | | | | 1 | 1 |
| Boyeria grafiana | 4 | | 5 | 4 | | | 1 |
| Family Macromiidae | 4 | 1 | | | | | |
| Family Gomphidae | 4 | 2 | 2 | | | | 1 |
| Gomphus sp. | 4 | 1 | | | | | |
| Suborder Zygoptera | 4 | | | | | | |
| Calopteryx sp. | 4 | | 1 | | | 1 | 2 |
| Calopteryx maculata | 4 | 1 | | 1 | | | |
| Family Coenagrionidae | 4 | | | | | | 2 |
| Argia sp. | 4 | | | 1 | | | 1 |
| Order Plecoptera | 4 | | 2 | | | | |
| Allonarcys sp. | 6 | | 1 | | | | |
| Amphinemeura sp. | 6 | 2 | 1 | 2 | 1 | | |
| Family Perlidae | 4 | 1 | 2 | 1 | 1 | | |
| Perlesta sp. | 4 | 4 | 4 | | | 1 | |
| Perlesta placida | 4 | 18 | 12 | 11 | | 2 | 5 |
| Isoperla sp. | 4 | | 1 | | | | |
| Order Hemiptera | 7 | | | | | | |
| Family Gerridae | 7 | | | | | 3 | 2 |
| Order Coleoptera | 4 | | | | | | |
| Family Curculionidae | 6 | | 1 | | 1 | | |
| Family Dytiscidae | 1 | 1 | 0 | | 0 | 1 | 1 |

Table 4-1. (continued). Macroinvertebrates collected from the Reedy River and Langston Creek. May 2, 1991.

| Taxon | | Functional group number of organisms found | | | | | |
|---|---|---|---|---|---|---|---|
| | | Reedy River Upstream | Reedy River Midstream | Reedy river Downstream | Langston Cr. Upstream | Langston Cr. Mistream | Langston Cr. Downstream |
| Family Elmidae | 1 | 1 | | 2 | 1 | 2 | 2 |
| Ancyronyx variegatus | 1 | 2 | 5 | 3 | 6 | 5 | 13 |
| Macronychus glabratus | 1 | 4 | 3 | 2 | 4 | 1 | 6 |
| Microcylloepus pusillus | 1 | 2 | | | 2 | 5 | 4 |
| Oulimnius latiusculus | 1 | | | | | | 1 |
| Stenelmis sp. | 3 | | | | | 1 | |
| Family Gyrinidae | 4 | | | | | | |
| Dineutus sp. | 4 | 1 | | | 1 | 1 | 2 |
| Gyrinus sp. | 4 | | | 1 | 8 | | 11 |
| Peltodytes sp. | 6 | | 1 | | | | |
| Family Hydrophilidae | 4 | | 1 | 2 | 1 | 2 | |
| Tropisternus sp. | 4 | | | 5 | 1 | 3 | |
| Hydroporus sp. | 4 | | | | | 2 | |
| Order Trichoptera | 1 | | | | | | |
| Family Hydropsychidae | 2 | | 1 | | | | |
| Symphitopsyche alhedra | 2 | 3 | | | | | |
| Hydropsyche sp. | 2 | 1 | | | | | |
| Family Leptoceridae | 1 | | | | | | 1 |
| Nectopsyche sp. | 6 | | | | | | 1 |
| Oecetis sp. | 4 | 2 | | | | | |
| Triaenodes sp. | 6 | | | 1 | 1 | 2 | |
| Pycnospyche divergens | 6 | | | 1 | | | |
| Order Diptera | 1 | | | | | | |
| Palpomyia sp. | 4 | 8 | 3 | 1 | 3 | 5 | 10 |
| Family Culicidae | 2 | | | | | | |
| Aedes sp. | 2 | | | | 3 | | |
| Dixa sp. | 1 | | | | 1 | | 1 |
| Family Empididae | 4 | | | | | 1 | |
| Hemerodromia sp. | 4 | | | 2 | | 0 | |
| Simulium sp. | 2 | 8 | 7 | 2 | 23 | 51 | 34 |
| Family Tipulidae | 6 | 2 | | | 1 | | 1 |
| Tipula sp. | 6 | 2 | | | | 1 | 2 |
| Pilaria sp. | 6 | | | | | | 2 |
| Family Chironomidae | 0 | 3 | | 2 | 8 | 7 | 13 |
| Subfamily Tanipodinae | 4 | 3 | | 1 | | 1 | 2 |
| Ablebesmyia sp. | 4 | 3 | 1 | | | 1 | 15 |
| Clinotanypus sp. | 4 | 1 | | | 1 | | |
| Conchapelopia grp. | 4 | 2 | | | 3 | 1 | 4 |
| Procladius sp. | 4 | 3 | | 1 | | | 1 |
| Subfamily Orthocladiinae | 1 | | | | 8 | | 3 |
| Brillia sp. | 1 | 6 | 6 | 3 | 5 | 5 | 8 |
| Corynoneura sp. | 1 | 4 | | | 2 | | 2 |
| Cricotopus sp. | 6 | 2 | | | | 1 | 7 |
| Eukiefferiella sp. | 1 | 5 | | 3 | 5 | 2 | |
| Parametriocnemus sp. | 1 | 3 | 2 | 1 | 12 | 8 | 5 |
| Symposiocladius sp. | 6 | 1 | | | 2 | 1 | 3 |
| Thienemanniella sp. | 1 | 1 | | 1 | | | 1 |
| Tvetenia sp. | 1 | 5 | | | | | |
| Tribe Chironomini | 1 | 3 | 4 | | 4 | 3 | |
| Chironomus sp. | 1 | 5 | | 1 | 1 | | |
| Cryptochironomus sp. | 4 | 1 | | | | | 4 |
| Phaenopsectra sp. | 3 | | 3 | | 1 | 1 | 2 |
| Polypedilum sp. | 6 | 12 | 4 | 3 | 70 | 72 | 27 |
| Robackia sp. | 1 | 1 | | | | | |
| Tribe Tanytarsini | 2 | | | | | | |
| Rheotanytarsus sp. | 2 | 6 | | | 2 | 3 | 15 |
| Tanytarsus sp. | 2 | 2 | 1 | 0 | 2 | 3 | 2 |
| Subfamily Diamesiinae | 1 | 3 | | | | | 2 |
| Potthastia sp. | 1 | 1 | | | 2 | 1 | |

Table 4-2. Summary physical characteristics and water quality parameters recorded at sampling sites on the Reedy River and Langston Creek, May 2, 1991.

| | Reedy River Upstream | Reedy River Midstream | Reedy River Downstream | Langston Creek Upstream | Langston Creek Midstream | Langston Creek Downstream |
|---|---|---|---|---|---|---|
| Predominant Surrounding Land Use | forest | forest | under highway 253 bridge | industrial | industrial | commercial/ industrial |
| Local Watershed Erosion | none | none | none | none | none | none |
| Local Watershed NPS Pollution | no evidence | no evidence | some potential sources | some potential sources | obvious sources | some potential sources |
| Estimated Stream Width | 11 | 10 | 6 | 4 | 3 | 4 |
| Estimated Stream Depth | | | | | | |
| Riffle (ft.) | no riffles | no riffles | no riffles | no riffles | 0.5 | 0.5 |
| Run (m) | 0.3 | 0.6 | 0.4 | 1.5 | 0.3 | 0.25 |
| Pool (m) | 0.5 | no pools | no pools | no pools | 0.25 | 0.25 |
| Current Velocity (m/sec) | 0.53 | 0.54 | 0.5 | 0.13 | 0.32 | 0.32 |
| Dam Present | no | no | no | yes | yes | yes |
| Channelized | yes | no | yes | no | yes | no |
| Canopy Cover | partially shaded | partially shaded | partially shaded | shaded | partially shaded | partly open |
| Sediment odors | normal | normal | normal | normal | chemical | normal |
| Sediment Oils | absent | absent | absent | absent | absent | absent |
| Substrate Type and % Composition | sand-99% silt-1% | sand-98% silt-2% | boulder-1% sand-98% silt-1% | sand-95% silt-5% | cobble-5% gravel-5% sand-90% | Sand-98% silt-2% |
| Water Odors | normal | normal | normal | normal | chemical | normal |
| Water Surface Oils | none | none | none | none | none | none |
| Turbidity | turbid | turbid | turbid | turbid | turbid | turbid |
| Temperature (C) | 15.9 | 16.5 | 16.7 | 18.3 | 18.1 | 17.5 |
| Dissolved Oxygen (mg/l) | 6.82 | 7.6 | 7.6 | 7.9 | 8.6 | 8.7 |
| pH | 6.38 | 6.54 | 6.47 | 6.33 | 6.53 | 6.59 |
| Conductivity | 43 | 47 | 46 | 42 | 45 | 49 |

Table 4-3. Score sheet comparing biological index scores at midstream and downstream sites to upstream control sites on the Reedy River and Langston Creek. May 2, 1991

| Score(a) Metric | Reedy River Upstream | Reedy River Midstream | Reedy River Downstream | Langston Creek Upstream | Langston Creek Midstream | Langston Creek Downstream |
|---|---|---|---|---|---|---|
| Taxa Richness | 6 | 4 | 4 | 6 | 6 | 6 |
| Biotic Index | 6 | 0 | 0 | 6 | 4 | 2 |
| Ratio of Scrapers to Filterer-Collectors | 0 | 0 | 0 | 6 | 6 | 6 |
| Ratio of EPT and Chironomidae Abundances | 6 | 6 | 6 | 6 | 6 | 6 |
| % Contribution of Dominant Taxon | 2 | 6 | 4 | 4 | 4 | 4 |
| EPT Index | 6 | 6 | 4 | 6 | 4 | 4 |
| Community Loss Index | 6 | 4 | 4 | 6 | 6 | 6 |
| Ratio Shredders/Total | 6 | 4 | 6 | 6 | 6 | 6 |
| Total of Scores | 38 | 30 | 28 | 46 | 42 | 40 |
| %Comparability to Reference Score | | 79 | 74 | | 91 | 87 |
| Biological Condition Category | | Slightly impaired | Slightly impaired | | Non-impaired | Non-impaired |

(a)based on US EPA guidelines set forth in Figure 3-1.

the reference site as compared to the midstream (14) and downstream (1) sites (Table 4-1). This resulted in a high percent contribution of dominant taxon (Table 4-4) at the upstream reference site, therefore skewing the final metric score (Table 4-3). Baetids were the dominant organism collected at both the midstream and downstream sites. The predominantly sand/silt substrate present at all sites is a good habitat for Oligochaeta and Chironomid organisms. The type of habitat, (no riffle areas and a predominantly sand/silt substrate) and the conditions at the time of sampling (high water levels due to recent heavy rains) contribute to a situation that would not normally support a very diverse benthic macroinvertebrate community even under pristine water quality conditons.

The overall biological condition category, based on % comparability to the reference site score, indicates slight impairment (79% comparability) at Reedy River midstream site and slight impairment (74% comparability) at the downstream site (Table 4-3). These results could be misleading because without proper reference conditions biosurveys tend to underestimate impairment (EPA 1991).

## 4.2 LANGSTON CREEK

The highest taxa richness was observed at the downstream site with 47 unique macroinvertebrate taxa collected. At the upstream control site, 41 unique macroinvertebrate taxa were collected; 42 unique taxa were found at the midstream site (Table 4-4).

The Biotic Index was lowest (0.68) at the upstream site and highest (0.92) at the downstream site (Table 4-4). The calculated BI is indicative of excellent water quality at all sites. Again, these values are misleading because the dominant organisms Oligochaeta (generally pollution tolerant) could not be

Table 4-4. Biological water quality indices for macroinvertebrates collected from the Reedy River and Langston Creek. May 2, 1991.

| | Reedy River Upstream | Reedy River Midstream | Reedy River Downstream | Langston Creek Upstream | Langston Creek Midstream | Langston Creek Downstream |
|---|---|---|---|---|---|---|
| METRIC | | | | | | |
| Total # in sample | 528 | 127 | 114 | 406 | 368 | 552 |
| Taxa richness | 43 | 30 | 30 | 41 | 42 | 47 |
| Biotic Index | 0.59 | 1.30 | 1.22 | 0.68 | 0.92 | 0.99 |
| Ratio Scrapers /Filterers | 0/21=0.00 | 4/14=0.29 | 4/10=0.4 | 16/88=0.18 | 10/62=0.16 | 15/60=0.25 |
| Ratio of EPT and Chironomid Abundances | 83/76=1.09 | 52/21=2.48 | 52/16=3.25 | 14/128=.11 | 23/110=.21 | 120/116=1.03 |
| % Contribution of Dominant Taxon | 39% | 16% | 26% | 28% | 29% | 28% |
| EPT Index | 8 | 10 | 7 | 6 | 5 | 5 |
| Community Loss Index | 0 | 0.67 | 0.57 | 0 | 0.21 | 0.24 |
| Ratio Shredders/ Total | 2/49=.04 | 3/60=.05 | 6/108=.56 | 13/64=.20 | 28/124=.23 | 29/112=.26 |
| Numerically Dominant taxon | Oligochaeta | Baetidae | Baitidae | Oligochaeta | Oligochaeta | Oligochaeta |

assigned tolerance values because of the inability, due to specimen condition, to identify them beyond the class level. If these numerically dominant organisms had been assigned tolerance values, the calculated BI would have increased dramatically, indicating possible impairment.

The EPT/Chironomidae abundance ratio increased from the upstream to the downstream site (Table 4-4). All sites on Langston Creek were dominated by pollution tolerant Oligochaeta and the Chironomid, Polypedilum sp. (Table 4-5). The Ephemeropteran, Baetidae (20%), was the second most dominant organism collected at the downstream site (Table 4-5).

The values of the EPT Indexes at all three Langston Creek sites are indicative of poor water quality (note contrast with results for BI). The ratio of shredders/total organisms increased steadily from the upstream site to the downstream site suggesting recovery downstream. As stated earlier, high water conditions, recent flooding, few riffle areas, and a predominantly sand/silt substrate all contribute to a habitat that would not normally support a diverse benthic macroinvertebrate community.

The overall biological condition category, based on % comparability to the reference site score, indicates non-impairment at the Langston Creek midstream site (91% comparability) and non-impairment (87% comparability) at the Langston Creek downstream sites (Table 4-3). Again, these results are misleading because without proper reference conditions biosurveys tend to underestimate impairment.

Table 4-5. Numerically dominant taxon for each sampling site on the Reedy River and Langston Creek. May 2, 1991.

| Sampling Site | % Composition |
|---|---|
| **Reedy River** | |
| Reedy River Upstream | |
| Class Oligochaeta | 39.4% |
| Order Pelecypoda | 14.2% |
| Family Sphaeridae | 5% |
| Reedy River Midstream | |
| Family Baetidae | 15.7% |
| Class Oligochaeta | 11% |
| Reedy River Downstream | |
| Family Baetidae | 26% |
| **Langston Creek** | |
| Langston Creek Upstream | |
| Class Oligochaeta | 28.1% |
| Order Pelecypoda | 7.0% |
| Family Sphaeridae | 8.0% |
| *Simulium* | 6.0% |
| *Polypedilum* sp. | 17% |
| Langston Creek Midstream | |
| Class Oligochaeta | 29% |
| *Simulium* | 14% |
| *Polypedilum* sp. | 20% |
| Langston Creek Downstream | |
| Class Oligochaeta | 28% |
| Family Baetidae | 20% |
| *Simulium* | 6% |
| *Polypedilum* sp. | 5% |

## 5.0 SUMMARY

On May 2, 1991, a study was performed to assess the biological condition of sites on the Reedy River and Langston Creek in Greenville, South Carolina.

Locations upstream and downstream of previously impacted sites (see SCDHEC 1982) on the Reedy River and Langston Creek were chosen by J.L. Rogers and Callcott personnel. Each site was characterized by normally shallow (0.5 m - 1.5 m), slow moving water and a sand/silt substrate. One week prior to the sampling date, a heavy rainfall event occurred and both the Reedy River and Langston Creek water levels were still higher than normal when sampling took place. Water levels at all sites, except Langston Creek Midstream where the water level is controlled by a dam, were above normal pool. The conditions could have altered the composition of the macroinvertebrate community through scouring or drift.

The site specific upstream control sites chosen by J.L. Rogers and Callcott, Inc. were of comparable habitat to the study sites. The rapid bioassessment protocols used in this study are based on comparing umimpaired or least-impacted reference waters that operationally represent best attainable conditions. Without proper reference conditions biosurveys tend to underestimate impairment. The upstream control sites appear to have been impacted by non-point source pollution from the farther upstream urban areas or other sources. The use of these potentially impaired control sites for comparison would skew the scores obtained through the RBP metrics.

The health of the benthic macroinvertebrate community was assessed by computing a value to each of eight RBP III metrics. Although values for individual metrics were suggestive of impaired conditions, final scores based on a compilation of all eight metric values for a given site, when compared to the reference site indicated no impairment or slight impairment at the downstream locations as compared to the reference station in both Langston Creek and Reedy River.

Based on the somewhat conflicting results of the individual metrics and the RBP final scores influenced perhaps by the prior flood event and the high water level conditions at the time of sampling, the results of this report should not be considered conclusive with respect to the current biological water quality of either Langston Creek or the Reedy River.

Sampling conducted under normal water level and flow conditions and the use of an unimpaired reference stream similar in habitat to the study sites would contribute to a study whose results would be more representative of the true conditions of the water bodies under consideration.

## 6.0 LITERATURE CITED


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APPENDIX

Appendix Table 1.

Tolerance values for Hilsenhoff-type biotic index (0-5), for all taxa with n>10. "*" indicates n<25.

| Taxon | Value |
|---|---|
| EPHEMEROPTERA | |
| ACENTRELLA AMPLUS | 1.6 |
| ACERPENNA PYGMAEUS | 1.7 |
| AMELETUS LINEATUS | 1.2 |
| ATTENELLA ATTENUATA | 1.5* |
| BAETIS BRUNNEICOLOR | 2.5* |
| BAETIS EPHIPPIATUS | 2.3 |
| BAETIS FLAVISTRIGA | 3.6 |
| BAETIS FRONDALIS | 2.5 |
| BAETIS HAGENI | 0.6* |
| BAETIS INTERCALARIS | 3.0 |
| BAETIS PLUTO | 2.3 |
| BAETIS PROPINQUUS | 3.0 |
| BAETIS SPP | 3.3* |
| BAETIS TRICAUDATUS | 1.1 |
| BAETISCA BERNERI | 0.7* |
| BAETISCA CAROLINA | 1.4 |
| BAETISCA GIBBERA | 0.1 |
| BRACHYCERCUS SPP | 1.3 |
| CAENIS SPP | 3.7 |
| CALLIBAETIS | 4.8 |
| CENTROPTILUM SPP | 3.1 |
| CINYGMULA SUBAEQUALIS | 0.6 |
| CLOEON SPP | 3.6 |
| DANNELLA SIMPLEX | 2.0 |
| DRUNELLA ALLEGHENIENSIS | 0.9 |
| DRUNELLA CONESTEE | 0.6 |
| DRUNELLA CORNUTELLA | 0.0 |
| DRUNELLA LATA | 0.4 |
| DRUNELLA TUBERCULATA | 0.6 |
| DRUNELLA WALKERI | 0.4 |
| DRUNELLA WAYAH | 0.7 |
| EPEORUS DISPAR | 0.3 |
| EPEORUS PLEURALIS | 0.9 |
| EPEORUS RUBIDUS | 0.4 |
| EPEORUS SPP | 1.0 |
| EPHEMERA BLANDA | 1.3 |
| EPHEMERA GUTTULATA | 0.2* |
| EPHEMERA SPP | 1.4 |
| EPHEMERELLA BERNERI | 0.2* |
| EPHEMERELLA CATAWBA (GROUP) | 1.8 |
| EPHEMERELLA HISPIDA | 0.4 |
| EPHEMERELLA INVARIA (GR) | 1.0 |
| EPHEMERELLA NEEDHAMI | 0.8* |
| EPHEMERELLA ROSSI (GR) | 0.9 |
| EPHEMERELLA ROTUNDA | 1.3 |
| EPHEMERELLA SEPTENTRIONALIS | 0.4 |
| EPHEMERELLA SPP | 1.1 |
| EPHORON LEUKON | 0.6 |
| EURYLOPHELLA SPP | 2.1 |
| EURYLOPHELLA BICOLOR | 2.5 |
| EURYLOPHELLA COXALIS | 1.3 |
| EURYLOPHELLA FUNERALIS | 1.3 |
| EURYLOPHELLA TEMPORALIS | 2.1 |
| EURYLOPHELLA VERISIMILIS | 0.5* |
| HABROPHLEBIA VIBRANS | 0.4 |
| HEPTAGENIA MARGINALIS | 1.5 |
| HEPTAGENIA PULLA | 1.9* |
| HEPTAGENIA SPP | 1.8 |
| HETEROCLOEON | 2.3 |
| HEXAGENIA SPP | 2.4 |
| ISONYCHIA SPP | 2.0 |
| LEPTOPHLEBIA SPP | 3.0 |
| LEUCROCUTA APHRODITE | 1.2 |
| NEOEPHEMERA PURPUREA | 0.9 |
| NEOEPHEMERA YOUNGI | 0.8* |
| PARACLOEODES | 3.7 |
| PARALEPTOPHLEBIA SPP | 1.1 |
| POTAMANTHUS SPP | 0.5 |
| PSEUDOCLOEON SPP | 2.2 |
| RHITHROGENA SPP | 0.2 |
| SERRATELLA CAROLINA | 0.0* |
| SERRATELLA DEFICIENS | 1.4 |
| SERRATELLA SERRATA | 1.9 |
| SERRATELLA SERRATOIDES | 1.0 |
| SIPHLONURUS SPP | 2.3 |
| SIPHLOPLECTON SPP | 1.2 |
| STENACRON CAROLINA | 1.0 |
| STENACRON INTERPUNCTATUM | 3.6 |
| STENACRON PALLIDUM | 1.5 |
| STENONEMA CARLSONI | 1.4 |
| STENONEMA EXIGUUM | 2.7 |
| STENONEMA FEMORATUM | 3.8 |
| STENONEMA INTEGRUM | 2.7 |
| STENONEMA ITHACA | 2.3 |
| STENONEMA MEDIOPUNCTATUM | 2.2* |
| STENONEMA MERIRIVULANUM | 1.1* |
| STENONEMA MODESTUM | 2.9 |
| STENONEMA N SP | 1.1 |
| STENONEMA PUDICUM | 1.3 |
| STENONEMA TERMINATUM | 2.6 |
| STENONEMA VICARIUM | 0.7* |
| TRICORYTHODES SPP | 2.8 |
| PLECOPTERA | |
| ACRONEURIA ABNORMIS | 1.2 |
| ACRONEURIA ARENOSA | 1.0 |
| ACRONEURIA CAROLINENSIS | 0.5 |
| ACRONEURIA LYCORIAS | 0.8 |
| AGNETINA ANNULIPES | 0.8* |
| AGNETINA CAPITATA | 1.7 |
| AGNETINA FLAVESCENS | 0.3* |
| ALLOCAPNIA SPP | 1.4 |
| AMPHINEMURA SPP | 1.7 |
| BELONEURIA SPP | 1.0 |
| CLIOPERLA CLIO | 2.1 |
| CULTUS DECISUS | 0.7 |
| DIPLOPERLA DUPLICATA | 1.2 |
| DIPLOPERLA MORGANI | 1.1* |
| ECCOPTURA XANTHENES | 2.7 |
| HAPLOPERLA BREVIS | 1.0 |
| HELOPICUS BOGALOOSA | 0.3* |
| HELOPICUS SUBVARIANS | 0.3 |
| ISOGENOIDES HANSONI | 0.7* |
| ISOPERLA BILINEATA | 2.7 |
| ISOPERLA DICALA | 0.6 |
| ISOPERLA HOLOCHLORA | 0.5 |
| ISOPERLA NAMATA (GR) | 0.8 |
| ISOPERLA NR HOLOCHLORA | 0.1* |
| ISOPERLA NR SLOSSONAE | 0.7 |
| ISOPERLA ORATA | 0.3 |
| ISOPERLA SIMILIS | 0.8 |
| ISOPERLA SLOSSONAE | 1.1* |
| ISOPERLA SPP | 1.8 |
| ISOPERLA TRANSMARINA (GR) | 2.7 |
| LEUCTRA SPP | 0.9* |
| MALIREKUS HASTATUS | 1.2 |
| NEOPERLA SPP | 0.8 |
| PARACAPNIA ANGULATA | 0.1 |
| PARAGNETINA FUMOSA | 2.1 |
| PARAGNETINA ICHUSA | -0.0 |
| PARAGNETINA IMMARGINATA | 0.9 |
| PARAGNETINA KANSENSIS | 0.8 |
| PELTOPERLA SPP | 2.4 |
| PERLESTA PLACIDA | 2.4 |
| PERLESTA SPP | 0.7 |
| PERLINELLA DRYMO | 0.9 |
| PROSTOIA | 3.3 |
| PTERONARCYS DORSATA | 1.3 |
| PTERONARCYS SPP | 1.1 |
| REMENUS BILOBATUS | 0.0 |
| SHIPSA ROTUNDA | 0.6* |
| STROPHOPTERYX SPP | 1.2 |
| SWELTSA SPP | 0.5 |
| TAENIOPTERYX BURKSI | 2.7 |
| TAENIOPTERYX METEQUI | 1.1* |
| TAENIOPTERYX SPP | 2.6 |
| TALLAPERLA SPP | 0.9 |
| YUGUS ARINUS | 0.6* |
| YUGUS BULBOSUS | 0.8* |
| TRICHOPTERA | |
| AGAPETUS SPP | 0.0 |
| ANISOCENTROPUS PYRALOIDES | 0.6 |
| APATANIA | 0.3 |
| ARCTOPSYCHE IRRORATA | 0.9 |
| BRACHYCENTRUS APPALACHIA | 0.4* |
| BRACHYCENTRUS LATERALIS | 0.5* |
| BRACHYCENTRUS NIGROSOMA | 1.1 |
| BRACHYCENTRUS NUMEROSUS | 1.0 |
| BRACHYCENTRUS SPINAE | 0.2 |
| BRACHYCENTRUS SPP | 1.3 |
| CERACLEA ANCYLUS | 0.8 |
| CERACLEA FLAVA | 0.8* |
| CERACLEA MACULATA | 3.1 |
| CERACLEA MENTIEA | 0.7* |
| CERACLEA RESURGENS | 2.2* |
| CERACLEA SPP | 1.2* |
| CERACLEA TRANSVERSA | 1.1 |
| CHEUMATOPSYCHE SPP | 3.3 |
| CHIMARRA SPP | 1.3 |
| CYRNELLUS FRATERNUS | 3.1 |
| DIPLECTRONA MODESTA | 1.4 |
| DOLOPHILODES SPP | 0.7 |
| FATTIGIA PELE | 1.4 |
| GLOSSOSOMA SPP | 0.8 |
| GOERA SPP | 0.3 |
| HELICOPSYCHE BOREALIS | 0.0 |
| HETEROPLECTRON AMERICANUM | 0.8 |
| HYDATOPHYLAX ARGUS | 0.8 |
| HYDROPSYCHE BETTENI | 4.0 |
| HYDROPSYCHE DECALDA | 2.4 |
| HYDROPSYCHE DEMORA | 0.9 |
| HYDROPSYCHE HAGENI | 0.8* |
| HYDROPSYCHE INCOMMODA | 2.7 |
| HYDROPSYCHE PHALERATA | 2.2 |
| HYDROPSYCHE ROSSI | 2.7 |
| HYDROPSYCHE SCALARIS | 2.0 |
| HYDROPSYCHE VENULARIS | 2.7 |
| HYDROPTILA SPP | 3.2 |
| IRONOQUIA PUNCTATISSIMA | 4.0 |
| LEPIDOSTOMA SPP | 0.7 |
| LEUCOTRICHIA PICTIPES | 2.2 |
| LYPE DIVERSA | 2.1 |
| MACROSTEMUM SPP | 1.9 |
| MICRASEMA BENNETTI | 0.0 |
| MICRASEMA CHARONIS | 0.0 |
| MICRASEMA RICKERI | 0.0 |
| MICRASEMA SPP | 1.0* |
| MICRASEMA WATAGA | 1.9 |
| MOLANNA BLENDA | 0.7* |
| MOLANNA TRYPHENA | 0.6* |
| MYSTACIDES SEPULCHRALIS | 1.3 |
| NECTOPSYCHE CANDIDA | 2.2 |
| NECTOPSYCHE EXQUISITA | 2.4 |
| NECTOPSYCHE [illegible] | 2.2 |
| NEOPHYLAX CONCINNUS | 0.5 |
| NEOPHYLAX MITCHELLI | 0.8 |
| NEOPHYLAX OLIGIUS | 1.4 |
| NEOPHYLAX ORNATUS | 0.8* |
| NEOPHYLAX SPP | 1.0 |
| NEURECLIPSIS SPP | 2.3 |
| NYCTIOPHYLAX CELTA | 0.2* |
| NYCTIOPHYLAX MOESTUS | 1.1 |
| NYCTIOPHYLAX NEPHOPHILUS | 1.2 |
| NYCTIOPHYLAX SPP | 0.3 |
| OCHROTRICHIA SPP | 3.1* |
| OECETIS SPP | 2.8 |
| OECETIS SP1 | 2.2 |
| OECETIS SP2 | 1.8 |
| OLIGOSTOMIS PARDALIS | 2.0* |
| ORTHOTRICHIA SPP | 2.7* |
| PARAPSYCHE CARDIS | 1.0 |
| PHYLOCENTROPUS SPP | 2.3 |
| POLYCENTROPUS SPP | 1.7 |
| PROTOPTILA SPP | 1.7 |
| PSILOTRETA SPP | 0.7 |
| PSYCHOMYIA FLAVIDA | 1.3 |
| PSYCHOMYIA NOMADA | 0.7 |
| PTILOSTOMIS SPP | 3.2 |
| PYCNOPSYCHE GENTILIS | 0.8 |
| PYCNOPSYCHE GUTTIFER | 1.1 |
| PYCNOPSYCHE LEPIDA | 1.1 |
| PYCNOPSYCHE LUCULENTA | 2.3* |
| PYCNOPSYCHE SCABRIPENNIS | 1.6 |
| PYCNOPSYCHE SPP | 1.2 |
| RHYACOPHILA ACUTILOBA | 0.0 |
| RHYACOPHILA ATRATA | 0.7* |
| RHYACOPHILA CAROLINA | 0.6 |
| RHYACOPHILA FUSCULA | 1.2 |
| RHYACOPHILA LEDRA | 1.7* |
| RHYACOPHILA NIGRITA | 0.6 |
| RHYACOPHILA TORVA | 1.3 |
| RHYACOPHILA VUPHIPES | 0.0 |
| SETODES SPP | 0.8* |
| SYMPHITOPSYCHE ALHEDRA | 0.3* |
| SYMPHITOPSYCHE BIFIDA | 1.2* |
| SYMPHITOPSYCHE BRONTA | 1.3 |
| SYMPHITOPSYCHE MACLEODI | 0.8 |
| SYMPHITOPSYCHE MOROSA | 1.9 |
| SYMPHITOPSYCHE SLOSSONAE | 0.0 |
| SYMPHITOPSYCHE SPARNA | 1.9 |
| TRIAENODES ABUS | 2.1 |
| TRIAENODES INJUSTA | 0.7 |
| TRIAENODES SPP | 1.1* |
| TRIAENODES TARDUS | 2.4 |
| WORMALDIA SPP | 1.0* |
| COLEOPTERA | |
| ANCHYTARSUS BICOLOR | 2.8 |
| ANCYRONYX VARIEGATUS | 3.5 |
| BEROSUS SPP | 4.4 |
| COPELATUS SPP | 4.6* |
| COPTOTOMUS SPP | 3.6 |
| DINEUTUS SPP | 2.8 |
| DUBIRAPHIA SPP | 3.0 |
| ECTOPRIA NERVOSA | 1.3 |
| ENOCHRUS SPP | 4.3 |
| FALLOPORUS SPP | 1.5* |
| GYRINUS SPP | 3.3 |
| HALIPLUS SPP | 3.7* |
| HELICHUS SPP | 2.7 |
| HELOPHORUS SPP | 2.4* |
| HYDROCHUS SPP | 2.6* |
| HYDROPORUS SPP | 4.2 |
| HYDROVATUS SPP | 2.3* |
| LACCOBIUS SP | 3.3 |
| LACCOPHILUS SPP | 5.2 |
| MACRONYCHUS GLABRATUS | 2.4 |
| MICROCYLLOEPUS PUSILLUS | 2.1 |
| OPTIOSERVUS OVALIS | 1.4 |
| OPTIOSERVUS SPP | 1.6 |
| OULIMNIUS LATIUSCULUS | 1.0 |
| PELTODYTES SPP | 4.0 |
| PROMORESIA ELEGANS | 1.1 |
| PROMORESIA TARDELLA | 1.0 |
| PSEPHENUS HERRICKI | 1.3 |
| SPERCHOPSIS TESSELLATUS | 3.4 |
| STENELMIS SPP | 2.8 |
| TROPISTERNUS SPP | 4.8 |
| ODONATA | |
| ARGIA SPP | 4.2 |
| BASIAESCHNA JANATA | 3.5 |
| BOYERIA GRAFIANA | 2.9 |
| BOYERIA VINOSA | 3.1 |
| CALOPTERYX SPP | 4.2 |
| CORDULEGASTER SPP | 3.0 |
| DIDYMOPS TRANSVERSA | 2.1* |
| DROMOGOMPHUS | 3.3 |
| ENALLAGMA SPP | 4.3 |
| EPICORDULIA PRINCEPS | 2.0* |
| GOMPHUS SPINICEPS | 2.4 |
| GOMPHUS SPP | 3.0 |
| HAGENIUS BREVISTYLUS | 2.1 |
| HELOCORDULIA SPP | 3.0* |
| HELOCORDULIA UHLERI | 1.9* |
| HETAERINA SPP | 3.3 |
| [illegible] | 2.9* |

Appendix Table 1 (continued).

Tolerance values for Hilsenhoff-type biotic index (0-5), for all taxa with n>10. "*" indicates n<25.

| | |
|---|---|
| ...NTHUS SPP | 2.3 |
| ...NTHUS VERNALIS | 0.9 |
| ...BELLULA SPP | 5.0 |
| MACROMIA GEORGIANA | 3.3* |
| MACROMIA SPP | 3.4 |
| NASIAESCHNA PENTACANTHA | 4.3 |
| NEUROCORDULIA MOLESTA | 2.6* |
| NEUROCORDULIA OBSOLETA | 2.7 |
| NEUROCORDULIA SPP | 3.0 |
| NEUROCORDULIA VIRGINIENSIS | 0.9 |
| OPHIOGOMPHUS SPP | 2.9 |
| PACHYDIPLAX LONGIPENNIS | 4.8 |
| PERITHEMIS SPP | 4.9 |
| PLATHEMIS LYDIA | 5.0 |
| PROGOMPHUS OBSCURUS | 4.5 |
| SOMATOCHLORA SPP | 4.8 |
| STYLOGOMPHUS ALBISTYLUS | 2.5 |
| SYMPETRUM SPP | 3.2* |
| TETRAGONEURIA CYNOSURA | 4.3 |
| TETRAGONEURIA SPP | 4.4 |
| **MEGALOPTERA** | |
| CHAULIODES PECTINICORNIS | 3.4* |
| CORYDALUS CORNUTUS | 3.0 |
| NIGRONIA FASCIATUS | 3.0 |
| NIGRONIA SERRICORNIS | 2.7 |
| SIALIS SPP | 3.6 |
| **DIPTERA: CHIRONOMIDAE** | |
| ABLABESMYIA ANNULATA | 1.7* |
| ABLABESMYIA MALLOCHI | 3.7 |
| ABLABESMYIA PARAJANTA/JANTA | 3.6 |
| ABLABESMYIA PELEENSIS | 2.5* |
| BRILLIA SPP | 2.6 |
| BRUNDINIELLA EDMORPHA | 4.6 |
| CARDIOCLADIUS SPP | 3.3 |
| CHIRONOMUS SPP | 4.8 |
| CLADOTANYTARSUS SPP | 1.8 |
| CLADOTANYTARSUS SP2 | 1.3 |
| CLADOTANYTARSUS SP2A | 0.6* |
| CLADOTANYTARSUS SP5 | 2.4 |
| CLADOTANYTARSUS SP6 | 2.1* |
| CLINOTANYPUS PINGUIS | 4.4 |
| COELOTANYPUS CONCINNUS | 3.1* |
| ...CLOTANYPUS SPP | 3.5* |
| ...CHAPELOPIA GROUP | 4.4 |
| ...RDITES SPP | 2.8* |
| ...RYNONEURA SPP | 3.1 |
| CRICOTOPUS/ORTHOCLADIUS SP1 | 4.3 |
| CRICOTOPUS/ORTHOCLADIUS SP10 | 4.4 |
| CRICOTOPUS/ORTHOCLADIUS SP12 | 3.6 |
| CRICOTOPUS/ORTHOCLADIUS SP13 | 4.2 |
| CRICOTOPUS/ORTHOCLADIUS SP14 | 1.9* |
| CRICOTOPUS/ORTHOCLADIUS SP2 | 1.6* |
| CRICOTOPUS/ORTHOCLADIUS SP20 | 2.7 |
| CRICOTOPUS/ORTHOCLADIUS SP3 | 4.5 |
| CRICOTOPUS/ORTHOCLADIUS SP46 | 2.5 |
| CRICOTOPUS/ORTHOCLADIUS SP47 | 1.8* |
| CRICOTOPUS/ORTHOCLADIUS SP5 | 4.6 |
| CRICOTOPUS/ORTHOCLADIUS SP51 | 1.9* |
| CRICOTOPUS/ORTHOCLADIUS SP54 | 2.9 |
| CRICOTOPUS/ORTHOCLADIUS SP6 | 3.8 |
| CRICOTOPUS/ORTHOCLADIUS SP7 | 3.0 |
| CRICOTOPUS/ORTHOCLADIUS SP9 | 3.6* |
| CRICOTOPUS/ORTHOCLADIUS SP48 | 2.6 |
| CRYPTOCHIRONOMUS BLARINA | 4.0 |
| CRYPTOCHIRONOMUS FULVUS | 3.2 |
| CRYPTOCHIRONOMUS SPP | 4.8 |
| CRYPTOTENDIPES SPP | 3.3 |
| DEMICRYPTOCHIRONOMUS SPP | 1.2 |
| DEMICRYPTOCHIRONOMUS SP1 | 0.7* |
| DEMICRYPTOCHIRONOMUS SP2 | 1.1* |
| DIAMESA SPP | 4.1 |
| DICROTENDIPES MODESTUS | 3.1* |
| DICROTENDIPES NEOMODESTUS | 4.0 |
| DICROTENDIPES NERVOSUS | 5.0 |
| DICROTENDIPES SIMPSONI | 4.7* |
| DICROTENDIPES SPP | 4.6 |
| DIPLOCLADIUS CULTRIGER | 4.6 |
| EINFELDIA SPP | 2.8* |
| ENDOCHIRONOMUS NIGRICANS | 3.9* |
| ENDOCHIRONOMUS SPP | 2.4* |
| EPOICOCLADIUS SPP | 0.8* |
| EUKIEFFERIELLA SP1 | 2.0 |
| EUKIEFFERIELLA SP11 | 3.1 |
| EUKIEFFERIELLA SP12 | 2.5 |
| EUKIEFFERIELLA SP14 | 1.7* |
| EUKIEFFERIELLA SP2 | 2.1 |
| EUKIEFFERIELLA SP3 | 2.3 |
| ...IEFFERIELLA SP6 | 1.3 |
| ...PTOTENDIPES SPP | 4.5 |
| ...LIDICHIRONOMUS HOLOPRASINUS | 3.2 |
| ...ANNISCHIA SPP | 2.9* |
| NELENIELLA SPP | 1.0* |
| HETEROTRISSOCLADIUS SPP | 2.3* |
| HYDROBAENUS SPP | 4.2* |
| KIEFFERULUS DUX | 5.2* |
| LABRUNDINIA PILOSELLA | 2.0 |
| LABRUNDINIA SPP | 3.8 |
| LABRUNDINIA VIRESCENS | 3.0* |
| LARSIA SPP | 3.8 |
| LIMNOPHYES SPP | 3.5* |
| LOPESCLADIUS SPP | 1.3 |
| MICROPSECTRA SPP | [illegible] |
| MICROPSECTRA SP1 | 1.0 |
| MICROTENDIPES SPP | 2.7 |
| MICROTENDIPES SP1 | 1.1 |
| MICROTENDIPES SP2 | 1.0 |
| MICROTENDIPES SP3 | 2.9 |
| NANOCLADIUS DOWNESI | 1.2 |
| NANOCLADIUS SPP | 3.5 |
| NATARSIA SPP | 5.1 |
| NILOTANYPUS SPP | 2.1 |
| NILOTHAUMA SPP | 2.3 |
| ODONTOMESA FULVA | 3.2 |
| PAGASTIA SPP | 2.2 |
| PAGASTIELLA OSTANSA | 2.3* |
| PARACHAETOCLADIUS SPP | 0.0 |
| PARACHIRONOMUS MONOCHROMUS | 3.3* |
| PARACHIRONOMUS PECTINATELLAE | 3.4* |
| PARACHIRONOMUS SPP | 4.7 |
| PARACLADOPELMA NEREIS | 1.3* |
| PARACLADOPELMA SPP | 3.1 |
| PARACLADOPELMA UNDINE | 2.5 |
| PARAKIEFFERIELLA SPP | 1.2 |
| PARAKIEFFERIELLA SP4 | 2.3 |
| PARAKIEFFERIELLA TRIQUETA | 3.2 |
| PARALAUTERBORNIELLA NIGROHALTERALE | 2.5 |
| PARAMERINA SPP | 2.0* |
| PARAMETRIOCNEMUS LUNDBECKI | 2.0 |
| PARATANYTARSUS SPP | 4.4 |
| PARATENDIPES SPP | 2.2 |
| PENTANEURA SPP | 2.4 |
| PHAENOPSECTRA FLAVIPES | 4.3 |
| PHAENOPSECTRA JUCUNDUS | 3.5* |
| PHAENOPSECTRA SPP | 3.3 |
| PHAENOPSECTRA SP2 | 2.9 |
| PHAENOPSECTRA SP3 | 3.1 |
| PHAENOPSECTRA SP4 | 2.6 |
| POLYPEDILUM ANGULUM | 1.7* |
| POLYPEDILUM AVICEPS | 2.3 |
| POLYPEDILUM CONVICTUM | 2.7 |
| POLYPEDILUM FALLAX | 3.5 |
| POLYPEDILUM HALTERALE | 3.5 |
| POLYPEDILUM ILLINOENSE | 4.4 |
| POLYPEDILUM SCALAENUM | 4.2 |
| POTTHASTIA GAEDII | 1.1 |
| POTTHASTIA LONGIMANUS | 3.8 |
| PROCLADIUS SPP | 4.5 |
| PRODIAMESA OLIVACEA | 4.1 |
| PSECTROTANYPUS DYARI | 5.3 |
| PSECTROTANYPUS SPP | 2.9* |
| PSEUDOCHIRONOMUS SPP | 1.7 |
| PSEUDORTHOCLADIUS SPP | 1.0* |
| RHEOCRICOTOPUS SP1 | 3.8 |
| RHEOCRICOTOPUS SP2 | 3.6 |
| RHEOCRICOTOPUS SP3 | 2.2* |
| RHEOSMITTIA SP1 NR DELICATULA | 4.3 |
| RHEOTANYTARSUS SPP | 3.3 |
| ROBACKIA CLAVIGER | 2.4 |
| ROBACKIA DEMEIJEREI | 2.1 |
| SAETHERIA TYLUS | 3.9 |
| STELECHOMYIA PERPULCHRA | 2.5* |
| STEMPELLINELLA SPP | 1.7* |
| STENOCHIRONOMUS SPP | 3.3 |
| STICTOCHIRONOMUS SPP | 3.6 |
| SUBLETTEA COFFMANI | 1.0 |
| SYMPOSIOCLADIUS LIGNICOLA | 3.2 |
| SYMPOTTHASTIA SPP | 2.2 |
| SYNORTHOCLADIUS SPP | 2.3 |
| TANYPUS SPP | 4.6* |
| TANYTARSUS SPP | 3.2 |
| TANYTARSUS SP10 | 2.4* |
| TANYTARSUS SP13 | 2.4* |
| TANYTARSUS SP2 | 3.6 |
| TANYTARSUS SP3 | 3.4 |
| TANYTARSUS SP5 | 1.2* |
| TANYTARSUS SP6 | 3.7 |
| THIENEMANNIELLA SPP | 3.1 |
| TRIBELOS SPP | 3.3 |
| XENOCHIRONOMUS XENOLABIS | 3.2 |
| XYLOTOPUS PAR | 3.5 |
| ZAVRELIA SPP | 2.8* |
| ZAVRELIMYIA SPP | 4.5 |
| **DIPTERA: OTHER** | |
| ALLUAUDOMYIA SPP | 2.5* |
| ANOPHELES SPP | 4.4 |
| ANTOCHA SPP | 2.3 |
| ATHERIX LANTHA | 1.1 |
| ATHERIX SPP | 0.6 |
| ATRICHOPOGON SPP | 2.8 |
| BLEPHARICERA SPP | 0.4 |
| CHAOBORUS PUNCTIPENNIS | 4.3 |
| CHAOBORUS SPP | 3.3* |
| CHRYSOPS SPP | 3.6 |
| CULEX SPP | 5.1* |
| CULICOIDES SPP | 3.0 |
| DICRANOTA SPP | 1.0 |
| DIXA SPP | 1.6 |
| DOLICHOPODIDAE | 4.7 |
| EMPIDIDAE | 4.0 |
| HEXATOMA SPP | 2.4 |
| LIMNOPHORA SPP | 3.9* |
| LIMONIA SPP | 3.4* |
| MUSCIDAE | 2.4* |
| PALPOMYIA (COMPLEX) | [illegible] |
| PERICOMA SPP | 2.1* |
| POLYMEDA/ORMOSIA SPP | 3.7 |
| PROSIMULIUM MIXTUM | 2.2 |
| PROSIMULIUM SPP | 1.1 |
| PROTOPLASA FITCHII | 1.8 |
| PSEUDOLIMNOPHILA SPP | 4.1 |
| PSYCHODA SPP | 5.4* |
| SIMULIUM (PSILOZIA/HEMICNETHA) SPP | 1.9 |
| SIMULIUM SPP | 2.2 |
| SIMULIUM TUBEROSUM | 1.3 |
| SIMULIUM VENUSTUM | 3.8 |
| SIMULIUM VITTATUM | 4.1 |
| TABANUS SPP | 4.8 |
| TIPULA SPP | 3.9 |
| **OLIGOCHAETA** | |
| AULODRILUS LIMNOBIUS | 2.4* |
| BRANCHIURA SOWERBYI | 4.1 |
| CAMBARINCOLA SPP | 2.7 |
| DERO SPP | 5.0 |
| ENCHYTRAEIDAE | 5.1 |
| HABER SPECIOSUS | 1.4* |
| ILYODRILUS TEMPLETONI | 4.7 |
| ISOCHAETIDES FREYI | 2.3* |
| LIMNODRILUS CERVIX | 3.8* |
| LIMNODRILUS HOFFMEISTERI | 4.9 |
| LIMNODRILUS SPP | 4.2 |
| LIMNODRILUS UDEKEMIANUS | 5.0* |
| LUMBRICULIDAE | 3.6 |
| NAIS SPP | 4.2 |
| NAIS VARIABILIS | 4.2* |
| OPISTHOPORA SPP | 4.4 |
| PELOSCOLEX SPP | 2.7 |
| PRISTINA SPP | 4.7 |
| SLAVINA APPENDICULATA | 3.5 |
| SPIROSPERMA NIKOLSKYI | 2.4 |
| STYLARIA LACUSTRIS | 4.0 |
| TUBIFEX TUBIFEX | 5.1 |
| TUBIFICIDAE | 2.9* |
| **CRUSTACEA** | |
| ASELLUS SPP | 4.6 |
| ASTACIDAE | 3.9 |
| CAMBARUS SPP | 4.0 |
| CRANGONYX SPP | 4.0 |
| GAMMARUS SP | 3.9 |
| GAMMARUS FASCIATUS | 3.2 |
| HYALELLA AZTECA | 4.0 |
| LIRCEUS SPP | 4.1 |
| ORCONECTES SPP | 3.4 |
| PALAEMONETES PALUDOSUS | 3.2 |
| PROCAMBARUS SPP | 4.1 |
| **MOLLUSCA** | |
| CORBICULA FLUMINEA | 3.2 |
| ELLIPTIO COMPLANATA | 2.5 |
| ELLIPTIO SPP | 1.9* |
| EUPERA CUBENSIS | 3.4* |
| PISIDIUM SPP | 3.3 |
| SPHAERIUM SPP | 3.7 |
| AMNICOLA SPP | 2.0 |
| CAMPELOMA DECISUM | 3.4 |
| ELIMIA SP | 1.3 |
| FERRISSIA SPP | 3.3 |
| HELISOMA ANCEPS | 2.7 |
| LAEVAPEX FUSCUS | 3.7 |
| LEPTOXIS SPP | 0.6 |
| MENETUS DILATUS | 4.0 |
| PHYSELLA SPP | 4.4 |
| PSEUDOSUCCINEA COLUMELLA | 4.3 |
| SOMATOGYRUS SPP | 2.4 |
| STAGNICOLA | 4.0 |
| **OTHER** | |
| BATRACOBDELLA PHALERA | 2.8 |
| CLIMACIA AREOLARIS | 2.8 |
| CLIMACIA SPP | 3.5* |
| CURA FOREMANII | 2.8 |
| DUGESIA TIGRINA | 3.6 |
| ERPOBDELLA/MOOREOBDELLA | 4.2 |
| HELOBDELLA ELONGATA | 4.6 |
| HELOBDELLA STAGNALIS | 2.3* |
| HELOBDELLA TRISERIALIS | 4.2 |
| HYDRACARINA | 2.6 |
| HYDROLIMAX GRISEA | 2.2* |
| MOOREOBDELLA TETRAGON | 4.4 |
| NEMATODA | 2.4* |
| PETROPHILA SP | 1.1 |
| PLACOBDELLA PAPILLIFERA | 4.4 |
| PLACOBDELLA PARASITICA | 2.9 |
| PROSTOMA GRAECENS | 3.2 |
| BELOSTOMA SPP | 4.8 |
| RANATRA SPP | 3.4 |
| SIGARA SPP | 4.4 |

ADDENDUM

## HISTORICAL LITERATURE REVIEW

Langston Creek is a tributary of the Reedy River that originates to the northwest of the city of Greenville in Greenville County, SC and is classified as a Class B waters. The creek flows approximately 5.8 km in a southerly direction to its confluence with the Reedy River near SC Highway 253.

The Reedy River originates near Travelers Rest and flows southward through Greenville and Laurens counties to its confluence with Lake Greenwood. The entire length of the Reedy River is classified as Class B waters according to the Water Classification Standards System for the state of South Carolina (SCDHEC 1979).

Class B waters are freshwaters that are suitable for secondary contact recreation and as a potable water supply source after conventional treatment (SCDHEC 1980). Also, Class B waters are considered suitable for fishing, survival and propagation of fish, other fauna and flora and for industrial and agricultural uses (SCDHEC 1981).

The Union Bleachery Corporation site in Greenville, South Carolina, covering 257 acres, was built in 1902 as a textile dyeing and finishing plant and has been used as this type of facility since that time. In 1952 the plant was purchased by Cone Mills Corporation who operated it until 1984, when it was purchased by American Fast Print for textile dyeing processes.

A study conducted by SCDHEC in May of 1981 reported elevated total chromium levels in Langston Creek at and downstream from the Union Bleachery Corporation plant. These extremely high levels of chromium were also observed in the Reedy River downstream of the confluence with Langston Creek (SCDHEC 1982). Sediment data from this report strongly indicated that the source of the elevated chromium levels in Langston Creek was associated with the Union Bleachery plant.

After detection of the chromium contamination, Cone Mills initiated a hydrogeological study of the site. This study was conducted by Soil and Material Engineers, Inc. Subsequently, a ground-water extraction system for chromium Cr 6 removal was begun and has been in operation since November 1982 (S&ME 1985).

The source of chromium in the groundwater is assumed to have been from a leak in the chromium line from the chromium storage tank to the dye area. This storage tank and line were removed some years ago and chromium has not been used in the plant's dyeing process since about 1974 (S&ME 1985).

A study conducted by Law Engineering Testing Company to detect the source of the chromium contamination was initiated in February 1982. Preliminary conclusions supported the contention that the most likely source of chromium in the groundwater was a break in the line between the old chromium storage tank and the dyeing area (LETCO. 1982).

In 1989, American Fast Print/US Finishing Company filed suit against Cone Mills for not disclosing a complete documentation of all environmental impacts known to Cone Mills at the time of purchase of the Union Bleachery Corporation facility. A site assessment of the area was conducted by GeoTrans at this time.

On September 4, 1985, a macroinvertebrate assessment of Langston Creek was conducted by Aquatic Analysts of Columbia, SC at the US Finishing Plant in Greenville, SC. It was determined that groundwater containing traces of chromium had impacted the benthic macroinvertebrate communities of the creek.

This survey was conducted at the same or very nearly the same sites and using the same collection methods as the recent study performed by Normandeau Associates, Inc., in May 1991. The results of these two surveys are presented in Table 1.

In the 1985 study, species diversity and equitability values were computed from the data using the Shannon-Weaver function and Margalef measure, respectively (Weber USEPA 1973). Species diversity is a measure of the combined effects of the number of taxa identified from a station (richness) and the distribution of individuals among the taxa (evenness). Taxa diversity generally increases as the number of taxa found at a site increases, and if the distribution of animal abundances is fairly even among the taxa present (few dominant or rare taxa; Price 1975). However, the Shannon-Weaver diversity index is insensitive to the effects of many pollutants, including heavy metals (Lenat et al. 1980). The use of diversity indices is only valid where organic wastes are the only pollutants (Lenat et al. 1980).

Equitability is an index that compares the number of species in a sample with the number of species expected from a well balanced community found in unpolluted habitats. This index has been found to be very sensitive to even slight levels of degradation (Margalef 1957). Values above 0.5 are indicative

Table 1. Comparison of Aquatic Analysts' 1985 survey of Langston Creek and Normandeau Associates' 1991 survey.

| | Station 1 Langston Creek Upstream | | Station 2 Langston Creek Midstream | | Station 3 Langston Creek Downstream | |
|---|---|---|---|---|---|---|
| | 1985 | 1991 | 1985 | 1991 | 1985 | 1991 |
| Total # Organisms | 188 | 406 | 51 | 368 | 42 | 552 |
| Total # Taxa | 19 | 42 | 12 | 42 | 13 | 47 |
| Diversity | 3.12 | 2.78 | 2.61 | 2.65 | 2.92 | 2.81 |
| Equitability | 0.68 | 0.21 | 0.68 | 0.19 | 0.84 | 0.21 |
| Water Quality Parameters | | | | | | |
| Dissolved Oxygen (mg/l) | 7.9 | 7.9 | 8.2 | 8.6 | 7.2 | 8.7 |
| pH | 7.0 | 6.33 | 6.9 | 6.53 | 7.1 | 6.59 |
| Water Temperature (0°c) | 24.0 | 18.3 | 22.2 | 18.1 | 22.5 | 17.5 |
| Conductivity (μmhos/cm) | 15 | 42 | 20.0 | 45 | 380 | 49 |
| All Stations | | | | | | |
| Total # Organisms | 281 | 1326 | | | | |
| Total # Taxa | 28 | 67 | | | | |

of good water quality. Even slight levels of pollution have been found to reduce equitability below 0.5.

The diversity and equitability values reflected in the 1985 data have reduced reliability because the total number of specimens collected from each station was less than 100. Consequently in 1985, equitability values did not indicate impairment as they do in the 1991 data.

Total number of invertebrates collected and total number of species indentified, differed dramatically at all stations on Langston Creek from 1985 to 1991. Diversity values were slightly lower at Station 1 but remained relatively the same at Stations 2 and 3.

Although the difference in total number of organisms and total number of taxa collected in 1991 as compared to 1985 looks as though the stream has experienced a dramatic recovery, the numbers alone are misleading. There was a significant increase indicating some recovery, but most of the increase in total organisms collected was due to the abundance of pollution tolerant oligochaetes and chironomids.

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