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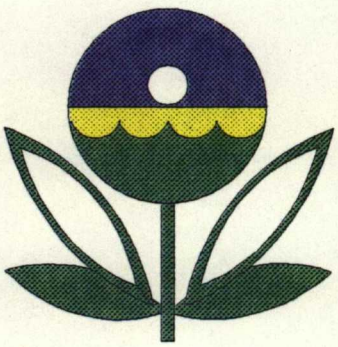
Other:

CALDWELL LACE LEATHER SUPERFUND SITE

FINAL
REMEDIAL INVESTIGATION REPORT
APRIL 14, 1994



U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION IV

VOLUME 1

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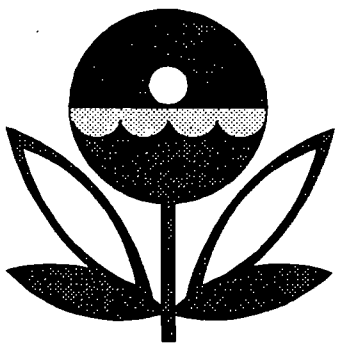

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REGION IV

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1.0 INTRODUCTION

In June 1988 the Caldwell Lace Leather Site was proposed for inclusion on the National Priorities List (NPL). The United States Environmental Protection Agency (EPA) entered into negotiations with the Potential Responsible Parties (PRPs) in September 1988 to conduct the Remedial Investigation/Feasibility Study (RI/FS). The PRPs declined to conduct the RI/FS in October 1989. EPA began the RI/FS in March 1990 (A) to determine fully the nature and extent of any threat to the public health or welfare or the environment caused by the release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site; and (B) to evaluate alternatives for the appropriate extent of any remedial action to prevent or mitigate the migration or the release or threatened release of hazardous substances, pollutants, or contaminants at and from the Site.

The following is a Remedial Investigation (RI) Report for the Caldwell Lace Leather Site conducted to meet the first objective above. The investigation was conducted in accordance with Section 104 and other provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), 42 U.S.C. Section 9601 et seq., as amended by the Superfund Amendments and Reauthorization Act (SARA) (P.L. 99-499) and the National Contingency Plan (NCP), Part 300, Subpart E. The Commonwealth of Kentucky has assisted EPA in the review of reports and site evaluations.

1.1 SITE BACKGROUND

1.1.1 SITE DESCRIPTION

The Caldwell Lace Leather (CLL) Site is located along State Highway 1039 (Cemetery Road), approximately 2.5 miles northwest of the City of Auburn, Kentucky (Site Location Map). CLL consists of two separate tracts, Tract 1 and 2. Tract 1 consists of approximately 15.6 acres and Tract 2 consists of approximately 41.2 acres.

Tract 1 was used for disposing of tanning wastes in unlined trenches and lagoons. The trenches and lagoons were filled and covered with several feet of clay and soil. Tract 1 was vegetated with a mixture of grasses and legumes. The ground surface is somewhat undulated due to settling of the waste in the former trenches and lagoons. No buildings or structures exist on the property. An access road from Cemetery Road traverses the property from the unlocked gate to the southwest corner. The road is used by a local landowner to access his property located south of Tract 1. Tract 1 is surrounded primarily by cropland and pasture.

Tract 2 received tannery sludges that were disked into the soil. Tract 2 is located adjacent and

to the east of Tract 1. Tract 2 was sold to a farmer who now uses the land as a pasture for his cattle. The eastern portion of the property has a barn and a partially built house with an access road that leads to the buildings. The owner has recently placed two mobile homes on the property for his tenants. A water tank and an access road are on the western portion of the landfarm. The landfarm is bounded on the north by Highway 1036 (Cemetery Road) and several residences. Surrounding property is primarily woodlands.

1.1.2 SITE HISTORY

The CLL Site is approximately 56 acres in size. From 1972 until 1985, the Site received sludge and solid wastes generated by the Caldwell Lace Leather tannery facility located in Auburn, Kentucky. Based on review of the collected records and interviews with knowledgeable government officials, the Caldwell Lace Leather Company, Inc. (Caldwell), of Auburn operated a tannery from the late 1800's until January 1985, when tanning ceased at the facility and only leather cutting operations were continued. There was no indication of what disposal locations were used for the tannery's waste streams prior to its use of the CLL Site in 1972. The Site and tannery were owned and operated by Caldwell until 1983, at which time they were purchased by a separate company named Lace Leather, Inc.

The tannery used a chrome-tanning process to tan cowhides which generated a wastewater sludge containing chromium. Laboratory analyses performed on samples of the wastewater sludge in 1971 by the Tanners' Council Research Laboratory revealed that the sludge contained between 2,580 and 3,940 milligrams per liter (mg/l) of trivalent chromium. The wastewater sludge, along with the tannery's other waste streams (cowhides, leather scraps, fleshings, cork, asbestos, cardboard and paper) were taken to a 15-acre area of the Site (hereinafter "Tract 1" or "landfill area") for disposal beginning in 1972. In general, the records revealed that Tract 1 contained at least 25 shallow trenches covering approximately 10 acres. The trenches were variously referred to as pits, lagoons, ponds, and basins in the Kentucky Department of Environmental Protection (KDEP) records. For clarification, they will be referred to as trenches. Most of the trenches were called drying trenches and were used to hold the liquid-based wastes until evaporation took place. The remaining trenches were used for the disposal of solid refuse, and according to KKDEP inspectors, were not covered on any regular schedule.

During the years of Tract 1 operations, numerous inspection were conducted at the Site by KKDEP. Problems regarding the uncovered scrap leather trench, overflowing sludge-drying trenches, and leachate running off of the Site property were constantly reported. Inspectors described the Site as covering 10 acres, with no buildings and many trenches containing different types of waste including hair, fat, dye, and rotten hides. Samples taken by the KKDEP from the scrap leather trench were analyzed and shown to contain between 5.9 mg/l and 11.4 mg/l

of total chromium. A sample taken by the KKDEP from a run-off pool on neighboring property owned by Mr. and Mrs. Bobby Reeves was analyzed and contained 13.2 mg/l of total chromium. Inspectors reported that remedial measures would have to be taken by Caldwell immediately to stop contamination of ground water and surface water caused by run-off and leachate from the unlined trenches.

In 1981, an adjacent 41-acre area (hereinafter "Tract 2" or "landfarm area") was purchased with the intent of using the property for landspreading, also referred to as landfarming in KKDEP records. A Site lay-out map is presented in Figure 1-2. In 1981, a sludge storage lagoon with 95,000 gallon capacity was constructed and was to be used when landspreading was impractical due to frozen ground or other unusual conditions. Although the lagoon was constructed on the Site, it is not clear whether the lagoon was constructed on Tract 1 or 2. In 1982, a construction permit was issued for a second 95,000-gallon sludge storage lagoon at the Site for use when landspreading was impossible due to freezing conditions. This lagoon was constructed along the eastern boundary of Tract 1.

On July 13, 1982, a conditional permit was issued to Caldwell for landfarming chromium and vegetable tanning sludge. This operation involved approximately 28.5 acres of Tract 2. On July 30, 1982, Caldwell was issued a Construction Permit for a third disposal area -- a residential landfill for disposal of solid waste (screenings, leather scraps, and gasket scraps) on approximately 5 acres adjoining the old landfilled area of Tract 1.

On October 12, 1982, Caldwell was notified by the KDEP that the company had violated numerous permit conditions at the Site. Some of the violations included: failure to submit a ground-water study report; failure to submit a separate $10,000 surety bond for the residential landfill; failure to maintain adequate landspreading records; failure to disk the sludge into the soil deeply enough; and gross deficiencies between the actual ongoing construction of the residential landfill and the construction permit. An Agreed Order was negotiated for several months, but never became final.

A KKDEP site inspection of the landfarming area was conducted on December 15, 1982. Some corrections had been made, but problems still existed including continued use of inadequate equipment and lack of a field gridding system. In December 1982, Caldwell acquired two surety bonds covering the residential area and the landspreading area. The company submitted to KKDEP a sludge application grid breakdown, which specified that 310,800 gallons per year of sludge would be spread over 29.6 acres of the Site. Conditional operating permits were issued for both the residential landfill (March 1983) and landfarming areas (February 1983).

On April 20, 1983, Caldwell (i.e., Caldwell Lace Leather Company, Inc.), changed its name

to Lace Leather, Inc. Lace Leather, Inc., sold its original name and all its assets to Auburn Leather Co., Inc. On the same date, Auburn Lace leather Co., Inc., incorporated by Mr. J. Richard Howlett and Mr. Harry Williamson, changed its name to Caldwell Lace Leather Co., Inc.

Additional transactions occurred regarding assets and liability -- thereby confusing the issue of the owner's true and correct name. Nonetheless, the title documents confirmed the sale of the Site and, by reference, the sale of the tannery to Caldwell Lace Leather Co., Inc. Therefore, based on this information the owner and operator of the Site and tannery after April 1983 was Caldwell Lace Leather Co., Inc. (Caldwell Lace Leather).

An inspection of the Site was conducted on March 18, 1983, by KKDEP staff to investigate reports that Caldwell had drained waste trenches. The inspector reported that Caldwell had dug a ditch which allowed the contents of two of the trenches to discharge of the Site property. The volume of discharge was estimated to be between 2,900 and 9,000 gallons.

On April 15, 1983, Caldwell Lace Leather was notified that the KKDEP had approved certain remedial actions. These included removal or covering of the remaining sludge in the two discharged trenches; removal or covering of fleshings in the open trenches; and landspreading of the fleshing liquid.

On April 29, 1983, Caldwell Lace Leather notified KKDEP that the remaining sludge in the two discharged trenches was being covered with a mixture of sawdust and earth, and that the company had applied for a variation from the landspreading permit to allow for the spreading of liquids collected in the old fleshing trenches and subsequent covering and compaction of the trenches.

An inspection of the Site was made on April 30, 1983, following a complaint that fleshing trenches were overflowing and that the leachate was running across Mr. Bobby Reeves' property. The inspector reported that black material from the fleshing trenches was discharging across the property and into a sinkhole. It was estimated that 100 gallons per minute were discharging into the sinkhole. A similar inspection was made on May 15, 1983, following another complaint and the inspector again reported that the fleshing trenches were overflowing onto Mr. Reeves' property. The inspector noted that it was raining very hard on both occasions.

On October 1, 1984 an Agreed Order was entered into between Caldwell Leather Company and with the Commonwealth of Kentucky Natural Resources and Environmental Protection Cabinet (KNREPC). As statements of fact, the Order listed numerous violations which had occurred at the Site. It stated that the permit issued for the old disposal area in 1972 was revoked and

superseded by conditions of the landfarming and residential landfill permits. The Caldwell Leather Company was ordered to maintain vegetation at the old disposal area in accordance with an approved closure plan which had been submitted by the company on September 2, 1983. The company was also directed to perform quarterly sampling and analysis of water in the diversion ditch below the old disposal area, to submit a complete diversion ditch below the old disposal area, to submit a complete leachate control system plan, to manage leachate from the inert waste section of the area and to pay a civil penalty of $3,000.

On February 22, 1985, KNREPC Division of Waste Management approved a closure plan for the old landfilled area on Tract 1. The closure plan stated that the area to be closed consisted of 5.5 acres and that solid waste had been disposed of there continuously from 1972 through the fall of 1982. The work was regulated by Solid Waste within the Division of Waste Management. Closure and post closure activities were to include application of lime and fertilizer, regrading and revegetation, and ground water/surface water monitoring. All phases of the closure plan were not completed until late 1989. The landfarm area was never closed.

On February 28, 1985, Caldwell Lace Leather was notified by KNREPC that a soil sample taken from the landfarming area in October had been analyzed and shown to contain extremely high concentrations of total chromium (3,630 mg/l). The letter warned that such a high concentration level suggested that the potential for off-Site contamination as well as local plant toxicity was extreme. KNREPC requested that the company submit a testing plan including comprehensive soil testing, sampling analysis of collected rainwater, and a study of vegetation cover both on the landfarming area and on adjacent property to determine the effects of the toxicity.

In June 1985, Caldwell Lace Leather notified KNREPC that a leachate collection system had been installed and was operational at the Site. Details on this system were not presented in the KNREPC records. However, later inspection reports revealed that the collection system was not effective and that leachate from the leather scrap pit continued to present a problem at the Site.

An inspection of the Site conducted on March 21, 1985, revealed that the residential landfill had not been covered and was in poor condition. The inspector reported that there was still a problem with a discharge from the old leather scrap trench.

In November 1985, the tannery and the Site were purchased by North Park, Inc., a subsidiary of the Auburn Leather Co., Inc. Caldwell Lace Leather Co., Inc., has terminated the tanning operations earlier in 1985 and North Park, Inc., retained only the leather cutting operation which produced leather trimmings and scraps as its only waste stream.

In December 1985, the KNREPC completed a Preliminary Assessment and recommended a low priority for site inspection. Inspectors reported that the Site was unsuitable for the disposal of any hazardous waste due to the topography and hydrology of the area. In October 1986, a Hazard Ranking Score (HRS) package was prepared. The Site was proposed for inclusion on the National Priorities List (NPL) in 1988 and became final in August 1990.

1.2 NATURE AND EXTENT OF PROBLEM

The CLL Site is a disposal area in which chrome-bearing sludge was either landfilled or landfarmed between 1972 and 1985. A significant portion of the waste disposed of at the Site is chromium-bearing sludge landfilled in the northwest section of the property between 1972 and 1982; and landfarmed between 1983 and 1985. Also landfilled at the Site were fleshings, spoiled hides, screening, leather scraps and gasket scraps. The fleshings and screenings also contained chromium contamination.

Extensive sampling by the KNREPC indicated that the wastes disposed of at the Site had contaminated the landfill area with chromium. A composite soil sample collected from the landfarming area showed the presence of elevated chromium concentrations. 21 domestic wells were sampled in July 1983. Two of the ground water samples contained elevated chromium contamination. One of the wells is located approximately 1,200 feet northwest from the landfill. The other is an onSite monitoring well located in the landfarming area. Both of the wells sampled are within the aquifer of concern. Numerous sampling events at the CLL Site have shown the presence of chromium at elevated concentrations. On two separate occasions, hexavalent chromium was reported by KDEP at elevated concentrations in leachate samples collected from the landfill section of the Site.

The following is an estimate of the wastes disposed of at the landfill based upon operator records:

Landfill (based on 10 years of operation)

Chrome-bearing sludge:	15,000 - 42,350 tons
Fleshings:	1,040 - 1,610 tons
Screenings:	780 tons - 810 tons
Dry Waste (paper and cardboard):	162,500 tons

Landfarm (based on three years of operation)

Chrome-bearing sludge: 4,700 - 5,600 tons

The potential exists for ground water contamination in the vicinity of the Site based upon the fact that chromium-bearing sludge was disposed of in unlined trenches and disked into the surficial soils. These disposal techniques, coupled with the karst topography of the region result in a potential threat to the local ground water.

1.3 REFERENCES

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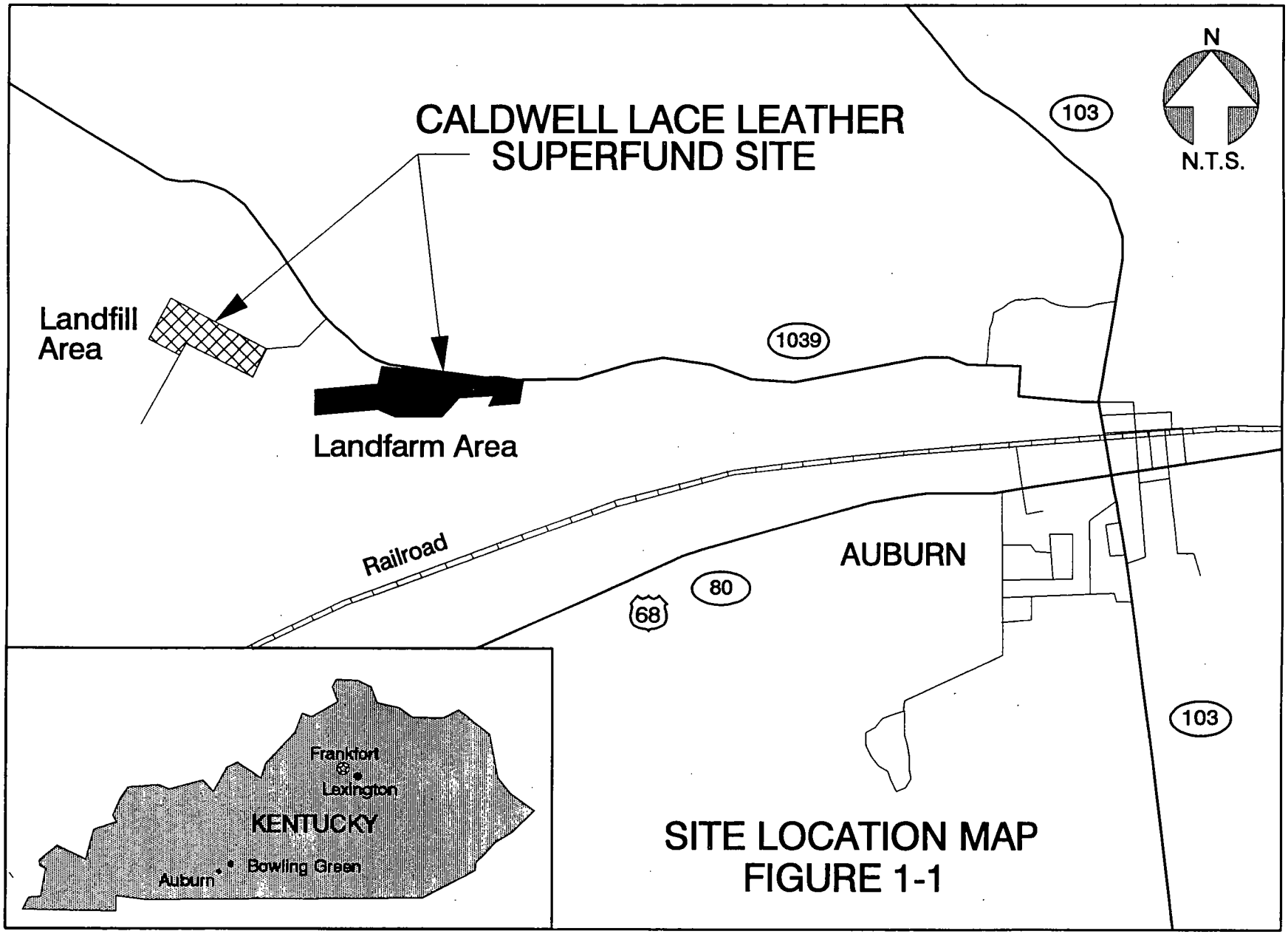
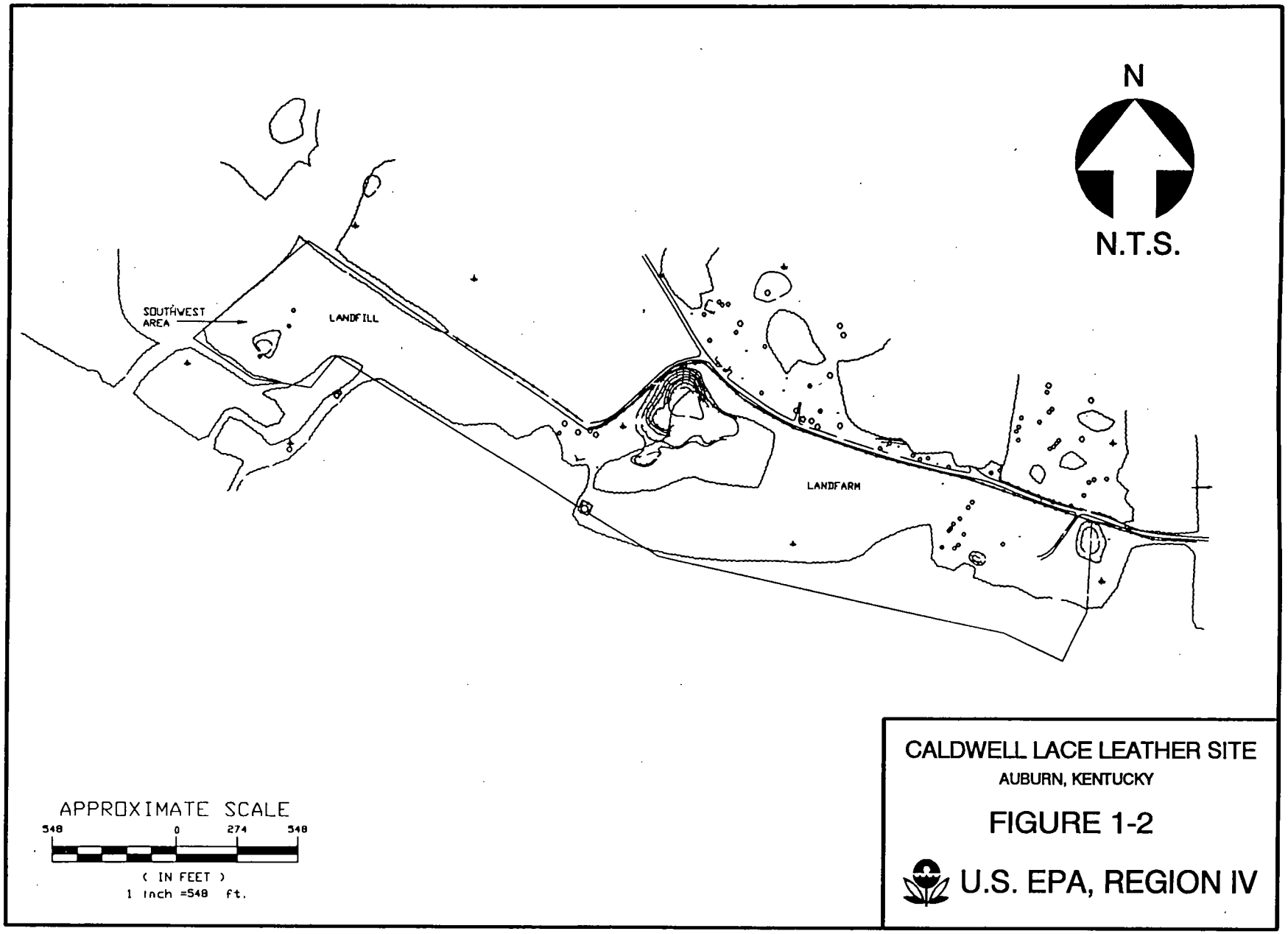


SITE LOCATION MAP
FIGURE 1-1



CALDWELL LACE LEATHER SITE

AUBURN, KENTUCKY

FIGURE 1-2

U.S. EPA, REGION IV

2

2.0 PHYSICAL CHARACTERISTICS OF THE SITE

2.1 DEMOGRAPHY AND LAND USE

The property is in a rural area a few miles northwest of Auburn, Kentucky. The Site is bounded on the north by Cemetery Road and in the other directions by pasture, cropland and woodland. Areas north of the road are principally woodland and farmland. The nearest residence is on the landfarm area of the Site. Other nearby residences are along the north side of Cemetery Road. Much of the site is now cropland and pasture. Cropland and pasture, and mixed forest are the predominant forms of land use within a 2-mile radius of the Site (EPIC, 1990)

The town of Auburn, population approximately 1,500, is the closest population center and has the nearest school. Auburn obtains its water supply from the Blue Hole, a large spring, which is located on the south edge of town. At one time all residents in the Site vicinity obtained their potable water supply from private wells, but many now obtain it from the East Logan Utility District, which purchases water from Auburn (ATSDR, 1990).

2.2 HYDROLOGY

The Site is in the Mississippian Plateaus physiographic province of Kentucky and includes broad gently rolling valleys and relatively narrow flat-topped ridges. The Site is along the crest of an east-west trending ridges; the ridge top is about 170 feet above the valleys. In general, sinkholes with swallets are more common on the eastern part of the ridge.

The ridge is both a topographic and a groundwater divide in the immediate area. The two distinct groundwater basins discharge to two different rivers, the Mud River, which is located 4 miles southwest of the Site, and the Gasper River which is located 2.4 miles northeast of the Site. The Mud River discharges into Lake Hancock approximately 5 miles from the point of its origin.

Karst features such as sinkholes, springs, karst windows, and sinking streams are common in the broad valleys north and south of the ridge-top Site. The karst features are developed on limestone and, for the most part, have formed as a result of the dissolution of carbonate bedrock by percolating ground water. Most karst features are hydrologically significant because of their unique relation to the ground-water system; that is, they collect and discharge water into, store and transmit, or discharge water from the ground-water system (USGS, 1993)

Based on aerial photography analysis, it was determined that surface drainage flows radially away from the Site, north toward Wigginton Creek, west toward Auburn, and to the south.

Ninety-six sinkholes, seven sinkhole plains, seventeen seeps and springs, five seep areas and two swallets were discovered within approximately a 2-mile radius around the Site (EPIC, 1990).

Landfill

The former locations of trenches and a possible lagoon area have been approximated from changes in elevation and contrast in appearance of vegetation (Figure 2-1). The areas they formerly occupied are annotated by short dashed lines. A small trench area is located in the southwest corner of the tract. These trenches are empty, and vegetation covers the mounds (not annotated) between each trench.

The landfill drainage exists to the southwest. Intermittent drainage and suspected intermittent drainage flow through the possible lagoon area in the eastern portion of the landfill. Channelized drainage flows southwest along both sides of the road. Channelized drainage also flows through two pipes under the access road in the western portion of the landfill. Channelized and intermittent drainage flows from three possible trench areas in the western half of the site into the channelized drainage. Suspected intermittent drainage flows south toward the pond (possibly a former impoundment). Channelized drainage flows toward the pond from a revegetated small trench area. Channelized drainage flows along the mounded area (MA) in the northwest corner of the landfill, and also flows southwest and then southeast along the southwestern landfill boundary. A section of the berm surrounding the pond has been cut away. A pipe passes through the berm.

Landfarm

Cropland has been replaced by pasture (Figure 2-2). Disking equipment, a ditch and a ground scar are seen within the probable injection area (outlined). Drainage travels from a pipe in a berm toward a sinkhole which contains liquid and debris. A pond is located southeast of two buildings. A berm now surrounds the pasture (not annotated) on three sides. Liquid is visible in low-lying areas along the revegetated berm, running parallel to Cemetery Road. Two areas of intermittent drainage exit the pasture (not annotated) to the south. Intermittent drainage flows east along the northern berm. Intermittent drainage flows north, away from the water tank.

Two areas of stains/wet ground are evident within the pasture. A narrow trench is seen between the edge of the slope and the berm to the west. A pond with a break in its berm (not annotated) and a ground scar are visible in the western portion of the landfarm.

Two sinkholes appear in the wooded area in the western portion of the landfarm.

2.3 SOILS

Near the Site, bedrock is overlain by soil and residuum that is generally thin but variable in thickness. Soil depths, as determined by drilling, range from 1 to 43 feet (Quinlan, 1982). According to the Soil Survey of Logan County, soil depths near the Site range from 40 to 48 inches and include the Linker series, a well-drained sandy clay loam derived from sandstone, and the Talbot series, a moderately deep, well-drained clayey soil derived from limestone.

2.4 GEOLOGY

Only the near-surface geology is discussed in the report, because nearly all ground water in the study area is present at relatively shallow depths. The following discussion proceeds from younger or uppermost geologic units to successively older and deeper rocks; the descriptions have been taken from USGS published 7½ minute geologic quadrangle maps that are listed in the references. Each geologic quadrangle map includes a detailed stratigraphic column, lithologic descriptions, and structural features.

The Site is underlain by limestone, shale, and sandstone of Mississippian age that includes, in descending order, the Big Clifty Sandstone member of the Golconda Formation, the Girkin Formation, and the Ste. Genevieve Limestone. The Site is on an east-west trending ridge underlain by as much as 70 feet of the Big Clifty Sandstone that is gray to light-brown, fine grained, massive to thin-bedded, cliff forming, crossbedded, and locally shaley. The Big Clifty Sandstone caps many ridges throughout the region.

The Girkin Formation underlies the Big Clifty Sandstone and outcrops at the surface at the eastern and western ends of the Site and underlies the intensely karstified lowlands that surround the ridge where the Site is located. The Girkin Formation is about 170 feet thick and is mostly limestone, medium-gray to pale-yellow gray, aphanitic to coarsely detrital, and oolitic. Discontinuous shale and sandstone units that range from 0 to 5 feet in thickness are present about 45 feet above the base of the formation. These two formations are the ones most relevant to groundwater movement in the immediate vicinity of the Site.

The Ste. Genevieve Limestone underlies the Girkin Formation and is light gray to light brown, fine to coarsely detrital and oolitic, and thin-bedded to very-thick bedded and massive. The Ste. Genevieve Limestone is about 200 feet thick and is basal limestone in the study area, but outcrops only near Mud River Spring and southeast of Auburn. The Ste. Genevieve limestone underlies extensively highly-karstified areas to the south and west of the Site.

Structural contours on the geologic quadrangle maps indicate that bedrock dips north-northwest at about 40 feet per mile. No mapped faults exist in the area; however, a fault zone is mapped about 5-miles northwest of the Site. Several lineaments are present in the area and seem to be subparallel to the fault zone (USGS, 1993).

Most of the landfill area is on soil-covered limestone and most of the landfarm area is on soil-covered sandstone that has repeatedly been breached by the development of sinkholes (Quinlan, 1982).

2.4.1 SINKHOLES

Sinkholes are commonly the most typical evidence of karstification. As used in this report, the term sinkhole refers to a naturally occurring closed topographic depression caused from subsidence or collapse of the land surface resulting from karst processes. The principal cause of development of sinkholes in this area is the transport of surficial material into solution-enlarged openings in bedrock. This process usually results in the formation of a funnel-shaped depression (sinkhole) in the land surface.

Mapped sinkholes in the vicinity of the Site are circular to irregular in outline and range from less than 10 to about 500 feet in diameter. Most sinkholes are less than 20 feet deep but a few are as deep as 50 feet below the surrounding area. In general, sinkholes on the broad valleys are less deep but much larger in outline than sinkholes on the ridge near the Site. For example, a sinkhole south of highway US 68 and about 2.5 miles southwest of the Site is about 30 feet deep and 0.6 miles in diameter.

The drain (swallet) at the bottom of a sinkhole may be open or plugged with soil. Swallets are hydrologically significant because the openings are usually connected to subsurface conduits that lead directly to the ground-water system. Thus, all surface runoff collected by the sinkhole is funneled directly into the ground-water system without enhancement of water quality which may occur as water drains through the sediment plug. Because of the direct hydraulic connection to the ground-water system and the fact that surface runoff from the Site can drain into several sinkholes with open swallets, all dye-tracer tests performed by USGS during the RI originated in those sinkholes with open swallets.

2.4.2 SPRINGS

A spring is a natural point of discharge from the ground-water system where the land surface intersects with the water table or water-bearing conduits. Discharge from a spring may issue from openings ranging in size from less than an inch to many feet in diameter. Water may

either discharge under gravity or rise under pressure to from small seeps or large rise pools. Springs in the area range from a relatively small wet-weather resurgence that flows only during or after a period of rainfall (Green Boiling Spring) to relatively large springs that discharge from cave-like openings in limestone are generally perennial (Mossy Spring).

The largest springs in the area are Mud River Spring, Mossy Spring, Auburn Spring and Crawford Spring. Each spring is fed by a converging subsurface drainage system that can be considered as a large branching pattern of pipe-like openings that collects water over an extensive area, funnels water to the main conduit of the spring, and then discharges water at the land surface at the mouth of the spring. Surface runoff funneled by sinkholes is a major source of recharge to these springs. Thus, the quality of water from a spring tends to reflect the surface activities in the basin. Springs may be appropriate and convenient points to monitor ground-water quality for a particular basin, because springs are the principal outlets for ground water in a karst ground-water basin. Before a spring can be considered as a valid monitoring site, it must be shown to drain a particular basin. This can be accomplished by performing dye-tracer tests.

2.4.3 KARSTS WINDOWS

A karst window is a topographic depression formed by subsidence or collapse of the land surface which results in exposure of an underground stream. Karst windows range from pit-like sinkholes with water flowing at the bottom of the pit to large valley-like depressions containing streams flowing several hundred feet across the valley floor. Most karst window in the study area are relatively small and have been characterized as pits with cave streams.

One karst window in the area is a steep-sided funnel-shaped depression with water flowing in the bottom of the depression. The sinkhole is about 30 feet in diameter at the land surface and about 15 feet deep. During low flow conditions, the water does not rise in the sinkhole but only flows across the bottom of the sinkhole. As water levels rise, the ground water drains from the sinkhole through a series of horizontal openings at different levels above the bottom of the sinkhole. During the high-flow conditions, water rises in the sinkhole, and during intense storms the water surface is turbulent as a result of the force of water rising in the sinkhole.

Karst windows are hydrologically significant because the exposed streams provide a direct path to the subsurface for any contaminants placed in or allowed to enter the sinkhole. Also, and perhaps of greater importance within the context of this RI, karst windows serve as convenient and appropriate ground-water monitoring sites because the exposed stream provides access to ground water within a major subsurface conduit.

2.4.4 GROUNDWATER FLOW

Ground-water flow in bedrock underlying mature karst terrain is much different from non-karst terrain, primarily because of the presence of pipe-like openings or conduits that permit relatively rapid movement of water. It is the presence of these openings that contribute to the unique nature of ground-water flow in the area.

Ground-water flow in karst aquifers is of two main types: diffuse (slow, laminar flow) and conduit (rapid, turbulent flow). Both types of ground-water flow can exist in the same karst aquifer. Diffuse flow typically occurs where dissolutional enlargement of primary openings in bedrock has not developed sufficiently to permit turbulent flow and most often occurs near the boundaries of ground-water basins and in the weathered and fractured uppermost zone of bedrock near the contact with the overlying residuum. In areas where ground-water flow is primarily diffuse, flow is usually not concentrated in particular zones of the aquifer; typical karst landforms, such as sinkholes, may be absent or poorly developed.

Conduit flow in carbonate bedrock occurs in solution-enlarged openings that range in size from less than an inch to cave-size, such as the opening that forms the cave-like conduit at Mossy Spring. These conduits are dendritic or trellised and develop along horizontal or vertical open fractures and bedding planes. Where conduit flow predominates, karst landforms are common and well developed. As mentioned earlier, the hydrologic significance of conduit flow is the rapid introduction and movement of water through the aquifer system. The relation between diffuse and conduit flow is shown by the generalized block diagram (Figure 2-3).

In a mature karst aquifer, such as occurs in the Site area, conduits concentrate water that enters the subsurface at discrete points, such as sinkholes, or by slow drainage from the overlying strata. In this way, contaminants placed on the land surface or disposed of in sinkholes have the potential for rapid transport into the subsurface and impairing ground-water quality downgradient from the input point.

Conduit flow in major conduits converge to the springs that serve as the natural discharge points for these conduits. Flow in major conduits is typically turbulent, with highly-variable turbidity and temperature, and has a relatively rapid response to precipitation. These are characteristics of several large springs -- Mud River Spring, Mossy Spring, and the Auburn Spring -- that are the discharge point of major conduits draining ground-water basins in the Site area.

Ground water moves in response to hydraulic gradients from points of recharge to points of discharge. In the study area, most points of recharge are in the uplands and points of discharge are in valleys and streams. The general direction of ground-water flow can be estimated by

drawing flow lines perpendicular to water-level contours of a potentiometric (water table) map. However, the local direction of ground-water flow at a specific site may differ from that of general regional flow because the water follows available routes whose orientation depends on the development of secondary openings and local structure, including dip of the rocks. For this reason, ground-water dye tracing is commonly the most accurate, or even the only method, of defining the direction of ground-water flow in karst terrain.

Before the EPA RI, two separate groundwater studies for the area were performed by consulting hydrogeologists. The first study was completed and reported by James F. Quinlan, PhD, in November 1982 and the second by Ralph O. Ewers, PhD, in March 1983. Quinlan determined through dye tracing that ground water from the landfill portion of the Site traveled to Wigginton Creek, a tributary to the Gasper River, via springs, sinking streams, and overland streams. Quinlan also inferred the possibility that groundwater from the landfill area may, in part, flow toward the southwest to one or more of the springs that eventually flow to the Mud River. The Quinlan and Ewers studies confirmed that the ground-water flow direction from the adjoining landfarming area was in a southwest direction toward Mud River. Ewer's study mentioned the possibility that some infiltration from the extreme eastern portion of the landfarm may flow northward to the source of the Gasper River.

2.5 REFERENCES

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TechLaw, Inc. March 23, 1988. *Responsible Party Search, Final Report, Caldwell Lace Site, Auburn, Kentucky.* USEPA Contract No. 68-01-7331. CDM Federal Programs Corporation Work Assignment No. 393.

USEPA, Environmental Monitoring Systems Laboratory, October 1990. *Site Analysis Caldwell Lace Leather Disposal Site, Auburn, Kentucky.* TS-PIC-90096 by The Bionetics Corporation, Warrenton, Virginia 22186

US Geological Survey, by D.S. Mull 1993. *Use of Dye Tracing to Define the Direction of Ground-Water Flow from a Superfund Waste-Disposal Site in Karst Terrane.* Water Resources Investigations Report 92-4195, in cooperation with U.S. Environmental Protection Agency.

3

3.0 INVESTIGATION METHODOLOGIES

3.1 INTRODUCTION

The RI was conducted in accordance with the Pre-Remedial Study Plan, 1990; the Remedial Investigation Pilot Study Work Plan; and the Work Plan submitted by Weston, 1992. The Work Plans were developed to guide the sampling activities at the CLL Site located in Auburn, Kentucky. The Work Plans discussed the procedures that were used to assure the precision, accuracy, completeness, and representativeness of the samples collected and the data quality objectives.

The RI was conducted in several phases. The remainder of this section will discussion chronological order the sampling activities and investigation methodologies used in each phase of the RI.

3.2 PRE-REMEDIAL SAMPLING 1990

Prior to the NPL listing, very little data had been gathered concerning wastes disposed of at the Site. It was determined that a pre-remedial sampling study was required to determine what contaminants were present at the Site. In June of 1990, personnel from EPA, Region IV, Environmental Services Division (ESD) and Waste Management Division (WMD) collected samples from the Site. Surface and sub-surface soil grab samples were collected from eleven locations, surface water from one location, sediment from four locations, and ground water/leachate from six locations. Samples were analyzed for the complete Target Compound List (TCL)/Target Analyte List (TAL).

The Pre-Remedial Sampling Report and complete analytical results may be found in Appendix F.

3.3 WELL/SPRING INVENTORY 1991

All wells and springs in a one-mile radius of the Site were inventoried. Each site was visited and the depth of the well, depth to water, temperature, and specific conductance were measured. Spring discharge was estimated. Information on the type of pump, water usage, and ownership was also collected. For sites one-to-two and two-to-three miles from the CLL Site, only general information was collected, mainly, the location and type (well or spring) and, in some cases, owner's name and water usage.

The inventory prepared by the U.S. Geological Survey may be found in Appendix C.

3.4 GROUNDWATER SAMPLING AND GEOPHYSICAL REPORT 1991

The purpose of this phase of the investigation was to sample a representative number of private drinking water wells and naturally occurring springs located within the suspected ground-water migration pathway. Five private water wells and four naturally occurring springs were sampled. Also, a geophysical study was conducted to locate possible locations for ground-water monitoring wells. Two soil samples were collected from the landfarm to verify previous samples showing chromium contamination in the landfarm surface soils. All samples were analyzed for the complete TCL/TAL.

Twelve sub-parallel profiles were investigated using a WADI Very Low Frequency (VLF) instrument. This instrument was used in an attempt to detect electrically conductive subsurface features such as ore bodies and water-filled fractures. It was hoped that limestone solution cavities if present (and if filled with water), would present an electrically conductive feature detectable by the WADI.

Although numerous anomalies were indicated at various locations along each of the profiles surveyed with the instrument, they could not be correlated with any certainty. This data was deemed useless for determining subsurface features and possible future well locations.

The Groundwater Sampling and Geophysical Report and complete analytical results may be found in Appendix I.

3.5 RESAMPLING OF PRIVATE WELLS 1991

Two private wells had shown the presence of chromium and lead during the Groundwater Sampling 1991 event. The contaminant levels were close to their respective Safe Drinking Water Act Maximum Contaminant Levels (MCLs). The private wells were resampled by an On-Scene Coordinator (OSC) and the Technical Assistance Team (TAT). The samples were analyzed for metals only.

The data collected from resampling the private wells is presented in Appendix H.

3.6 REMEDIAL INVESTIGATION PILOT STUDY 1991

The objectives of this pilot study were to provide initial estimates of contaminant concentration variability on the landfarm area and the area to the southwest of the landfill; to identify exposure units which may require further investigation; and to define vertical extent of contamination in the landfill area. 137 composite soil samples and one groundwater sample were taken. All

samples from the landfarm were analyzed for metals. A select number of samples were analyzed for the complete TCL/TAL list. All samples collected from the landfill and southwest areas were analyzed for the complete TCL/TAL list.

In previous sampling events, high concentrations of chromium, as well as organic acids and alcohols normally associated with tanning, were detected in the subsurface soil (> 1 foot) at the landfill. Lead, mercury, chlorinated solvents, and PAHs were also detected in the subsurface soil at the landfill. High concentrations of chromium were detected in the surface soil (< 1 foot) of the landfarm. This finding caused suspicion that some of the wastes were dumped on the ground rather than disked into the soil. Groundwater sampling (springs and residential wells) events conducted prior to the Pilot Study had shown the presence of chromium and lead at levels below MCLs or action levels. The potential human exposure routes identified by the risk assessor included ingestion and inhalation of soil.

The planning team (Remedial Project Manager (RPM), Field Sampling Expert, Hydrogeologist, and Statistician) decided to focus statistical planning on the soil media at the landfarm and the area southwest of the landfill. The plan for the landfill area was systematic sampling. The team also decided to design a groundwater study based on best professional judgement. A statistical approach was not considered because of the karstic topography.

The Remedial Investigation Pilot Study and complete analytical results can be found in Appendix G.

3.6.1 LANDFARM

Since only a handful of samples were taken from the landfarm area in previous sampling events, and these varied from non-detects to fairly high levels, phased sampling events were planned. The first phase was a preliminary study (Pilot) to determine whether chromium was the only contaminant contributing significantly to risk; to estimate the approximate magnitude and variability of contamination; and identify problem areas (if they existed) with a desired level of confidence. If needed, a second phase would have been planned to more accurately define the problem areas; and a third phase would then have been planned to further refine problem areas and estimate the volume of contaminants requiring remediation.

The first decision that should be made was stated as follows: determine whether sections of the landfarm (soil) pose an unacceptable risk to human health. The range of actions that would result from this decision included: no action (no area of the Site was a problem); sampling for higher resolution (at least one area appeared to be a problem and further sampling would be needed); or initiate an expedited response action (if an area posed a serious and immediate risk).

Certain assumptions and techniques were specified in order to determine what contaminants and at what concentrations would pose an unacceptable risk. Initial assumptions about risk were established for the Site as follows:

The primary contaminant expected to contribute to risk was chromium. In all likelihood, the majority would be in the trivalent state; however, hexavalent chromium was considered a possibility. Soil ingestion and inhalation were considered viable pathways. The landfarm is currently being used as pasture land and could conceivably become developed for residential purposes based on land use trends in the area.

A 10^{-5} risk level was selected to generate risk-based concentration values (preliminary remediation goals). Risk Assessment Guidance, Part B was used in calculating the preliminary remediation goals (PRGs). The soil PRG for chromium was calculated to be 140 mg/kg. The PRG reflected a 10^{-5} risk level and was based on the carcinogenicity of hexavalent chromium by the inhalation route of exposure. Hexavalent chromium is not considered to be a carcinogen by the oral route of exposure, but it is considered to be a potent carcinogen via the inhalation exposure route. Trivalent chromium has not been evaluated by EPA for evidence of human carcinogenic potential. The soil PRG, based on human carcinogenic properties, is very conservative in that it assumes all chromium is in the hexavalent form.

The health-based soil concentration for chromium based on its noncarcinogenic toxicity was 130 mg/kg. This value, for the most part, reflected the systemic inhalation toxicity of total chromium. (The inhalation RfD is the same for the trivalent and hexavalent forms of chromium). Incidentally, this concentration is about the same as the concentration that would reflect a 10^{-5} cancer risk level.

It is important to note that the PRGs developed for the Site were initial PRGs that were considered adequate for purposes of planning. PRGs were developed for all contaminants of concern (COCs), but chromium was considered to be the COC that would drive risk at the Site. The PRGs were modified during the RI to reflect the data collected as part of the RI (e.g., reevaluation of the media of concern, the contaminants of concern, the land-use assumptions and exposure pathways, toxicity information, and changes made in guidance). In the particular case of chromium, guidance was revised causing the PRG to increase an order of magnitude higher than the original calculated value. Region IV made the determination that chromium data (species-specific toxicity and the toxicity/carcinogenicity of the exposure route) is generally not available to make the critical judgement needed to derive meaningful point estimates for risk or cleanup values. EPA Region IV recalculated the risk-based range for chromium in soil. The range was calculated to be 600 to 1200 ppm for this Site. This range of values has conservative exposure-assumption aspects and can be considered a reasonable risk range for total chromium.

Surface soil was defined as the top 12 inches of soil within the geographic boundaries of the 29-acre landfarm area, excluding the forested areas (where landfarming could not have taken place). The Site was divided into grids based on the smallest area within which exposure could be limited under the most conservative, reasonable, future use scenario (residential development). The grids were defined as 200 feet x 200 feet. These areas are referred to as exposure units (EUs).

A map of the Site was generated depicting each grid. See Figure 3-1. Grids which overlapped the Site boundaries were combined with adjacent grids to come up with areas of approximately the same acreage. If any EU was determined to be a problem (the COC concentrations exceeded the PRG), then subsequent phases of study would be needed to look at smaller areas within EUs.

The RPM with the assistance of the risk assessor developed performance constraints to express the desire to avoid decision errors. Figure 3-2 is a graphical representation of the desired confidence limits. The statistician was given the task of developing a sampling design to meet these performance constraints. If the Site posed a risk greater than 10^{-4} risk, the RPM wanted to limit this kind of error to $< 1\%$. The RPM also wanted to limit error to $< 1\%$ of deciding the Site was a problem if in truth the Site posed $< 10^{-6}$. Between 5×10^{-6} and 10^{-6}, the RPM was willing to tolerate at most, a 50% chance of deciding to perform further study. When true risk was between 5×10^{-5} and 10^{-4}, the RPM wanted at least a 70% chance of studying the EU further. The darker gray region between 5×10^{-5} and 5×10^{-6} indicates that either decision was tolerable.

In order to develop the sampling design, the statistician needed at least three things: data from the site to understand the COCs and their distribution and variability (i.e., within EUs); information on the sensitivity, precision, and bias associated with available sampling an analysis methodologies, and an idea of the resources and practical constraints on the sampling design. The statistician recommended a preliminary study (Pilot Study), because the existing historical data was inadequate to estimate variability, especially at the EU scale.

A spatially intensive design was then developed which would gather composite surface soil sample from each EU using a systematic grid sampling design. Figure 3-3 illustrates the location of the aliquots in the example grid pattern. In four of the EUs, an offset composite sample was taken (Figure 3-4). The offset samples provided estimates of variability.

Many of the landfarm's grided areas (EUs) contained treed areas where no landfarming occurred. Aliquots were collected from the open areas of these EUs. At the same time, there were some small open areas of the landfarm which were not contained in designated EUs. For decision making and sampling purposes, these areas were combined with neighboring EUs.

After combining, the open areas sampled were close to the same size as other EUs. The following areas were combined:

H-9 and OG1 (the off-grid area to the NW of H-9)
H-18 and OG2 (the off-grid area to the west of H-18)
H-19 and OG3 (the off-grid area to the north and west of H-19)
H-26, OG4 and OG5 (the off-grided areas to the west of H-26)
H-29, H-30 and OG6 (the off-grid area to the west of H-30)
H-27 and H-28
H-20 and H-21

No special problems were expected for locating aliquots for EU's H-1 through H-8. These EUs had very few trees or other obstructions. If an aliquot fell on such an obstacle, the sampler selected a location close to the obstruction and kept a written record.

- The regular pattern, when applied to H-9, was expected to yield only 4 aliquots in the open area. The remaining 5 aliquots were taken from off-grid area 1 (OG1).

- For H-11 and H-13, obstructions existed for a few aliquots. 8 aliquots were taken from each grid.

- H-14 had a large treed area. Five aliquots were taken from the open area.

- H-15 had one aliquot located in the treed area. Eight aliquots were taken from the open area.

- H-16 and H-17 were totally in the open. To determine variability, these areas required two composites. The first composite aliquots were taken using the regular grid spacing. Locations for the second composites were offset from the nine original aliquot location as shown in Figure 3-4.

- H-18 was only about half open. Five aliquots were taken on or close to the regular aliquot location. The remaining five aliquots were taken from OG-2.

- H-19 had 7 of the regular aliquot locations in the open. Remaining aliquots were taken in OG-3. A second composite was taken from this area.

- H-20 and H-21 were combined; however, only 7 aliquots were taken due to the large treed areas.

- 7 aliquots were taken from H-25.
- H-26 had 3 aliquots in the open. The remaining aliquots were taken from OG-4 and OG-5.
- H-27 had 1, 2, and 3 in the open, while H-28 had 1, 2, 3, 4, 5, and 6 in the open. Aliquots were taken from these locations.
- H-29 and H-30 each had six aliquots in the open. Three additional aliquots were taken from OG-6.

A single subsurface soil sample (no compositing) was taken at three feet from the center of each EU. Several EUs were not sampled since they have centers in treed areas and are located in areas not suspected of landfarming (EUs H-20, 21, 27 and 30).

The planning team did not expect subsurface soil to be a problem due to the landfarming disposal method and trivalent chromium's low solubility. The performance analysis of this systematic sampling had a 90% chance of detecting any one-acre area of elevated subsurface contamination. The probability of hitting a single elliptical hot spot of 1-acre size (if it existed) was less than 90%, while the probability of hitting an existing hot spot of 2-acres was greater than 90%.

As previously stated, a select number of surface soil samples from the landfarm were analyzed for the full TCL/TAL. Grids H-25 and H-26 were analyzed for the full scan because grab samples in previous investigations had shown high concentrations of chromium.

3.6.2 SOUTHWEST AREA

The area to the southwest of the landfill (Grids HV-1 through HV-8, Figure 3-1) was included in the RI due to the likelihood of contaminants deposited in the area by surface runoff from the landfill. The grids in this area were sampled by collecting a composite sample from each grid. The number of aliquots and the pattern of their collection was the same as that used for the landfarm area. An offset sample was collected from each grid in this area to measure the variability of concentrations within each grid. The offset aliquot pattern used the same scheme as the landfarm (Figure 3-4).

Subsurface soil within this area was sampled by collecting a grab sample from a depth of three feet at the center of each grid in the same manner as the landfarm.

3.6.3 LANDFILL AREA

The landfill area (Grids V-1 through V-18, Figure 3-1) is known to have been used to bury wastes in unlined trenches to a depth of approximately six feet. Previous sampling indicated that clean fill material was used to cover the trenches upon closure. Therefore, it was expected that contaminants in this area would primarily be a subsurface soil problem.

Sampling in the landfill area was accomplished by collecting systematic samples at the center of each grid. Grab samples were attempted from the surface and depths of three feet, six feet, and nine feet. Native soils were expected at depths no greater than 10 feet.

Subsurface soil samples from the second level (6') were not collected from grids V-7, V-9, V-13 and V-16. Auger refusals due to rock at grids V-9, V-13 and V-16 were the reason for no sampling at this depth. At grid V-7, waste materials (nylon, leather and rubber scraps) were encountered down to a depth of 8 feet. Since the materials had been sampled at the level 1 subsurface location, the samplers attempted to auger below the wastes for the level 2 sample. The waste materials prevented auger advance prior to encountering native soils.

Level 3 subsurface soils were sampled at only three locations. The samples collected were from grids V-5, V-11 and V-12. Auger refusal due to rock or impenetrable waste caused the remaining samples to go uncollected.

3.7 DYE TRACING TO DEFINE THE DIRECTION OF GROUND-WATER FLOW

The U.S. Geological Survey (USGS) performed a series of dye-tracer tests to determine the direction of ground-water flow and the location of natural discharge points (springs) for the karst aquifer system that drains the Site. The tracer tests would also determine if ground water from CLL Site drains to a karst spring that is the source of water for the City of Auburn.

The types of tracers, tracer injections, sampling and analyses performed during this dye-trace may be found in Appendix C.

3.8 RAIN EVENT AND QUARTERLY MONITORING

Roy F. Weston, Inc., (Weston) was tasked with performing rain event and quarterly sampling of selected springs that receive surface runoff and are recharged by ground water flowing from the CLL Site. The springs were selected based upon USGS recommendations and studies by Quinlan and Ewers.

A rain event, was defined as when significant accumulation of rainfall occurred over a 24 - 48 hour period. Under these circumstances, surface runoff and rainwater percolating through soils would result in recharging of the various hydraulically connected streams within a period of three to five days. Hence, any form of off-Site migration of contaminants resulting from rainfall would theoretically be traceable at the sampling locations within three to five days. Two rain monitoring events were performed as part of the RI.

All rain sampling events were performed in cooperation with EPA Region IV ERRB and the TAT office located in Louisville, Kentucky. The complete analytical results for these sampling events may be found in Appendix J.

Specific dates for conducting rain event samples were determined through the interpretation of rainfall accumulation as recorded by the Eastern Kentucky Climatology Center located in Bowling Green, Kentucky. Although this data was not specific to the Site, the data was considered to be representative considering the close proximity (approximately 10 miles due east from the Site). When rainfall periods occurred, representatives of the Louisville TAT office would contact the Climatology Center for rainfall accumulation records.

The two rainfall event sampling were conducted on June 3, 1992 and September 23, 1992. The following table summarizes rainfall accumulation for the dates preceding each rainfall sampling event.

SUMMARY OF RAINFALL ACCUMULATION

June 3, 1992		September 23, 1993	
May 29	2.91 inches	September 19	0.67 inches
May 30	0.06 inches	September 20	----
May 31	----	September 21	0.39 inches
June 1	----	September 22	1.73 inches
June 2	----		

In order to assess the potential for off-Site migration during periods of non-rain event weather conditions, three quarterly monitoring events were performed during the RI. All groundwater data collected prior to the last quarterly sampling event, indicated that metals were the only contaminants of concern. Thus, only metals were sampled in the last quarterly sampling event. Previous sampling events included full-scan water samples. The last quarterly sampling event

included the collection of sediment samples (TAL) from two locations downstream from the spring discharge point.

3.9 SOIL BORINGS 1992

In December 1992, Weston installed nine soil borings as part of the hydrogeologic investigation. If during the installations groundwater was encountered, the boreholes would be converted into temporary wells and sampled. The boreholes were to be installed in the landfill downgradient of known trenches. The purpose of the boreholes was to gain a better understanding of possible migration of contamination from the trenches in the vadose zone and if possible at the saturated zone boundary.

Each soil boring was installed utilizing an all-terrain mobile drill rig operating under standard ASTM methods. Soil samples were collected through the use of a split-spoon sampling rod on a continuous basis from land surface to auger refusal or a maximum depth of 60 feet. As each sample was retrieved, a Weston field geologist examined the soils and noted the geologic characteristics. All soils were classified using the Unified Soil Classification System. Copies of the geologic logs are presented in Appendix E. With the exception of soil boring #3, soil samples were collected at three distinct points throughout the soil column. These sampling points consisted of a surficial sample (0.0 - 1.5 ft), an intermediate sample (9.0 - 10.5 ft), and a deep sample as determined by auger refusal or termination based on footage. For soil boring no. 3, auger refusal occurred at 10.5 feet. All samples were ultimately forwarded to the assigned CLP Laboratory for analysis of TAL/TCL including PCBs and pesticides.

The complete analytical results for this sampling event may be found in Appendix K.

3.10 SAMPLE COLLECTION AND HANDLING PROCEDURE

All samples were collected, preserved, handled and documented in accordance with Appendix D of the Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual, April 1986 (SOP) or as specified by the current USEPA standard procedures and protocols for the contract analytical laboratory program. All TAL/TCL samples collected for analysis was booked into the Environmental Services Division laboratory through the Regional Sample Control Center (RSCC).

In order to insure homogeneity of composite soil samples collected during the Remedial Pilot Study, additional mixing was required. To accomplish this, a special mixing procedure was devised to use on all composite samples (except VOAs). Mixing of the composite samples were accomplished as follows:

- An auger bucket of soil from the first aliquot location was placed in a glass pan. The soil was mixed with a stainless steel spoon. Two spoonfuls of the homogenized soil was placed into a second glass pan. When this procedure was completed for all aliquots with the grid, the contents of the second glass pan was homogenized and then placed into sample jars. A slight deviation from this procedure occurred with regards to mixing some aliquots. The first aliquot was mixed in the auger hole before placing the homogenized sample into the glass plan. Thus, reducing the need for a second glass pan.

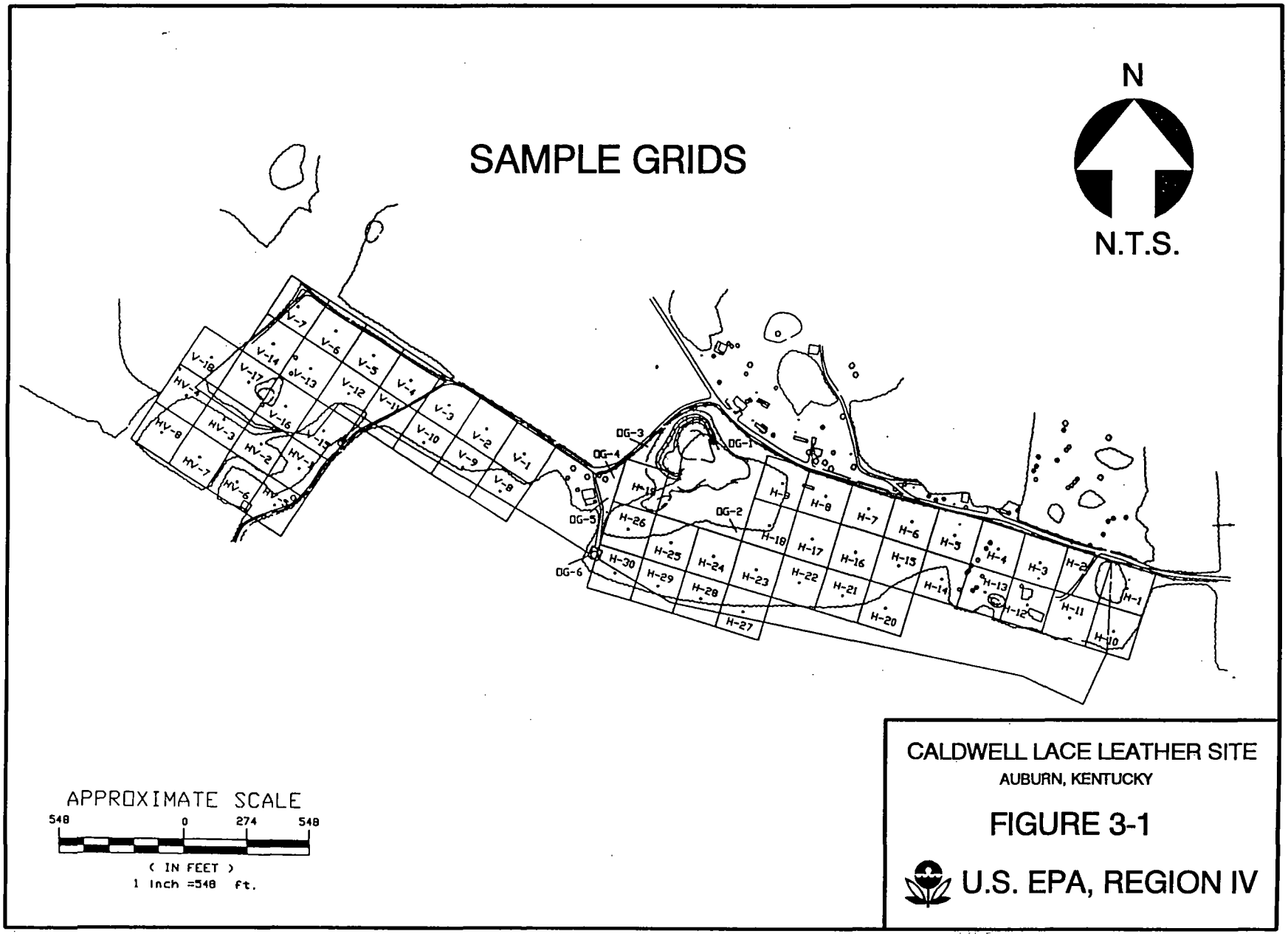
Also, as part of the Remedial Pilot Study, twelve soil samples were collected for hexavalent chromium. An EPA standard method for hexavalent chromium in soil does not exist. However, a field screening method has recently been marketed by the Hach company. The method is a colorimetric test which the manufacturer claims is capable of parts per billion sensitivity. The sample locations were selected so as to give results representative of background conditions, contaminated soil, and waste.

For quarterly and rain sampling events, duplicate samples were taken for hexavalent chromium analysis. EPA Method #SW-846 and method #117A were used for the analyses by two laboratories in Bowling Green, Kentucky.

3.11 ABBREVIATIONS

Several abbreviations are used in the remainder of the report with regard to analytical results. They include:

NA	-	Not analyzed.
J	-	Estimated Value.
N	-	Presumptive evidence of presence of material.
--	-	Material was analyzed for but not detected.
U	-	Material was analyzed for but not detected. The number is the minimum quantitation limit.
R	-	Quality control indicates that data are unusable, compound may or may not be present. Resampling and reanalysis is necessary for verification, the value is that reported by the laboratory.
ppb	-	Parts-per-billion (ug/l-micrograms per liter or ug/kg-micrograms per kilogram).
ppm	-	Parts-per-million (mg/l-milligrams per liter or mg/kg-milligrams per kilogram).
MCL	-	Safe Drinking Water Act Maximum Contaminant Level


SAMPLE GRIDS
N
N.T.S.
APPROXIMATE SCALE
548 0 274 548
(IN FEET)
1 Inch =548 ft.
CALDWELL LACE LEATHER SITE
AUBURN, KENTUCKY
FIGURE 3-1
U.S. EPA, REGION IV

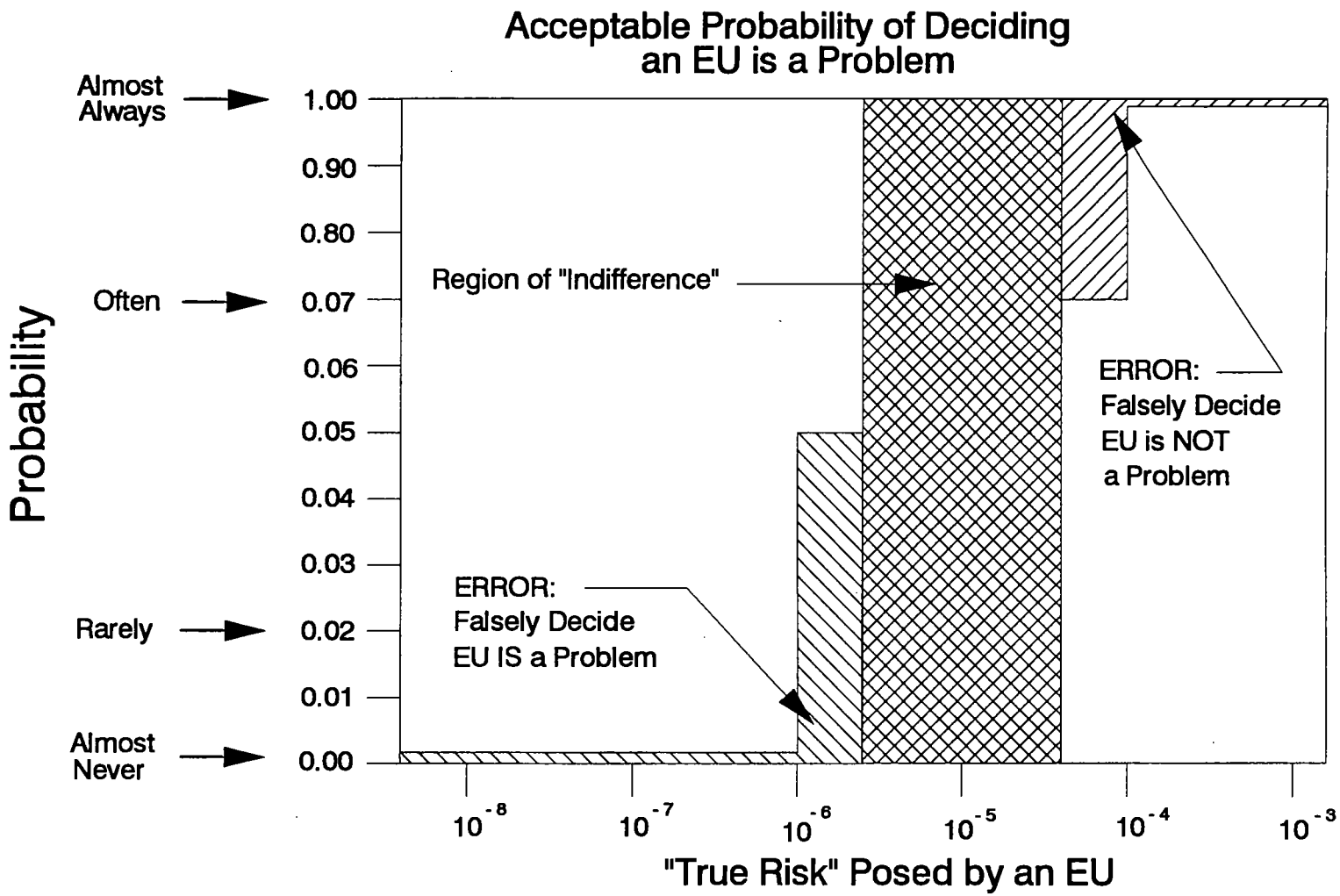
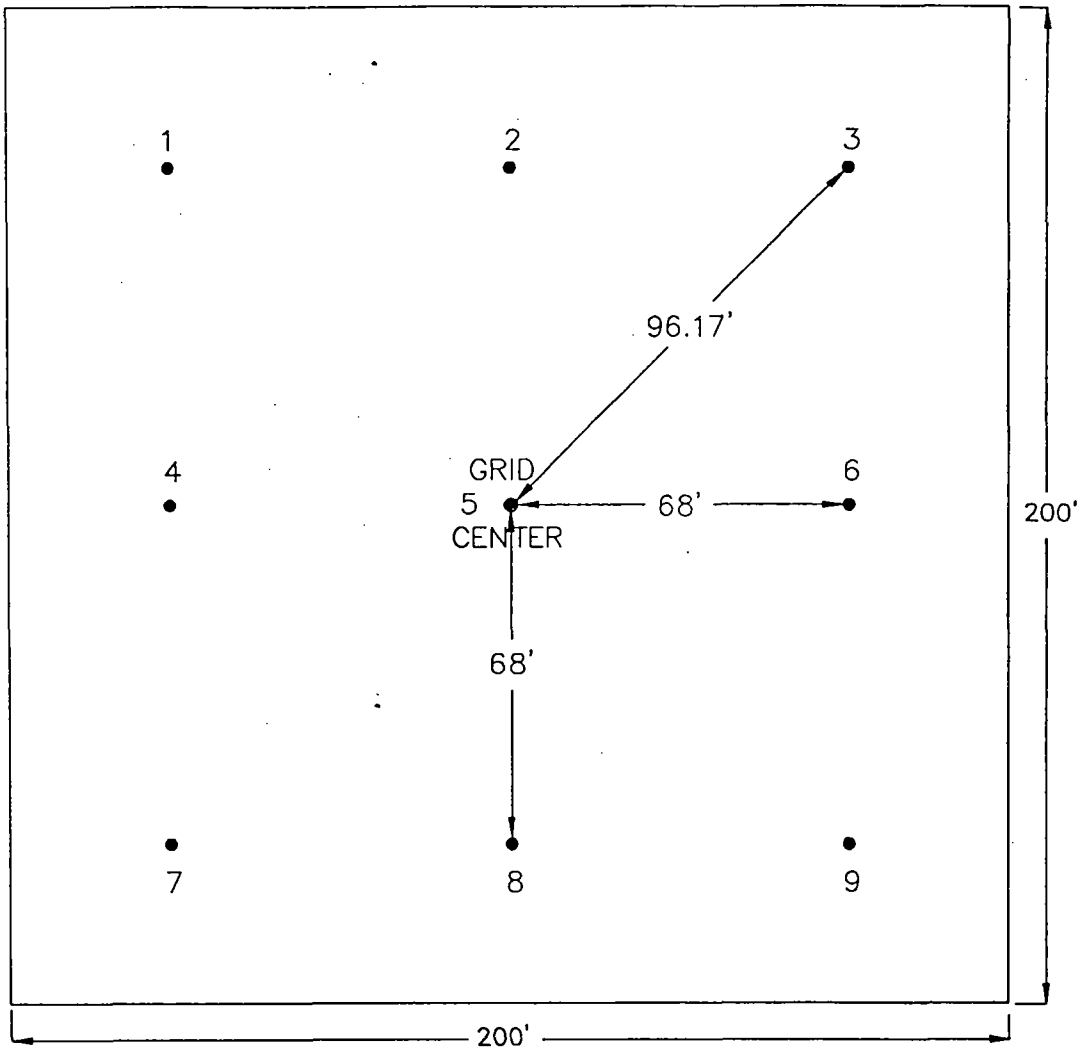


FIGURE 3-2 DESIRED CONFIDENCE LIMITS
CALDWELL LACE LEATHER
AUBURN, KENTUCKY

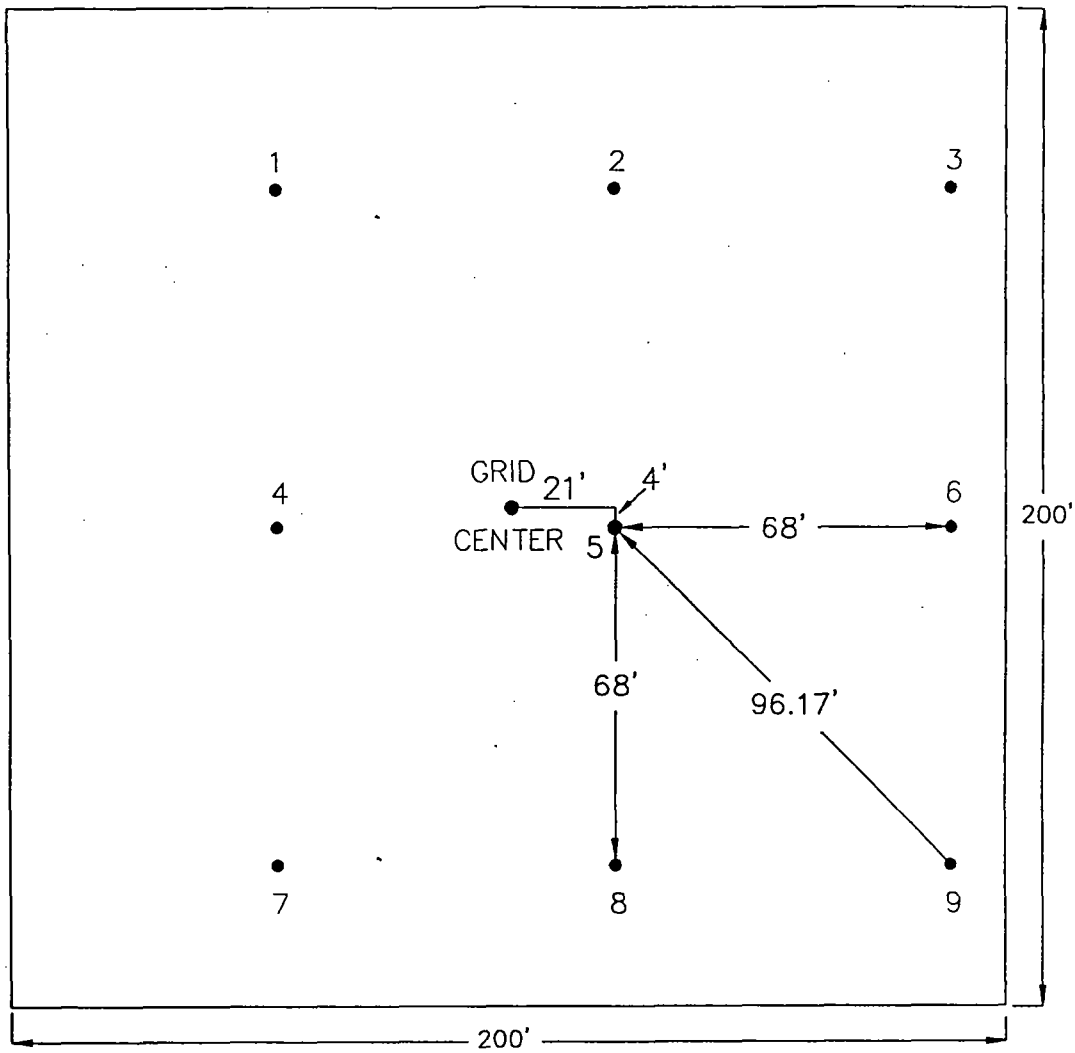


TYPICAL SURFACE SOIL SAMPLE PATTERN

CALDWELL LACE LEATHER SITE
AUBURN, KENTUCKY

FIGURE 3-3

U.S. EPA, REGION IV



OFFSET GRID SAMPLE PATTERN

CALDWELL LACE LEATHER SITE
AUBURN, KENTUCKY

FIGURE 3-4

U.S. EPA, REGION IV

4

4.0 MEDIA INVESTIGATION

4.1 SOILS

4.1.1 PRE-REMEDIAL SAMPLING 1990

4.1.1.1 SAMPLE LOCATIONS AND RATIONALE

Surface and subsurface soil samples (CL-001-SLA and CL-001-SLB) were collected from the northwest corner of a pasture owned by Miss Emma Belle Hall (Photo Map Number 123) of Auburn (Figure 4-1). The purpose of this sample was to provide control data as to soil conditions and possible contaminants from an area not influenced by the Site. The surface sample was collected from the surface to a depth of 4 inches. The subsurface sample was collected at a depth of 25 feet. Groundwater was not encountered.

Samples CL-003-SLA and CL-003-SLB were collected from the area to the east of the landfarm area (Figure 4-1). Reportedly, no waste was disposed in this area. The surface soil at this location was collected from the surface to a depth of 4 inches, and the subsurface soil was collected from a depth of 2 to 2.5 feet, which was similar to that of the previous two samples from the landfarm area where waste material was encountered. The purpose of these samples was to determine if any waste disposal occurred beyond the reported east end of the landfarming area.

Two surface soil (CL-004-SLA and CL-005-SLA) and two subsurface soil samples CL-004-SLB and CL-005-SLB) were collected from the landfarm area (Figure 4-1). The surface soils were collected from the surface to a depth of 4 inches. The subsurface soils were collected at a depth between 2 and 2.5 feet. The purpose of these samples was to characterize the waste reportedly disposed in this area.

Surface and subsurface soils (CL-006-SLA and CL-006-SLB) were collected from the bed of the old sludge storage pond in the landfill area (Figure 4-2). The surface soil was collected from the surface to a depth of 4 inches. The subsurface soil was collected from a depth between 2 to 2.5 feet, which was the zone just above native soil assumed to be the bottom of the storage pond. The purpose of these samples was to detect any contaminants in the soil resulting from the locations previously used for sludge storage.

Surface and subsurface soil samples CL-007-SLA and CL-007-SLB were collected from disposal pit TR-7 in the landfill area of the Site (Figures 4-2 and 4-4). The surface soil sample was collected from the surface to a depth of 4 inches. The subsurface soil sample was collected at

the same location from a depth between 2 to 2.5 feet where waste material was encountered. The purpose of these samples was to characterize the waste reportedly disposed of in the pit.

Surface and subsurface soil samples CL-008-SLA and CL-008-SLB were collected from disposal pit TR-13 in the landfill area of the Site (Figures 4-2 and 4-4). The surface soil was sampled from the surface to a depth of 4 inches. The subsurface soil was sampled at the same location from a depth between 5 to 5.5 feet where waste material was encountered. The purpose of these samples was to characterize the waste reportedly disposed of in the pit.

CL-009-SLA and CL-009-SLB were surface soil and subsurface soil samples collected from a pit in the "Phase II" closure portion of the landfill area (Figure 4-2). The surface soil sample was collected from the surface to a depth of 4 inches. The subsurface soil sample was collected from the same location at a depth between 3.5 and 4.5 feet which was where material was encountered. The purpose of these samples was to characterize the waste reportedly disposed in the pit.

Surface and subsurface soil samples CL-010-SLA and CL-010-SLB were collected from a pit in the "Phase II" closure portion of the landfill area (Figure 4-2). The surface soil was sampled at a depth between 1 and 1.5 feet, which was where waste material was encountered. The purpose of these samples was to characterize the waste reportedly disposed of in the pit.

Two of the pits in the "Phase III" closure portion of the landfill area (Figure 4-2) were sampled. CL-013-SLA and CL-013-SLB were surface soil and subsurface soil samples. CL-013-SLA was collected from the surface to a depth of 4 inches. The subsurface soil sample (CL-013-SLB was collected from the same pit at a depth between 3 and 3.5 feet which was where waste material was encountered. CL-014-SLA and CL-014-SLB were surface and subsurface soil samples collected from a second pit in the area. The surface soil at this location was sampled to a depth of 3 inches, while the subsurface soil was sampled at a depth of between 2 and 2.5 feet, which is where waste material was encountered. The purpose of these samples was to characterize the waste reportedly disposed of in the pits.

4.1.1.2 DATA DISCUSSION

Complete analytical results are presented in Appendix F. The results are summarized in Tables 4-1 through 4-4.

- High concentrations of chromium, as well as organic acids and alcohols normally associated with tanning, were detected in the landfill subsurface soil.

- Lead, mercury, chlorinated solvents and PAH compounds were detected in the landfill. Landfill leachate showed metal concentrations above background.

- Concentrations of chromium was detected above background concentrations in the surface soil of the landfarm. This finding causes suspicion that some of the wastes were merely dumped on the ground rather than being disked into the ground.

- Lead, mercury, chlorinated solvents and PAH compounds were detected. This indicates a possibility that materials other than tanning wastes were disposed of at the Site.

- Highly contaminated leachate was detected on the surface of the Site.

SURFACE SOIL

Analytical results for surface soil samples showed the presence of several contaminants; some were at fairly high concentrations. Samples collected from the landfarm area contained both organic and inorganic compounds. Prominent among these was the reported presence of chromium at location CL-005-SLA at a concentration of 1,100 mg/kg. The sample collected from location CL-003-SLA also contained chromium, but at a much lesser concentration (64 mg/kg). CL-003-SLA also showed the presence of lead at an estimated concentration of 18 mg/kg. Pentadecanoic and hexadecanoic acids were presumed present in samples from CL-003-SLA and CL-004-SLA at trace levels. A summary of analytical results for the landfarm surface soil results are presented in Table 4-1.

Samples collected from the landfill area showed chromium present in the sample from CL-014-SLA at 73 mg/kg. Lead was detected at sample locations CL-010-SLA and CL-013-SLA at estimated concentrations of 210 mg/kg and 39 mg/kg, respectively. Samples from CL-009-SLA and CL-010-SLA contained mercury at concentrations of 0.10 mg/kg and 0.46 mg/kg respectively. Organic acids associated with tanning (i.e. pentadecanoic acid, hexadecanoic acid, etc.) were detected at all surface soil sample locations in the landfill area except CL-006-SLA. Estimated concentrations ranged from 300 to 2,000 μg/kg. Sample locations CL-010-SLA and CL-014-SLA showed the presence of polynuclear aromatic hydrocarbon (PAH) compounds at low concentrations. A summary of landfill surface soil results are presented in Table 4-3.

SUBSURFACE SOIL

Subsurface soil sample results from the landfarm are not significantly different than

background samples (CL-001-SLB and CL-003-SLB). A summary of landfarm subsurface soil results are presented in Table 4-2.

Landfill subsurface soil samples indicated that several organic and inorganic contaminants were present, some were detected at high concentrations. Chromium was detected at five locations. The sample from the pit at CL-008-SLB contained 5,600 mg/kg, while locations CL-006-SLB, CL-010-SLB, and CL-013-SLB showed lower concentrations ranging from 110 mg/kg to 370 mg/kg. Locations CL-008-SLB, CL-009-SLB, and CL-014-SLB contained lead at estimated concentrations ranging from 13 mg/kg to 46 mg/kg. Mercury at 0.11 mg/kg, was detected at location CL-010-SLB.

A variety of organic acids and alcohols associated with tanning, were detected at all locations sampled in the landfill area. Concentrations ranged from estimated levels of 730 μg/kg to 200,000 μg/kg. 1,2 dichlorobenzene was detected in the sample from CL-008-SLB at an estimated concentration of 500 μg/kg, and n-nitrosodiphenylamine/diphenylamine was detected at CL-009-SLB at a concentration of 680 μg/kg. A variety of PAH compounds was detected in low concentrations at location CL-006-SLB, CL-009-SLB and CL-014-SLB. Sample location CL-013-SLB showed a variety of volatile organic compounds including acetone at an estimated concentration of 5,000 μg/k, toluene at 470 μg/kg, and methyl ethyl ketone (MEK) at an estimated concentration of 1,400 μg/kg. Acetone was also detected at location CL-014-SLB at an estimated concentration of 3,500 μg/kg. A summary of the landfill subsurface soil results are presented in Table 4-4.

4.1.2 GROUNDWATER SAMPLING AND GEOPHYSICAL REPORT 1991

The objectives of this pilot study were to provide initial estimates of contaminant concentration variability on the landfarm area and the area to the southwest of the landfill; to identify exposure units which may require further investigation; and to define vertical extent of contamination in the landfill area.

4.1.2.1 SAMPLING LOCATIONS AND RATIONALE

Two surface soil samples were collected as part of this sampling effort. The purpose of these samples was to confirm the presence of chromium concentrations found at the landfarm portion of the Site, and to investigate possible accumulation of contaminants by surface drainage deposition near a large sinkhole. Description of the two sample locations are as follows:

- CL038SLA

  This sample was collected from a pasture owned by Mr. Danny Basham. The sample location is downgradient of the area on the landfarm where previous sampling indicated the presence of chromium. The sample was of surface soil to a depth of 4 inches.

- CL039SLA

  This sample was collected from a location on the landfarm. Results of previous sampling showed this area to contain significant (approximately 1,000 mg/kg) concentrations of chromium in the surface soil. The sample of soil from this location was collected from the surface to a depth of 4 inches.

4.1.2.2 DATA DISCUSSION

Complete analytical results may be found in Appendix I. The data is summarized in Table 4-5.

Analyses of the two soil samples showed the presence of chromium at both the pasture and the landfarm locations. The pasture sample location (CL038SLA) showed the presence of chromium at 21 mg/kg and the landfarm location showed chromium at 120 mg/kg. Additionally, lead was detected at the pasture location at 22 mg/kg and at the landfarm at a concentration of 13 mg/kg. Trace levels of mercury were reported at 0.18 mg/kg for the pasture and 0.15 mg/kg for the landfarm.

4.1.3 REMEDIAL INVESTIGATION PILOT STUDY 1991

4.1.3.1 SAMPLING LOCATIONS AND RATIONALE

LANDFARM AREA

Contaminants in the landfarm area were expected to be primarily in the first foot of soil. Therefore, emphasis was placed on sampling surface soil, with subsurface soil studied to a lesser extent. The extent of contamination was determined based upon a statistical sampling approach. The area was divided into thirty grids (H-1 through H-30, Figure 4-6) each measuring 200 feet x 200 feet or approximately one acre. The surface of each full grid area was sampled by collecting a composite of up to nine aliquots each. Second samples were taken in select grids using an offset pattern to determine variability of concentrations within the grids. Subsurface soil samples from the landfarm area were

collected from the centers of grids. The samples were grabs taken from a depth of three feet.

SOUTHWEST AREA

The area to the southwest of the landfill (Grids HV-1 through HV-8, Figure 4-6) was included in this study due to the likelihood of contaminants deposited in the area by surface runoff from the landfill. The grids in this area were sampled by collecting a composite sample from each. The number of aliquots and the pattern of their collection was the same as that used for the landfarm area. An offset sample was collected from each grid in this area to measure variability of concentrations. The offset aliquot pattern used the same scheme as the landfarm.

Subsurface soil within this area was sampled by collecting a grab sample from a depth of three feet at the center of each grid in the same manner as the landfarm.

LANDFILL AREA

The landfill area (Grids V-1 through V-18, Figure 4-6) is known to have been used to bury wastes in unlined trenches to a depth of approximately six feet. Previous sampling indicated that clean fill material was used to cover the trenches upon closure. Therefore, it was expected that contaminants in this area would primarily be a subsurface soil problem.

Sampling in the landfill area was accomplished by collecting samples at the center of each grid. Grab samples were attempted from the surface and depths of three feet, six feet, and nine feet.

SINKHOLES

In order to address the possible route of surface runoff from the landfarm area in the groundwater via an area of sinkholes in the northwest corner of the Site, two composite soil samples were collected. Sample SHA was a three aliquot composite of surface soil from the sinkhole closest to the landfarm. SHB was a three aliquot composite of surface soil from the northernmost sinkhole. The samples were analyzed for full TCL/TAL parameters.

Surface soil samples were collected from two locations within a large sinkhole located on the southwest corner of the landfarm. Sample SHA was collected from the bottom

of the southern most portion of the sinkhole. The sample was composite consisting of three aliquots of soil from a depth of 6 to 12 inches.

Sample SHB was collected from the eastern edge of the main sinkhole where it borders the landfarm. This sample was also a composite consisting of three aliquots of soil from a depth of 6 to 12 inches.

SPECIAL SAMPLES

In an attempt to address the possibility of chromium in the hexavalent state being present on the Site, twelve samples were collected for this parameter.

Grids H-24 and H-25 (Figure 4-6) in the landfarm area were both sampled at the surface and at a depth of 3 feet. In the southwest area, samples from each of grids HV-2 and HV-3 were collected of the surface soil and subsurface soil at a depth of 3 feet. From the landfill area, samples were collected from Grid V-5 at a depth of 9 feet, Grid V-9 at a depth of 3 feet, Grid V-12 at the surface and at depths of 3 feet and 9 feet, and Grid V-16 at a depth of 3 feet.

4.1.3.2 DATA DISCUSSION

Complete analytical results may be found in Appendix G. The data is summarized in Tables 4-6 through 4-14.

The results of this study show that surface deposition of waste material on the landfarm resulted in no contaminant concentrations above preliminary remediation goals. The southwest area did not show any evidence of contamination. The landfill area showed high concentrations of contamination in the waste pits themselves. However, sample results indicate that little if any migration of wastes from the pits has occurred.

LANDFARM AREA

Analytical results of samples collected from the landfarm area showed a few locations which contained chromium in the surface soil. As expected, no elevated concentrations were detected in the subsurface soil.

All samples collected from the landfarm area were analyzed for metals. Complete TCL/TAL analyses were conducted for the surface soil (both standard and offset patterns) and subsurface soil from grid H-24 and H-25. Results from both grids showed no

organics or pesticides present above the minimum detectable limits. Results of analyses of surface soil samples from the landfarm area are summarized in Tables 4-6 and 4-7. Subsurface soil sample results from the landfarm are summarized in Tables 4-11, 4-12 and 4-13.

The highest concentrations of chromium detected were in grids H-22 and the combination of H-27/H-28/G2. Samples collected from these areas each contained 220 mg/kg. The null hypothesis was tested versus the alternative that the mean concentration was less than the PRG of 600 mg/kg. The null hypothesis, H_0 is an assumption that the sample area is "dirty."

H_0: Mean concentration in the EU is greater than or equal to 600 mg/kg.

The significance level of the test (probability of rejecting the null hypothesis when it is true) should be 5%.

In this report, "mean" refers to the geometric mean concentration. Because of the small variance, this is a trivial point. If the true standard deviation on the natural log scale is 0.20, then the true arithmetic mean and the true geometric mean for an exposure unit differ by a factor of about 2%. For example, the geometric mean corresponding to an arithmetic mean of 100.00 is 98.02. Statistical tests are done for the geometric mean to be consistent with the belief that standard deviation is roughly proportional to concentration level.

Table 4-15 provides information for testing the hypothesis at 5%. The upper 95% confidence limits are given to be consistent with RAGS guidance and should be compared with 600 mg/kg. Two key assumptions were made in using this confidence limit:

(1) The assumed distribution is lognormal and
(2) Results from the five EUs having two composites may be composited to provide a 5-degrees-of-freedom estimate of variance.

The second assumption is critical. If there was reason to believe that variability in different EUs was substantially different, then pooling would not make sense and there would be no way to test the hypothesis for EUs where only one composite was taken. Fortunately, there are reasons to accept this assumption. First, the Site history indicates that the surface soil was turned in an attempt to disperse the contaminants. Secondly, data from the five EUs do not indicate that the assumption is invalid (although they provide little power to reject the assumption if it were incorrect).

Notice that, under these assumptions, the null hypothesis may be rejected for ALL exposure units.

SOUTHWEST AREA

All grids in the southwest area of the Site were sampled for the full TCL/TAL parameters in both surface soil and subsurface soil.

Two organic compounds were presumed to be present in the surface soil. At grid HV-1, octahydrotrimethyl (methylethyl) phenanthrenol was presumed to be present at an estimated concentration of 1,000 μg/kg. Also, an estimated concentration of 700 μg/kg (propenyl)benzodioxole was presumed to be present.

Results of the analyses showed metals (including chromium) to be at levels consistent with background conditions of the area. Analytical results of surface soil samples from the southwest area are summarized in Tables 4-8. Subsurface soil analytical results are summarized in Table 4-9.

LANDFILL AREA

All samples from the landfill area were analyzed for the full TCL/TAL parameters in both the surface soil and subsurface soil.

Surface Soil

Analytical results of surface soil samples from the landfill area are summarized in Table 4-10.

Three grids showed the presence of metals above native soil concentrations on the surface. Grids V-9 and V-10 had respective concentrations of 5,600 mg/kg and 78 mg/kg of chromium, while grid V-5 had a concentration of 280 mg/kg of lead. Organic analyses showed the presumptive presence of (propenyl)benzodioxole at an estimated concentration of 6,000 ug/kg at grid V-13, while and unknown compound was detected at grid V-9 at an estimated concentration of 2,000 ug/kg. At grids V-9 and V-10, concentrated waste was encountered within three to four feet of the surface.

Subsurface Soil (Level 1)

Analytical results of level 1 subsurface soil samples from the landfill area are

summarized in Table 4-11.

Level 1 subsurface soil samples were collected at a depth of three feet for all grids in the landfill area. At grids V-4, V-9 and V-10 concentrated wastes were encountered at this shallow depth.

At grid V-4, the waste encountered consisted of mainly scraps of cloth and rubber. Analyses of this sample showed the presence of chromium at 45 mg/kg. Also present were a variety of semi-volatile organics, the most notable of which was bis (2-ethylhexyl)phthalate at a concentration of 42,000 μg/kg.

The waste encountered at three feet in grid V-9 was a black tar-like material. Analyses of this sample showed results for chromium at 280 mg/kg, lead at 45 mg/kg, and mercury at 0.18 mg/kg.

The level 1 sample from grid V-10 was from a black tar-like substance with a high moisture content. Analyses of the sample showed chromium present at a concentration of 5,000 mg/kg. Also detected were a variety of organic acids, phenols and volatile compounds. Among the volatile compounds were a number of industrial solvents and aromatics.

Subsurface Soil (Level 2)

Level 2 subsurface soil analytical results from the landfill are summarized in Tables -- and 4-12.

All level 2 subsurface soil samples were collected from depths of five to six feet. Samples were not collected from four of the grids. At grid V-7, waste consisting of leather/rubber scraps and an orange colored nylon material were encountered down to a depth of six feet. The materials were not suitable for a sample. Attempts were made to power auger through the waste to the soil below, but even this attempt failed to go beyond six feet. Therefore, a level 2 subsurface soil sample at this location was abandoned.

Grids V-9, V-13 and V-16 were not sampled at the level 2 depth because auger refusal due to a rock layer was encountered shortly after collection of the level 1 (3') sample.

The sample at grid V-4 was collected from a depth of six feet. Waste was encountered in the sample which consisted of rubber scraps. Analyses showed the presence of

chromium at a concentration of 1,900 mg/kg, lead at 33 mg/kg, and zinc at 160 mg/kg. Also detected were organic acids, phenols, and benzene compounds including toluene at estimated concentration of 49 μg/kg.

Soil collected from a depth of five at grid V-10 showed the presence of chromium at a concentration of 1,200 mg/kg. Also detected were a variety of organic acids, phenols and benzene compounds. This sample was collected from the soil underneath the waste material encountered in the level 1 sample.

The sample at grid V-11 was collected from a depth of six feet. The waste material encountered at this location consisted of a dense black sludge. Analyses showed the presence of chromium at a concentration of 4,600 mg/kg, lead at 39 mg/kg, mercury at 0.66 mg/kg, and zinc at along with phenolic compounds and a variety of chlorinated aromatic solvents.

Worthy of note among the landfill samples collected from level 2 was the one from grid V-18. This sample showed slightly elevated levels of chromium, lead and zinc not encountered in the surface or level 1 soil samples. Due to the location of this grid, these results may indicate some underground migration of the waste contaminants.

Subsurface Soil (Level 3)

At all but three grids in the landfill area, auger refusal due to a rock layer or impenetrable waste materials was encountered before reaching the level 3 depth. The three samples that were collected were analyzed for full TCL/TAL parameters.

The sample collected from grid V-5 was of the soil at a depth of nine feet. The analytical results of this sample showed the presence of chromium at a concentration of 71 mg/kg. No organic contaminants were detected.

Samples from grid V-11 and V-12 were collected from depths of 12 feet and nine feet respectively. Analytical results showed inorganic parameter concentrations consistent with background conditions, while no organic contaminants were detected. Analytical results of level 3 subsurface soil samples from the landfill area are summarized in Table 4-13.

SINKHOLES

Table 4-14 summarizes analytical results of the sinkhole samples.

Results of the analyses showed that only inorganic analytes were detected. Sinkhole SHA (closest to the landfarm) showed levels of inorganics slightly elevated above those detected in sinkhole SHB. The results of these samples suggest that some migration of contaminants via surface runoff to sinkholes is occurring.

SPECIAL SAMPLES

Results of analyses for hexavalent chromium showed no results at or above the detection limit of the method. It should be noted that an EPA standard method for hexavalent chromium does not exist. Therefore, the apparent absence of hexavalent chromium shown by the results cannot be accepted as conclusive.

4.1.4 SOIL BORINGS 1992

4.1.4.1 SAMPLE LOCATIONS AND RATIONALE

Roy F. Weston (Weston) under U.S. EPA Contract No. 68-W9-0057 was issued a work assignment (WA 05-4L4H) to provide field services in support of EPA's RI. A principal component was to perform a geologic investigation of subsurface soils at strategic locations to further evaluate the potential for downward migration of contaminants emanating from the trenches and determine the potential for adverse impact to ground water.

Based upon review of the data collected as a part of the Pre-Remedial Sampling (EPA, 1990) Investigation and the RI Pilot Study (EPA, 1991), a total of nine locations for installation of soil borings were identified. As shown in Figure 4-7, the criteria used for selection of the various soil boring locations included areas in which known disposal of wastes into unlined trenches or lagoons was known to have occurred, surface water drainage patterns which may have resulted in areas of contaminant deposition, and the natural topography of the land (east to west trending limestone ridge).

4.2.4.2 DATA DISCUSSION

Complete analytical results may be found in Appendix K. A summary of the analytical data may be found in Table 4-16.

VOLATILE ORGANICS

The Remedial Pilot Study analytical results indicated the presence of various volatile organics in samples which were characteristic of wastes. Specifically, a sample of wastes

encountered within grid V-10 at a level of 3 feet below land surface indicated the presence of xylenes (580 µg/kg), 1,4-Dichlorobenzene (620 µg/kg), and estimated concentrations of numerous other volatile organic compounds. At a depth of 6 feet in grid V-11, sample analyses revealed concentrations of 1,700 µg/kg of 1,4-Dichlorobenzene and estimated concentrations of xylene (80 µg/kg), 1,2-Dichlorobenzene (4,200 µg/kg), 1,3-Dichlorobenzene (260 µg/kg), chlorobenzene (5,400 µg/kg), and toluene (82 µg/kg). Toluene was also detected in a sample of the waste encountered in grid V-4 (49 - estimated µg/kg; whereas 1,2-Dichlorobenzene was detected in wastes of grid V-10 (33 - estimated µg/kg).

With respect to the surficial and subsurface soil samples collected as part of the soil borings, all samples were analyzed for volatile organics. In general, the results of the analyses indicated non-detectable concentrations for all analytes at virtually all sample depths. Notable exceptions to this general trend were the presence of toluene and carbon disulfide at concentrations of 16 µg/kg and 6 µg/kg (estimated) respectively, in the sample collected from 20.0-21.5 feet in SB-7. The presence of carbon disulfide is more than likely attributable to laboratory contamination at such a low level. In summary, when comparing the chemical characteristics of the various wastes present within the trenches, the results of the soil borings, with respect to volatile organics, migration does not appear to have occurred.

SEMI-VOLATILE ORGANICS

Previous sampling results (EPA, 1991) of a waste sample collected from a depth of three feet within grid V-4 indicated the presence of bis(2-ethylhexyl)phthalate at a concentration of 42,000 µg/kg, as well as estimated concentrations of various polyaromatic hydrocarbons (PAHs). Whereas, the sample from a depth of three feet within grid V-10 revealed estimated concentrations of various phenols and organic acids. Samples collected from wastes present at six foot depths within these grids and grid V-11 contained similar compounds at more significant concentrations. Semi-volatile organics were not detected in any of the samples collected by ESD at depths approaching nine feet.

With respect to semi-volatile organic compounds, analytical results indicate non-detectable concentrations at all depths. However, as noted in the ESD Qualifier Report, the holding times for several samples were exceeded prior to analysis by the laboratory. Consequently all data associated with these particular samples is appropriately annotated with a "UJ" data qualifier. In summary, a comparison of the waste characteristics to the analytical results, semi-volatile organics have not migrated from the trenches.

INORGANICS

Previous sampling events indicated the presence of metals above normal native soil concentrations were observed within surface samples collected from within grids V-5, V-9, and V-10. Specifically, grids V-9 and V-10 had respective concentrations of 5,600 mg/kg and 78 mg/kg of chromium, while grid V-5 had a concentration of 280 mg/kg of lead. Samples collected from a depth of three feet within grids V-9 and V-10 were of a black tar-like consistency; whereas a sample collected from grid V-4 was noted as containing scraps of cloth and rubber. Analysis of the V-4 sample indicated a chromium concentration of 45 mg/kg. Similarly, the samples collected from V-9 and V-10 had chromium concentrations of 280 mg/kg and 5,000 mg/kg respectively. Also noted was the presence of mercury in the V-9 sample at a concentration of 0.18 mg/kg. As sampling efforts reached six feet in grid V-4, the chromium concentration increased to 1,900 mg/kg. Also detected were lead (33 mg/kg) and zinc (160 mg/kg). The sample collected from grid V-10 at a level of five feet contained concentrations of chromium (4,600 mg/kg), lead (39 mg/kg), and mercury (.66 mg/kg). Additional samples collected from grids V-11 and V-12 at depths exceeding nine feet were observed to have inorganic concentrations which were consistent with background.

In summary, the previous sampling results indicated that wastes encountered in the areas of the former disposal trenches had significant levels of chromium, lead, and mercury. The concentrations of these inorganics generally increased with depth until such time as the soil boring penetrated the bottom soils of the trench, at which time the concentrations were dramatically reduced to levels approaching background. Thus, background can be defined by the examination of the inorganic concentrations for samples collected from the areas in which a waste was not encountered. In doing so, it becomes apparent that native soils at the Site have characteristic concentrations of chromium (10-20 mg/kg), lead (9-12 mg/kg) and mercury (0.10-0.12 mg/kg). Similar ranges for other inorganic constituents such as aluminum, manganese, zinc, barium, iron, potassium, and magnesium can also be established; however, such constituents were not characteristic of wastes encountered.

With respect to the samples collected by Weston, a review of the analytical data indicates that inorganic concentrations were more consistent with native soil levels than those observed for the various wastes encountered. For example, in surficial soil samples, concentrations of chromium were generally in the range of 10-20 mg/kg. One notable exception was the concentration of chromium for the surficial sample collected for CL-

SB-02 at 70 mg/kg. The location of this particular sample roughly corresponds to the location of the waste sample encountered in previous sampling in grid V-9 at a depth of three feet. Hence, the presence of lead in the surficial soil sample is more than likely associated with a lack of sufficient cover than migration of contaminants. Concentrations of lead were also consistent with background concentrations, ranging from 5-11 mg/kg. Mercury, another inorganic constituent generally associated with the wastes was not detected in any of the surficial soil samples.

For soil samples collected from intermediate depths (9-10.5 feet), concentrations of chromium, lead, and mercury were once again consistent with background levels. Specifically, concentrations of chromium ranged from 7-19 mg/kg, lead ranged from 7-23 mg/kg, and mercury was undetected.

Similarly, samples collected at the point of auger refusal or at a depth of 60 feet remained consistent with native soil concentrations. Concentrations of chromium ranged from a low of 6.3 mg/kg to a high of 23 mg/kg. Lead concentrations ranged from 3.6 to 18 mg/kg. Although mercury concentrations were generally not detected, a concentration of 0.18 mg/kg was noted in CL-SB-06; however, by comparison, concentrations of mercury in soils typical of the Site were in the range of 0.10-0.12 mg/kg.

4.2 SEDIMENT AND SURFACE WATER

4.2.1 PRE-REMEDIAL SAMPLING 1990

4.2.1.1 SAMPLE LOCATIONS AND RATIONALE

A sediment sample (CL-006-SD) was collected approximately 100 feet south of the old sludge storage pond (Figure 4-2) along the drainage pathway formed when the dam containing the sludge water was breached. The purpose of the sample was to determine the presence or absence of contaminants carried downgradient when the dam was breached or presently being carried downgradient by surface drainage.

A surface water sample (CL-011-SW) was collected from the pond located on the southwest corner of the landfill area (Figure 4-2). A sediment sample (CL-011-SD) was collected from the same location. The purpose of the surface water sample was to determine the presence or absence of contaminants currently entering the pond. The sediment sample from this location was used to determine the presence or absence of contaminants which may have been introduced into the pond in the past.

A sediment sample (CL-012-SD) was collected from the runoff collection pathway in the landfill section of the Site (Figure 4-2). The purpose of this sample was to determine what contaminants (if any) have drained down the runoff pathway to the pond.

A sediment sample (CL-016-SD) was collected from the area around the leachate collection tank (Figure 4-2). This sample was used to determine the presence or absence of contaminants that have overflowed from the system.

4.2.1.2 DATA DISCUSSION

Complete analytical results may be found in Appendix F. Summary tables are presented in Tables 4-17 and 4-18.

The surface water sample (CL-011-SW) collected from the pond on the landfill portion of the Site had no contaminants of concern at the time of sampling. The same was true for the four sediment samples collected except that CL-016-SD collected near the leachate collection system showed the presence of low level organics. Among the compounds detected were (3 and/or 4)methylphenol at a concentration of 490 μg/kg. Tetramethylpiperidinone, acetyloxyocatadecanoic acid - methylester, and hexadecanoic acid were presumed present at concentrations ranging from 700 to 2,000 μg/kg. Trace levels of toluene and xylene were also detected. A summary of surface water and sediment sample analytical results is given in Table 4-17. Table 4-18 presents Region IV Waste Management Division Screening Values (Water Quality Criteria and NOAA screening values).

4.2.2 RAIN EVENT AND QUARTERLY MONITORING

4.2.2.1 SAMPLING LOCATIONS AND RATIONALE

Eight springs that receive surface runoff and are recharged by ground water flowing from the CLL Site were monitored to assess potential off-Site migration (Figure 5-2). Ground water/surface water was monitored five times (quarterly and after rain events). The last sampling event (1/26/93) also included sediment samples from each of the eight springs. The purpose of the sediment samples was to determine whether metals had accumulated in the sediment.

Two locations (A and B) in each spring were sampled. Location A was the closest to the spring outfall (approximately five feet downstream) and Location B was located several feet downstream of Location B. Both locations were selected based upon the most likely depositional area in the stream.

4.2.2.2 DATA DISCUSSION

Complete analytical results may be found in Appendix J. A summary of the data is presented in Table 4-19.

Three COCs were identified based upon an exceedance of either the NOAA ER-L or ER-M -- chromium, lead, and silver. Mossy Spring exceeds NOAA ER-L and ER-M values for chromium; the ER-L value for lead; and the ER-L and ER-M values for silver.

McPherson Spring is not hydraulically connected to the CLL Site or to any of the other seven springs; however this spring does provide control data for comparison purposes. Three contaminants (chromium, zinc, and manganese) were found at levels more than twice levels found in McPherson Spring.

4.3 LEACHATE SAMPLING LOCATIONS AND RATIONALE

4.3.1 PRE-REMEDIAL SAMPLING 1990

4.3.1.1 SAMPLE LOCATIONS AND RATIONALE

The existing well on the southwest side of the landfill area proposed in the Pre-Remedial Sampling Study Plan as the location of sample CL-018-GW, was not sampled since it was dry at the time of sampling. However, CL-018-GW was collected from the disposal pit where soil samples Cl-009-SLA and CL-009-SLB were collected. Leachate encountered while boring into the pit at a depth of about six feet was sampled to characterize contaminants which could potentially impact the groundwater.

Leachate sample location CL-015-LE discussed in the Pre-Remedial Sampling Study Plan was not sampled since leaching was not occurring at this location during the time of the sampling. The second leachate sample (CL-016-LE) from the area adjacent to the leachate collection tank was collected. This sample was used to indicate what contaminants are overflowing the collection system.

4.3.1.2 DATA DISCUSSION

Complete analytical results may be found in Appendix F. A summary of the data is presented in 4-20.

The sample from location CL-018-GW showed the presence of a wide variety of organic and

inorganic contaminants. Chromium and lead were detected at estimated concentrations of 13,000 µg/l and 440 µg/l, respectively. Also present were mercury and cyanide at 2.2 µg/l and 13 µg/l, respectively. A number of organic acids, alcohols and amines were detected at estimated concentrations ranging from 10 µg/l to 1,000 µg/l. Toluene was present at a concentration of 350 µg/l. The leachate sample collected at location CL-016-LE showed the presence of the same compounds detected at CL-018-GW and low levels of benzene and xylene.

TABLE 4-1
CALDWELL LACE LEATHER
LANDFARM SURFACE SOIL RESULTS
JUNE 1990

Parameter	CL-001-SLA (4")	CL-003-SLA (4")	CL-004-SLA (4")	CL-005-SLA (4")
INORGANIC COMPOUNDS (mg/kg)				
Barium	52J	96J	--	73J
Chromium	--	64	--	1100
Cobalt	4.2	12	--	9.7
Lead	--	18J	--	--
Vanadium	22	19	17	19
Aluminum	13,000J	12,000J	11,000J	12,000J
Manganese	100J	970J	--	370J
Calcium	1,100	1,400	1,100	1,600
Magnesium	1,100	--	--	1,000
Iron	14,000J	11,000J	9,600J	11,000J
Potassium	530	620	650	460
PESTICIDE/PCB COMPOUNDS (ug/kg)				
Dieldrin	--	7.9J	--	--
EXTRACTABLE ORGANIC COMPOUNDS (ug/kg)				
7 Unidentified Compounds	--	6,000J	--	--
8 Unidentified Compounds	--	--	8,000J	--
9 Unidentified Compounds	--	--	--	8,000J
1 Unidentified Compound	600J	--	--	--
Pentadecanoic Acid	--	200JN	--	--
Hexadecanoic Acid	--	300JN	300JN	--
PURGEABLE ORGANIC COMPOUNDS (ug/kg)				
1 Unidentified Compound	40J	--	40J	--

TABLE 4-2
CALDWELL LACE LEATHER
LANDFARM SUBSURFACE SOIL RESULTS
JUNE 1990

Parameter	CL-001-SLB (2' - 2.5')	CL-003-SLB (2' - 2.5')	CL-004-SLB (2' - 2.5')	CL-005-SLB (2' - 2.5')
INORGANIC COMPOUNDS (mg/kg)				
Barium	--	54J	48J	--
Chromium	--	--	--	--
Cobalt	--	8.3	2.5	3.2
Copper	6.8	7.9	3.9	7.5
Nickel	6.6	10	5.7	9.6
Lead	--	--	--	--
Vanadium	18	30	10	44
Aluminum	18,000J	18,000J	7,400J	23,000J
Manganese	--	--	--	--
Calcium	--	--	--	--
Magnesium	--	--	--	1,300
Iron	--	18,000J	--	24,000J
Potassium	330	600	260	510
EXTRACTABLE ORGANIC COMPOUNDS (ug/kg)				
1 Unidentified Compound	--	600J	700J	--

TABLE 4-3
CALDWELL LACE LEATHER
LANDFILL SURFACE SOIL RESULTS
JUNE 1990

Parameter	CL-006-SLA (4")	CL-007-SLA (4")	CL-008-SLA (4")	CL-009-SLA (4")	CL-010-SLA (3")	CL-013-SLA (4")	CL-014-SLA (4")
INORGANIC COMPOUNDS (mg/kg)							
Silver	–	–	–	–	–	–	2.6JN
Barium	48J	67J	50J	170J	200J	210J	150J
Beryllium	–	–	–	1.9	1.5	2.1	2.2
Cadmium	–	–	–	–	–	–	1.7
Chromium	–	–	–	–	–	–	73
Cobalt	3.7	7.5	4.2	12	12	17	13
Copper	7.8	28	6	16	20	15	16
Nickel	8.9	12	11	21	17	20	14
Lead	–	–	–	–	210J	39J	–
Vanadium	26	24	19	40	37	48	48
Zinc	–	–	–	120J	150J	98J	200J
Mercury	–	–	–	0.10	0.46	–	–
Aluminum	17,000J	15,000J	14,000J	24,000J	17,000J	24,000J	14,000J
Manganese	–	230J	180J	1,300J	1,300J	2,000J	880J
Calcium	–	1,300	1,300	6,600	4,100	6,000	16,000
Magnesium	1,000	1,700	1,200	1,700	1,200	1,900	1,400
Iron	15,000J	15,000J	12,000J	21,000J	20,000J	22,000	24,000J
Potassium	470	780	1,500	1,200	1,200	1,400	1,200

TABLE 4-3 (Continued)
CALDWELL LACE LEATHER
LANDFILL SURFACE SOIL RESULTS
JUNE 1990

Parameter	CL-006-SLA (4")	CL-007-SLA (4")	CL-008-SLA (4")	CL-009-SLA (4")	CL-010-SLA (3")	CL-013-SLA (4")	CL-014-SLA (4")
EXTRACTABLE ORGANIC COMPOUNDS (ug/kg)							
Phenanthrene	–	–	–	–	240J	–	110J
Flouranthene	–	–	–	–	230J	–	76J
Pyrene	–	–	–	–	150J	–	80J
Benzo(a)anthracene	–	–	–	–	130J	–	–
Chrysene	–	–	–	–	140J	–	73J
Benzo(a and/or k)flouranthene	–	–	–	–	–	–	87J
Benzo-A-Pyrene	–	–	–	–	–	–	53J
1 Unidentified Compound	400J	–	–	–	–	–	–
5 Unidentified Compounds	–	3,000J	3,000J	–	–	–	–
Hexadecenoic Acid	–	–	700JN	–	–	–	–
10 Unidentified Compounds	–	–	–	8,000J	–	–	–
11 Unidentified Compounds	–	–	–	–	10,000J	–	–
14 Unidentified Compounds	–	–	–	–	–	10,000J	–
12 Unidentified Compounds	–	–	–	–	–	–	10,000J
Pentadecanoic Acid	–	200JN	–	300JN	600JN	500JN	700JN
Acetyloxyoctadecenoic Acid, Methylester	–	–	–	–	–	300JN	600JN
Hexadecenoic Acid (2 isomers)	–	–	–	900JN	–	–	2,000JN

TABLE 4-3 (Continued)
CALDWELL LACE LEATHER
LANDFILL SURFACE SOIL RESULTS
JUNE 1990

Parameter	CL-006-SLA (4")	CL-007-SLA (4")	CL-008-SLA (4")	CL-009-SLA (4")	CL-010-SLA (3")	CL-013-SLA (4")	CL-014-SLA (4")
Octadecanoic	--	--	--	--	--	--	500JN
Hexadecanoic Acid	--	400JN	800JN	1,000JN	2,000JN	2,000JN	3,000JN

TABLE 4-4
CALDWELL LACE LEATHER
LANDFILL SUBSURFACE SOIL RESULTS
JUNE 1990

Parameter	CL-006-SLB (2' - 2.5')	CL-007-SLB (2' - 2.5')	CL-008-SLB (5' - 5.5')	CL-009-SLB (3.5' 4.5')	CL-010-SLB (1' - 1.5')	CL-013-SLB (3' 3.5')	CL-014-SLB (2' - 2.5')
INORGANIC COMPOUNDS (mg/kg)							
Silver	--	--	24	--	--	3.5JN	--
Barium	--	--	80J	77J	68J	62J	1,000J
Chromium	150	290	5,600	--	110	370	--
Cobalt	3.4	--	--	15	6.8	6.7	4
Copper	7	7.3	85	7.1	7.6	6.6	6.5
Nickel	6.7	5.5	13	12	12	10	8.5
Lead	--	--	46J	13J	--	--	21J
Vanadium	24	18	27	21	23	25	27
Zinc	--	--	120J	--	--	92J	66J
Mercury	--	--	--	--	0.11	--	--
Aluminum	15,000J	10,000J	31,000J	14,000J	15,000J	14,000J	11,000J
Manganese	--	--	150J	790J	160	--	--
Calcium	22,000	3,700	130,000	1,200	--	1,600	7,800
Magnesium	--	--	1,500	1,200	1,300	1,200	3,000
Iron	13,000J	11,000J	--	14,000J	15,000J	13,000J	10,000J
Potassium	310	--	230	460	630	--	1,200

TABLE 4-4 (Continued)
CALDWELL LACE LEATHER
LANDFILL SUBSURFACE SOIL RESULTS
JUNE 1990

Parameter	CL-006-SLB (2' - 2.5')	CL-007-SLB (2' - 2.5')	CL-008-SLB (5' - 5.5')	CL-009-SLB (3.5' 4.5')	CL-010-SLB (1' - 1.5')	CL-013-SLB (3' 3.5')	CL-014-SLB (2' - 2.5')
EXTRACTABLE ORGANIC COMPOUNDS (ug/kg)							
1,2-Dichlororbenzene	--	--	500J	--	--	--	--
N-Nitrosodiphenylamine/Diphenylamine	--	--	--	680	--	--	--
Flouranthene	--	--	--	--	--	--	6,300J
Pyrene	--	--	--	--	--	--	7,800J
Benzyl Butyl Phthalate	3,900	--	--	--	--	--	--
Bis(2-Ethylhexyl)Phthalate	--	--	--	520	--	--	--
Chrysene	--	--	--	--	--	--	6,600J
Benzo(a and/or k)flouranthene	--	--	--	--	--	--	9,400J
Benzo-A-Pyrene	--	--	--	--	--	--	5,900J
2,4,5-Trichlorophenol	--	--	730J	--	--	--	--
13 Unidentified Compounds	50,000J	--	--	--	--	--	--
Nonylphenol	600JN	--	--	--	--	--	--
5 Unidentified Compounds	--	--	--	--	--	300JN	--
Tetramethylpiperidinone	--	--	--	2,000JN	--	--	--
Tetramethylbutylphenol (2 isomers)	900JN	--	--	4,000JN	--	--	--
Tetramethylbutylphenol	--	--	--	--	1,000JN	--	--
Nonylphenol (2 isomers)	--	--	--	5,000JN	--	--	--

TABLE 4-4 (Continued)
CALDWELL LACE LEATHER
LANDFILL SUBSURFACE SOIL RESULTS
JUNE 1990

Parameter	CL-006-SLB (2' - 2.5')	CL-007-SLB (2' - 2.5')	CL-008-SLB (5' - 5.5')	CL-009-SLB (3.5' 4.5')	CL-010-SLB (1' - 1.5')	CL-013-SLB (3' 3.5')	CL-014-SLB (2' - 2.5')
Phenanthrenecarboxylic Acid	--	--	--	1,000JN	--	--	--
Hexadecenoic Acid	--	200JN	90,000JN	--	--	200,000JN	--
15 Unidentified Compounds	--	--	--	40,000J	--	--	--
11 Unidentified Compounds	--	--	--	--	--	--	500,000J
21 Unidentified Compounds	--	--	--	--	20,000J	--	--
2 Unidentified Compounds	--	--	--	--	--	200,000J	--
Petroleum Product	--	--	--	N	N	--	N
Benzopyrene (not A)	--	--	--	--	--	--	10,000JN
Acetone	--	--	--	--	--	5,000J	3,500J
Toluene	--	4J	--	5J	--	470	30J
Methyl Ethyl Ketone	--	--	--	--	--	1,400J	--
Chlorobenzene	--	--	2J	--	--	--	--
Total Xylenes	--	--	13	--	--	--	--
Dimethylcyclohexenylethanone	10JN	--	--	--	--	--	--
Pentanone	--	--	--	--	--	40JN	--
Benzaldehyde	--	--	--	--	--	6OJN	--
Ethyldimethylbenzene	--	--	--	--	--	70JN	--
7 Unidentified Compounds	--	--	600,000J	--	--	--	600J
Ethyl Benzene	--	--	4J	--	--	--	--

TABLE 4-5
CALDWELL LACE LEATHER
LANDFARM SOIL SAMPLES
FEBRUARY 1991
(results in mg/kg)

Parameter	Pasture CL038SLA	Landfarm CL039SLA
INORGANIC COMPOUNDS		
Barium	140	75
Beryllium	–	0.56
Cobalt	13	7.1
Chromium	21	120
Copper	5.8	6.6
Nickel	8.5	8.1
Lead	22	13
Strontium	7.8	16
Titanium	230	200
Vanadium	23	25
Yttrium	16	6.3
Zinc	30	24
Mercury	0.18	0.15
Aluminum	12,000	13,000
Manganese	1,200	220
Calcium	960	3,700
Magnesium	940	1,200
Iron	12,000	13,000
Sodium	–	100
Potassium	630	480

TABLE 4-6
CALDWELL LACE LEATHER
LANDFARM AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H1	GRID H2	GRID H3	GRID H4	GRID H5	GRID H6	GRID H7	GRID H8
Aluminum	12,000	19,000	20,000	10,000	11,000	9,300	10,000	13,000
Arsenic	6.9	18	5.1	3.5	3.9	4.4	6.5	5.4
Barium	87	110	52	49	32	52	64	87
Beryllium	0.72	1.5	0.56	--	--	--	0.64	0.70
Cadmium	--	--	--	--	--	--	-	--
Calcium	1,700	3,700	320	1,800	520	1,300	1,300	1,100
Chromium	47	47	20	40	13	13	17	14
Cobalt	9.5	14	2.8	3.2	2.2	5.2	7.1	10
Copper	8.3	11	8.3	6.7	6.7	6.5	8.7	7.4
Iron	14,000	18,000	18,000	11,000	11,000	12,000	17,000	14,000
Lead	18	17	12	11	6.5	11	13	13
Magnesium	960	2,300	890	880	940	850	880	1,100
Manganese	680	560	57	120	64	230	290	410
Mercury	--	--	0.08	--	--	--	--	--
Nickel	9.6	25	9.5	6.1	7.2	5.9	6.8	9.3
Potassium	940	2,500	610	630	480	580	510	640
Strontium	10	16	5.2	8.8	6.0	6.5	7.1	7.9

TABLE 4-6
CALDWELL LACE LEATHER
LANDFARM AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H1	GRID H2	GRID H3	GRID H4	GRID H5	GRID H6	GRID H7	GRID H8
Tin	--	--	--	--	--	--	--	--
Titanium	160	100	160	140	140	140	160	180
Vanadium	24	31	33	20	20	21	26	26
Yttrium	10	27	4.1	3.9	2.2	4.6	4.5	6.8
Zinc	37	40	21	22	16	21	20	26

TABLE 4-6
CALDWELL LACE LEATHER
LANDFARM AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H9	GRID H10	GRID H11	GRID H12	GRID H13	GRID H14	GRID H15	GRID H16
Aluminum	11,000	7,600	11,000	9,000	5,400	6,100	12,000	11,000
Arsenic	4.0	2.6	3.5	3.4	1.6	2.1	5.4	4.8
Barium	81	58	54	160	43	43	50	79
Beryllium	0.60	–	0.55	–	–	–	0.51	0.62
Cadmium	–	–	–	0.60	–	–	–	–
Calcium	970	3,700	4,100	10,000	1,000	980	1,500	2,000
Chromium	13	160	100	14	7.4	8.7	87	36
Cobalt	7.2	6.5	5.7	4.9	2.6	2.7	3.8	8.3
Copper	6.7	5.0	6.9	18	3.8	3.9	7.0	6.7
Iron	12,000	7,900	11,000	11,000	5,800	6,700	13,000	12,000
Lead	12	12	11	52	9.4	8.6	10	15
Magnesium	960	850	1,000	1,300	420	520	1,000	980
Manganese	370	340	260	230	150	210	120	340
Mercury	–	–	–	–	–	–	–	0.08
Nickel	8.3	5.8	6.8	7.8	3.5	4.6	7.4	7.8
Potassium	580	340	550	530	350	340	660	620
Strontium	7.4	14	14	32	4.9	4.9	8.8	11

TABLE 4-6
CALDWELL LACE LEATHER
LANDFARM AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H9	GRID H10	GRID H11	GRID H12	GRID H13	GRID H14	GRID H15	GRID H16
Tin	--	--	--	8.4	--	--	--	--
Titanium	170	130	160	160	86	96	190	170
Vanadium	21	14	21	18	11	13	26	23
Yttrium	6.5	6.1	5.6	5.1	2.8	3.0	3.7	5.2
Zinc	25	23	29	270	15	15	25	27

TABLE 4-6
CALDWELL LACE LEATHER
LANDFARM AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H16 Offset	GRID H17	GRID H18	GRID H19	GRID H19 Offset	GRID H20	GRID H21	GRID H22
Aluminum	9,900	10,000	9,000	12,000	12,000	12,000	10,000	8,700
Arsenic	3.2	9.8	2.6	4.9	5.3	3.2	4.0	3.6
Barium	69	69	65	73	110	120	71	51
Beryllium	0.54	0.66	0.59	0.63	0.78	0.79	–	–
Calcium	2,100	1,300	1,400	1,400	1,700	1,100	4,300	3,300
Chromium	50	45	71	49	26	32	120	220
Cobalt	6.7	9.4	7.8	7.1	10	9.6	3.6	5.1
Copper	6.8	6.3	5.7	7.7	7.3	6.9	8.7	5.7
Iron	13,000	12,000	10,000	13,000	13,000	12,000	13,000	10,000
Lead	15	13	12	12	17	17	19	11
Magnesium	900	900	770	1,000	980	910	940	810
Manganese	230	370	300	260	800	800	140	190
Mercury	0.09	–	0.07	–	–	0.11	0.11	0.08
Nickel	7.0	7.4	6.4	8.4	8.6	8.5	6.8	5.6
Potassium	620	520	480	610	720	700	650	390
Strontium	11	8.2	8.6	9.5	9.1	8.0	17	16
Tin	–	–	–	–	–	–	26	–

TABLE 4-6
CALDWELL LACE LEATHER
LANDFARM AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H16 Offset	GRID H17	GRID H18	GRID H19	GRID H19 Offset	GRID H20	GRID H21	GRID H22
Titanium	140	180	120	160	150	150	130	100
Vanadium	22	22	19	24	23	23	19	17
Yttrium	4.8	6.0	5.6	5.7	11	12	3.3	3.7
Zinc	24	22	19	24	27	26	37	22

TABLE 4-6
CALDWELL LACE LEATHER
LANDFARM AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H23	GRID H23 Offset	GRID H24	GRID H24 Offset	GRID H25	GRID H26	GRID H27/28	GRID H29/30
Aluminum	8,500	8,800	12,000	9,200	10,000	8,000	9,800	8,300
Arsenic	3.9	–	4.9	–	2.2	3.3	3.2	4.0
Barium	60	60	75	63	72	86	74	68
Beryllium	0.50	–	0.60	0.53	0.58	0.59	0.65	0.52
Calcium	6,500	2,500	1,800	3,100	2,000	2,700	2,500	2,600
Chromium	160	170	140	170	120	44	220	180
Cobalt	6.1	6.1	8.4	7.2	8.1	7.1	10	5.8
Copper	5.4	5.6	6.9	5.3	6.2	5.2	5.8	5.8
Iron	10,000	10,000	12,000	11,000	12,000	9,400	10,000	11,000
Lead	11	11	12	9.8	12	12	13	14
Magnesium	860	850	1,000	870	920	820	830	890
Manganese	200	220	320	290	360	500	470	230
Mercury	0.07	0.07	0.08	0.09	0.08	0.08	0.08	0.07
Nickel	5.6	5.3	9.4	5.9	7.0	6.4	7.1	5.8
Potassium	450	410	600	470	520	490	380	390
Sodium	120	110	–	110	–	–	–	–
Strontium	19	13	12	15	11	10	16	13

TABLE 4-6
CALDWELL LACE LEATHER
LANDFARM AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H23	GRID H23 Offset	GRID H24	GRID H24 Offset	GRID H25	GRID H26	GRID H27/28	GRID H29/30
Tin	2.6	–	–	–	–	–	–	–
Titanium	140	130	160	120	130	120	130	130
Vanadium	17	18	23	19	20	17	19	18
Yttrium	4.3	4.2	6.1	5.2	5.9	7.3	6.2	4.5
Zinc	19	20	27	19	21	20	22	20

TABLE 4-7
CALDWELL LACE LEATHER
LANDFARM AREA
SUBSURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H1 3'	GRID H2 3'	GRID H3 3'	GRID H4 3'	GRID H5 2'	GRID H6 2'	GRID H7 2'	GRID H8 2'
Aluminum	14,000	25,000	12,000	8,600	11,000	34,000	11,000	8,400
Arsenic	4.4	14	–	2.1	8.8	11	4.6	2.3
Barium	48	71	48	53	54	49	26	25
Beryllium	–	0.80	0.52	–	0.50	–	–	–
Calcium	350	920	1,300	560	1,400	430	180	130
Chromium	12	35	34	9.0	13	48	16	10
Cobalt	9.7	5.1	3.7	6.8	3.9	–	1.3	1.2
Copper	7.4	9.8	7.6	4.1	6.6	12	5.9	4.3
Iron	12,000	26,000	17,000	10,000	12,000	37,000	16,000	8,300
Lead	12	15	12	7.8	8.9	14	4.7	4.1
Magnesium	750	1,600	800	670	920	1,700	810	820
Manganese	460	100	94	410	140	32	26	47
Mercury	0.09	0.13	0.09	0.06	0.08	0.22	0.09	0.07
Molybdenum	1.1	–	–	–	–	–	–	–
Nickel	7.9	14	6.0	6.1	6.8	10	3.8	4.3
Potassium	790	1,600	740	510	740	1,300	440	420
Strontium	5.0	11	8.1	5.9	7.9	8.5	3.1	3.2

TABLE 4-7
CALDWELL LACE LEATHER
LANDFARM AREA
SUBSURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H1 3'	GRID H2 3'	GRID H3 3'	GRID H4 3'	GRID H5 2'	GRID H6 2'	GRID H7 2'	GRID H8 2'
Tin	–	4.7	3.4	–	–	–	–	–
Titanium	150	82	87	110	120	72	90	110
Vanadium	25	49	26	18	21	82	27	15
Yttrium	2.9	5.2	4.0	3.4	4.3	5.3	1.6	2.2
Zinc	20	38	21	16	20	24	11	12

TABLE 4-7
CALDWELL LACE LEATHER
LANDFARM AREA
SUBSURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H9 3'	GRID H10 3'	GRID H11 3'	GRID H12 3'	GRID H13 2'	GRID H14 2'	GRID H15 1'	GRID H16 3'
Aluminum	9,400	8,600	25,000	19,000	11,000	5,800	6,700	10,000
Arsenic	2.8	3.2	5.0	6.1	3.1	2.6	–	1.9
Barium	72	34	62	39	27	42	14	18
Beryllium	0.51	–	0.70	0.58	–	–	–	–
Calcium	270	120	540	530	470	530	87	78
Chromium	10	12	25	28	20	12	8.8	12
Cobalt	5.1	3.3	3.2	2.0	1.4	3.4	–	1.6
Copper	5.4	6.1	9.2	8.6	5.3	3.8	2.4	4.2
Iron	9,200	10,000	20,000	25,000	14,000	8,500	5,600	12,000
Lead	6.8	7.9	10	13	8.2	6.0	4.5	7.6
Magnesium	720	820	1,200	680	440	440	360	970
Manganese	260	130	63	50	47	200	7.0	38
Mercury	0.06	0.08	0.15	0.16	0.09	0.07	0.07	–
Nickel	6.2	5.2	11	6.6	4.3	4.5	–	4.5
Potassium	610	550	1,100	720	550	460	380	410
Sodium	–	–	130	120	–	–	–	100
Strontium	4.0	3.3	8.7	6.1	4.3	3.9	1.6	3.5

TABLE 4-7
CALDWELL LACE LEATHER
LANDFARM AREA
SUBSURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H9 3'	GRID H10 3'	GRID H11 3'	GRID H12 3'	GRID H13 2'	GRID H14 2'	GRID H15 1'	GRID H16 3'
Titanium	100	150	130	140	110	76	36	100
Vanadium	18	18	41	48	24	14	12	23
Yttrium	5.2	2.3	4.3	3.3	1.6	4.8	1.7	4.9
Zinc	17	16	29	16	11	11	4.9	11

TABLE 4-7
CALDWELL LACE LEATHER
LANDFARM AREA
SUBSURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H17 2'	GRID H18 3'	GRID H19 3'	GRID H22 3'	GRID H23 2'	GRID H24 2'	GRID H25 3'	GRID H26 2'	GRID H27 3'	GRID H29 2'
Aluminum	24,000	20,000	10,000	7,800	9,600	8,400	14,000	8,100	16,000	9,900
Arsenic	5.5	5.1	3.4	3.4	2.0	1.9	5.4	3.3	6.3	2.6
Barium	40	78	36	18	31	29	72	190	60	29
Beryllium	0.56	0.79	--	--	--	--	0.65	0.89	0.62	--
Calcium	140	690	310	140	230	270	1,200	1,500	100	170
Chromium	25	22	18	13	20	11	18	11	19	28
Cobalt	2.2	5.1	1.6	1.5	1.7	1.6	4.2	8.6	3.0	1.5
Copper	8.3	14	5.6	5.2	5.1	4.8	8.4	5.0	12	4.8
Iron	22,000	26,000	12,000	9,000	9,800	8,200	17,000	8,500	23,000	10,000
Lead	7.9	15	6.2	5.7	5.6	5.4	9.8	16	13	5.1
Magnesium	1,300	1,900	600	740	870	720	1,000	690	1,900	680
Manganese	42	200	47	27	39	39	210	1,000	78	28
Mercury	0.09	0.11	0.08	0.06	--	0.07	0.07	0.11	0.16	0.09
Molybdenum	--	1.2	--	--	--	--	--	--	--	--
Nickel	7.3	10	4.1	3.3	7.6	4.6	8.5	7.5	7.8	7.6
Potassium	710	1,000	480	290	450	540	630	530	750	520
Sodium	--	--	--	220	180	--	120	--	--	160

TABLE 4-7
CALDWELL LACE LEATHER
LANDFARM AREA
SUBSURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg)

Parameter	GRID H17 2'	GRID H18 3'	GRID H19 3'	GRID H22 3'	GRID H23 2'	GRID H24 2'	GRID H25 3'	GRID H26 2'	GRID H27 3'	GRID H29 2'
Strontium	4.4	11	4.5	2.9	3.7	2.9	8.2	12	3.5	2.5
Titanium	96	160	110	90	96	69	140	97	110	63
Vanadium	46	41	24	18	20	17	29	16	35	22
Yttrium	3.5	4.6	2.2	3.2	3.0	2.4	5.2	12	5.0	2.6
Zinc	18	37	13	11	13	12	21	22	31	9.3

TABLE 4-8
CALDWELL LACE LEATHER
SOUTHWEST AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg, except where noted)

Parameter	GRID HV1	GRID HV1 Offset	GRID HV2	GRID HV2 Offset	GRID HV3	GRID HV3 Offset	GRID HV4	GRID HV4 Offset
Aluminum	10,000	12,000	11,000	9,900	11,000	8,600	10,000	12,000
Arsenic	6.6	6.0	5.1	5.1	5.0	4.1	4.2	4.7
Barium	97	100	78	74	76	60	78	90
Beryllium	0.71	0.77	0.64	0.65	0.63	--	0.59	0.64
Calcium	900	850	650	1,600	1,400	4,400	3,600	2,600
Chromium	12	12	18	16	15	14	13	14
Cobalt	9.8	11	8.2	8.7	8.3	7.0	7.8	8.1
Copper	6.2	6.6	7.1	6.4	6.8	5.7	6.3	7.2
Iron	11,000	12,000	13,000	12,000	12,000	10,000	11,000	13,000
Lead	17	18	15	13	14	13	13	14
Magnesium	820	960	860	800	860	750	910	1,100
Manganese	710	660	430	480	550	460	550	680
Mercury	--	0.07	0.07	0.07	0.07	--	0.08	--
Nickel	8.1	8.6	7.9	7.9	8.1	5.8	7.8	9.3
Potassium	620	760	640	570	640	480	870	920
Strontium	6.8	7.3	6.0	7.9	7.3	10	10	10
Titanium	170	200	180	160	190	150	150	180

TABLE 4-8
CALDWELL LACE LEATHER
SOUTHWEST AREA
SURFACE SOIL RESULTS (8/91)
(all soil results are in mg/kg, except where noted)

Parameter	GRID HV1	GRID HV1 Offset	GRID HV2	GRID HV2 Offset	GRID HV3	GRID HV3 Offset	GRID HV4	GRID HV4 Offset
Vanadium	20	23	23	21	22	18	20	24
Yttrium	12	12	8.8	9.4	9.2	7.5	8.1	8.7
Zinc	24	26	22	23	24	19	34	34
EXTRACTABLE ORGANIC COMPOUNDS								
Octahydrotrimethyl (Methylethyl) Phenanthrenol*	1000JN	–	–	–	–	–	–	–

* µg/kg

TABLE 4-8
CALDWELL LACE LEATHER
SOUTHWEST AREA
SURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID HV5	GRID HV5 Offset	GRID HV6	GRID HV6 Offset	GRID HV7	GRID HV7 Offset	GRID HV8	GRID HV8 Offset
Aluminum	9,500	10,000	12,000	11,000	13,000	12,000	9,200	10,000
Arsenic	6.0	5.9	5.4	5.5	5.7	7.5	5.7	6.7
Barium	79	110	100	92	90	97	73	74
Beryllium	0.60	0.72	0.69	0.72	0.70	0.70	0.55	0.59
Calcium	1,200	780	660	770	2,700	1,700	1,200	1,200
Chromium	12	11	12	12	16	17	17	21
Cobalt	9.5	11	11	11	9.5	12	8.0	8.6
Copper	6.3	5.5	6.8	6.6	8.3	7.5	6.7	6.9
Iron	13,000	11,000	13,000	13,000	16,000	14,000	12,000	12,000
Lead	18	19	17	18	15	17	17	18
Magnesium	850	850	950	960	1,200	1,100	820	880
Manganese	510	860	600	590	580	820	520	580
Mercury	0.06	–	0.09	–	0.07	–	–	–
Nickel	6.9	7.9	8.8	8.3	9.5	9.4	7.5	7.6
Potassium	520	660	740	640	890	770	680	680
Strontium	6.5	7.0	6.5	6.5	11	9.1	6.3	6.3
Titanium	170	180	180	190	210	200	150	160

TABLE 4-8
CALDWELL LACE LEATHER
SOUTHWEST AREA
SURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID HV5	GRID HV5 Offset	GRID HV6	GRID HV6 Offset	GRID HV7	GRID HV7 Offset	GRID HV8	GRID HV8 Offset
Vanadium	20	20	22	22	26	25	19	20
Yttrium	8.6	12	10	9.3	8.9	9.0	8.4	9.1
Zinc	30	30	35	26	30	28	24	24
EXTRACTABLE ORGANIC COMPOUNDS								
(Propenyl)* Benzodioxole			700jn					

* µg/kg

TABLE 4-9
CALDWELL LACE LEATHER
SOUTHWEST AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg)

Parameter	GRID HV1	GRID HV2	GRID HV3	GRID HV4	GRID HV5	GRID HV6	GRID HV7	GRID HV8
Aluminum	14,000	10,000	10,000	12,000	12,000	20,000	9,700	9,800
Arsenic	5.7	4.5	4.2	5.7	3.8	5.3	3.3	2.8
Barium	80	65	74	40	32	61	100	100
Beryllium	0.58	0.57	0.57	–	–	0.64	0.84	0.85
Calcium	810	660	360	1,300	120	430	480	150
Chromium	16	39	13	14	26	21	9.8	9.6
Cobalt	10	6.8	7.9	7.0	2.4	3.1	9.5	18
Copper	7.0	5.3	6.4	8.2	6.2	9.0	4.6	5.7
Iron	15,000	14,000	13,000	15,000	19,000	19,000	11,000	10,000
Lead	11	9.6	9.9	10	9.3	11	9.7	13
Magnesium	1,000	670	780	1,100	840	1,000	790	700
Manganese	450	260	720	260	130	88	960	750
Nickel	9.5	7.3	6.0	8.2	4.8	10	9.4	8.6
Potassium	660	660	510	710	410	720	500	590
Strontium	7.3	5.3	3.7	5.6	3.4	7.4	6.5	3.9
Titanium	200	150	200	200	190	220	170	180
Vanadium	26	24	23	26	34	38	20	18

TABLE 4-9
CALDWELL LACE LEATHER
SOUTHWEST AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg)

Parameter	GRID HV1	GRID HV2	GRID HV3	GRID HV4	GRID HV5	GRID HV6	GRID HV7	GRID HV8
Yttrium	5.5	5.4	4.9	2.7	2.5	4.8	10	15
Zinc	26	18	18	30	15	21	24	21

TABLE 4-10
CALDWELL LACE LEATHER
LANDFILL AREA
SURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V1	GRID V2	GRID V3	GRID V4	GRID V5	GRID V6	GRID V7	GRID V8	GRID V9
Aluminum	18,000	8,900	13,000	12,000	17,000	11,000	18,000	4,800	18,000
Arsenic	4.9	8.4	6.7	6.3	6.2	3.9	5.1	1.8	--
Barium	85	49	61	50	140	46	160	72	55
Beryllium	0.69	0.63	0.60	0.51	1.1	--	1.4	--	--
Cadmium	--	--	--	--	--	--	0.52	--	--
Calcium	780	2,100	1,100	650	2,800	810	4,000	680	63,000
Chromium	18	40	22	14	33	17	25	5.0	5,600
Cobalt	5.5	5.6	4.6	4.4	8.8	4.0	12	4.7	6.1
Copper	11	7.9	7.8	7.6	22	5.8	14	2.6	16
Iron	21,000	14,000	15,000	15,000	19,000	11,000	19,000	4,800	9,800
Lead	13	12	9.5	10	280	9.1	45	10	20
Magnesium	1,400	870	970	910	1,200	860	1,400	390	1,200
Manganese	180	200	230	120	740	140	1,500	400	180
Mercury	--	0.10	0.10	0.11	0.23	0.10	0.12	0.10	0.13
Nickel	12	10	7.6	6.1	13	6.2	15	3.2	--
Potassium	900	700	560	370	1,100	680	1,000	230	--
Sodium	130	--	--	--	--	--	--	--	--

TABLE 4-10
CALDWELL LACE LEATHER
LANDFILL AREA
SURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V1	GRID V2	GRID V3	GRID V4	GRID V5	GRID V6	GRID V7	GRID V8	GRID V9
Strontium	7.6	10	7.9	5.3	14	5.9	17	4.8	210
Titanium	210	81	160	160	130	110	200	95	150
Vanadium	36	20	25	24	38	20	40	8.8	28
Yttrium	6.6	7.0	4.6	4.2	12	4.3	20	7.8	4.9
Zinc	34	27	21	18	140	19	79	12	53

TABLE 4-10
CALDWELL LACE LEATHER
LANDFILL AREA
SURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V10	GRID V11	GRID V12	GRID V13	GRID V14	GRID V15	GRID V16	GRID V17	GRID V18
Aluminum	12,000	8,400	14,000	8,100	6,900	9,600	9,700	12,000	3,900
Arsenic	6.3	3.2	5.2	2.9	2.4	4.8	2.7	3.3	--
Barium	61	74	92	66	64	60	67	58	29
Beryllium	--	0.56	0.80	--	--	--	0.54	--	--
Cadmium	--	--	--	--	--	--	--	--	--
Calcium	340	700	900	640	330	520	800	490	180
Chromium	78	10	17	10	8.1	12	11	12	5.0
Cobalt	4.0	5.8	15	7.7	6.3	9.8	10	6.2	3.9
Copper	7.6	5.4	6.7	4.5	3.4	5.5	5.0	6.1	1.7
Iron	14,000	10,000	13,000	9,400	7,600	9,200	9,800	12,000	4,100
Lead	11	13	13	12	9.3	19	13	10	8.2
Magnesium	830	700	1,000	630	530	730	790	810	300
Manganese	92	300	340	340	310	450	300	190	80
Mercury	0.11	0.10	--	--	--	--	--	--	--
Nickel	6.5	5.7	9.6	6.2	6.0	6.5	7.7	8.0	2.5
Potassium	500	340	850	520	490	650	650	690	330
Strontium	--	--	--	4.1	3.9	4.7	5.5	5.5	2.2

TABLE 4-10
CALDWELL LACE LEATHER
LANDFILL AREA
SURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V10	GRID V11	GRID V12	GRID V13	GRID V14	GRID V15	GRID V16	GRID V17	GRID V18
Titanium	4.2	4.9	7.7	130	130	200	180	190	100
Vanadium	160	140	170	17	13	19	19	22	8.2
Yttrium	23	17	26	7.3	7.2	7.9	7.8	5.8	2.2
Zinc	4.5	8.8	10	17	16	21	19	21	9.4
EXTRACTABLE ORGANIC COMPOUNDS									
(Propenyl) Benzodioxole*	--	--	--	--	--	--	--	--	--

* µg/kg

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V1	GRID V2	GRID V3	GRID V4	GRID V5	GRID V6	GRID V7	GRID V8	GRID V9
Aluminum	11,000	2,300	12,000	9,300	14,000	17,000	15,000	8,100	20,000
Arsenic	3.8	–	4.1	4.4	4.9	18	6.3	1.2	7.0
Barium	44	8.9	47	89	52	64	55	48	71
Beryllium	–	–	–	0.63	0.54	–	0.54	–	–
Calcium	440	260	330	4,700	510	370	530	310	3,200
Chromium	17	4.9	21	45	17	19	18	7.0	280
Cobalt	2.5	–	3.0	12	6.0	6.0	4.3	3.6	–
Copper	5.9	1.5	6.0	7.0	8.8	8.5	7.7	4.8	7.9
Iron	13,000	3,400	14,000	12,000	15,000	16,000	15,000	5,900	20,000
Lead	7.3	2.4	9.0	15	11	12	10	7.6	45
Magnesium	480	170	670	7,200	1,200	1,200	1,200	410	960
Manganese	45	10	72	740	160	240	120	220	24
Mercury	0.10	–	0.12	0.11	0.10	0.10	–	–	0.18
Nickel	4.5	–	4.8	49	7.6	8.3	9.2	3.7	6.0
Potassium	300	–	360	330	630	890	930	270	1,200
Sodium	190	–	–	–	140	–	–	–	250
Strontium	4.4	2.0	5.3	12	6.1	7.1	7.4	4.0	46

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V1	GRID V2	GRID V3	GRID V4	GRID V5	GRID V6	GRID V7	GRID V8	GRID V9
Titanium	12-	50	140	140	140	200	190	91	79
Vanadium	25	7.2	26	19	28	32	27	14	45
Yttrium	3.6	--	3.2	10	4.2	3.8	4.0	5.3	6.7
Zinc	12	2.9	14	91	23	23	25	10	14
EXTRACTABLE ORGANIC COMPOUNDS									
Bis(2-Ethylhexyl)Phthalate	--	--	--	42,000	--	--	--	--	--
N-Nitrosodiphenylamine/ Diphenylamine	--	--	--	1,200J	--	--	--	--	--
1 Unidentified Compound	--	--	--	8,000J	--	--	--	--	--
Benzothiazolone	--	--	--	1,000JN	--	--	--	--	--
Dimethylphenanthrene	--	--	--	700JN	--	--	--	--	--
Diphenylbenzenediamine	--	--	--	1,000JN	--	--	--	--	--
Petroleum Product	--	--	--	N	--	--	--	--	--

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V10	GRID V11	GRID V12	GRID V13	GRID V14	GRID V15	GRID V16	GRID V17	GRID V18
Aluminum	21,000	19,000	21,000	21,000	16,000	16,000	6,100	19,000	12,000
Arsenic	–	5.1	4.3	5.8	4.5	5.4	3.4	2.0	4.9
Barium	36	42	47	76	47	45	30	47	45
Beryllium	–	–	–	0.59	–	–	–	0.57	–
Calcium	43,000	680	200	1,300	240	410	320	360	850
Chromium	5,000	33	31	32	16	17	13	33	16
Cobalt	–	2.5	2.4	1.6	2.6	6.8	3.9	2.6	3.6
Copper	16	9.5	9.3	7.8	6.9	7.4	4.1	9.5	7.2
Iron	8,800	21,000	19,000	25,000	14,000	16,000	8,800	21,000	14,000
Lead	27	9.6	11	10	8.4	10	4.5	14	11
Magnesium	960	830	1,200	970	790	940	480	990	940
Manganese	68	37	39	34	48	250	72	48	78
Mercury	0.10	0.17	0.17	0.13	0.06	0.08	–	0.10	0.09
Nickel	–	7.6	6.9	6.8	7.9	9.0	3.9	8.3	8.8
Potassium	–	720	820	980	700	820	320	840	910
Strontium	200	–	–	–	–	–	–	–	–
Sodium	1,700	8.3	5.2	16	4.9	4.9	3.7	6.7	6.9

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V10	GRID V11	GRID V12	GRID V13	GRID V14	GRID V15	GRID V16	GRID V17	GRID V18
Titanium	120	150	160	98	160	220	100	180	160
Vanadium	26	44	37	47	28	32	16	39	26
Yttrium	--	3.3	3.4	3.3	3.4	2.5	1.8	3.7	3.6
Zinc	78	17	22	17	18	23	11	21	21
EXTRACTABLE ORGANIC COMPOUNDS									
(3-and/or 4-)Methylphenol	38,000J	--	--	--	--	--	--	--	--
(Tetramethylbutyl)Phenol	40,000JN	--	--	--	--	--	--	--	--
1 Unidentified Compounds	3.0E6J	--	--	--	--	--	--	--	--
Bis(Dimethylethyl)Methylphenol	20,000JN	--	--	--	--	--	--	--	--
Chloro(Phenylmethyl)Phenol	40,000JN	--	--	--	--	--	--	--	--
Dihydroindolone	20,000JN	--	--	--	--	--	--	--	--
Heptadecanoic Acid	20,000JN	--	--	--	--	--	--	--	--
Hexadecanoic Acid	800,000JN	--	--	--	--	--	--	--	--
Hexadecanoic Acid, Methyl Ester	20,000JN	--	--	--	--	--	--	--	--
Hexadecanoic Acid	30,000JN	--	--	--	--	--	--	--	--
Octadecanoic Acid	200,000JN	--	--	--	--	--	--	--	--

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V10	GRID V11	GRID V12	GRID V13	GRID V14	GRID V15	GRID V16	GRID V17	GRID V18
Tetradecanoic Acid	100,000JN	--	--	--	--	--	--	--	--
PURGEABLE ORGANIC COMPOUNDS									
Styrene	--	--	--	--	--	--	--	--	--
(M- and/or P-)Xylene	580	--	--	--	--	--	--	--	--
1,2-Dichlorobenzene	3,900J	--	--	--	--	--	--	--	--
1,3-Dichlorobenzene	42J	--	--	--	--	--	--	--	--
1,4-Dichlorobenzene	620	--	--	--	--	--	--	--	--
Acetone	1,700J	--	--	--	--	--	--	--	--
Ethyl Benzene	110J	--	--	--	--	--	--	--	--
Methyl Ethyl Ketone	440J	--	--	--	--	--	--	--	--
O-Chlorotoluene	85J	--	--	--	--	--	--	--	--
O-Xylene	140J	--	--	--	--	--	--	--	--
Toluene	43J	--	--	--	--	--	--	--	--
Dimethyldisulfide	400JN	--	--	--	--	--	--	--	--
Dimethyltrisulfide	2,000JN	--	--	--	--	--	--	--	--
Petroleum Product	N	--	--	--	--	--	--	--	--

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V10	GRID V11	GRID V12	GRID V13	GRID V14	GRID V15	GRID V16	GRID V17	GRID V18
Trimethylbenzene	100JN	--	--	--	--	--	--	--	--

* µg/kg

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V1 6'	GRID V2 5'	GRID V3 6'	GRID V4 6'	GRID V5 6'	GRID V6 6'	GRID V8 6'	GRID V10 5'	GRID V11 6'
Aluminum	6,900	4,500	18,000	14,000	16,000	25,000	24,000	10,000	69,000
Antimony	--	--	--	18	--	--	--	--	--
Arsenic	1.6	--	3.7	4.1	5.9	6.4	--	--	--
Barium	13	16	42	60	48	71	59	22	74
Calcium	210	390	410	3,300	260	--	140	2,200	130,000
Chromium	11	30	29	1,900	22	24	17	1,200	4,600
Cobalt	1.4	3.2	2.2	6.4	2.6	4.2	--	1.7	--
Copper	3.6	3.2	8.7	31	9.2	11	11	7.2	69
Iron	5,900	4,700	18,000	14,000	17,000	18,000	6,800	8,800	6,800
Lead	3.4	6.0	7.8	33	11	13	13	5.8	39
Magnesium	280	300	970	6,100	970	1,400	880	430	1,800
Manganese	17	21	36	420	72	190	33	25	240
Mercury	0.10	0.11	0.13	0.14	0.11	0.11	0.15	0.13	0.66
Nickel	3.1	2.1	7.8	39	6.9	9.6	8.7	6.0	11
Potassium	290	320	980	430	680	1,100	1,100	370	--
Sodium	--	--	--	310	--	--	--	310	4,000
Strontium	2.1	4.1	8.3	15	3.8	5.0	7.1	12	690

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V1 6'	GRID V2 5'	GRID V3 6'	GRID V4 6'	GRID V5 6'	GRID V6 6'	GRID V8 6'	GRID V10 5'	GRID V11 6'
Titanium	61	48	110	220	180	200	180	91	87
Vanadium	12	9.8	38	22	33	38	25	22	54
Yttrium	1.5	1.3	3.2	4.8	2.6	6.4	2.6	1.4	5.1
Zinc	7.7	7.3	16	160	22	34	28	13	180
PESTICIDE/PCB COMPOUNDS									
Alpha-Chlordane/2	NA	NA	NA	NA	NA	NA	NA	NA	130
Alpha-Chlordene/2	NA	NA	NA	NA	NA	NA	NA	NA	58J
Chlordene/2	NA	NA	NA	NA	NA	NA	NA	NA	62J
Gamma-Chlordane/2	NA	NA	NA	NA	NA	NA	NA	NA	150
Trans-Nonachlor/2	NA	NA	NA	NA	NA	NA	NA	NA	54J
EXTRACTABLE ORGANIC COMPOUNDS									
(3- and/or 4-)Methylphenol	--	--	--	--	--	--	--	5,800J	--
2,4,5-Trichlorophenol	--	--	--	22,000J	--	--	--	--	--
N-Nitrosodiphenylamine/Diphenylamine	--	--	--	8,800J	--	--	--	--	--
Pentachlorophenol	--	--	--	--	--	--	--	5,700J	--
Phenol	--	--	--	--	--	--	--	5,700J	--

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V1 6'	GRID V2 5'	GRID V3 6'	GRID V4 6'	GRID V5 6'	GRID V6 6'	GRID V8 6'	GRID V10 5'	GRID V11 6'
(Isothiocyanatoethyl)benzene	--	--	--	--	--	--	--	5,000J	--
(Tetramethylbutyl)phenol	--	--	--	--	--	--	--	1,000JN	--
(Tetramethylbutyl)phenol (3 isomers)	--	--	--	--	--	--	--	--	40,000JN
2 Unidentified Compounds	--	--	--	100,000J	--	--	--	--	--
4 Unidentified Compounds	--	--	--	--	--	--	--	200,000J	5.0E6J
Benzeneacetic Acid	--	--	--	--	--	--	--	2,000JN	--
Benzothiazolone	--	--	--	10,000JN	--	--	--	--	--
Bis(dimethylethyl)methylphenol	--	--	--	4,000JN	--	--	--	--	--
Chloro(phenylmethyl)phenol	--	--	--	--	--	--	--	6,000JN	6,000JN
Dimethylbenzenamine	--	--	--	--	--	--	--	700JN	--
Dimethylpenanthrene	--	--	--	7,000JN	--	--	--	--	--
Diphenylbenzendiamine	--	--	--	40,000JN	--	--	--	--	--
Hexadecanoic Acid	--	--	--	300,000JN	--	--	--	100,000JN	--
Methylfluorene	--	--	--	5,000JN	--	--	--	--	--
Methylindole	--	--	--	--	--	--	--	700JN	--
Methylphenanthrene (2 isomers)	--	--	--	8,000JN	--	--	--	--	--
Nonylphenol (2 isomers)	--	--	--	--	--	--	--	--	20,000JN

TABLE 4-11
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
(all results are in mg/kg, except where noted)

Parameter	GRID V1 6'	GRID V2 5'	GRID V3 6'	GRID V4 6'	GRID V5 6'	GRID V6 6'	GRID V8 6'	GRID V10 5'	GRID V11 6'
Octadecanoic Acid	--	--	--	200,000JN	--	--	--	40,000JN	--
Pentachloromethoxybenzene	--	--	--	--	--	--	--	3,000JN	--
Petroleum Product	--	--	--	N	--	--	--	N	--
Phosporic Acid, Triphenyl Ester	--	--	--	80,000JN	--	--	--	--	--
Piperidinone	--	--	--	--	--	--	--	40,000JN	--
Tetradecanoic Acid	--	--	--	30,000JN	--	--	--	10,000JN	--
(Biphenyl)ol	--	--	--	--	--	--	--	900JN	--
PURGEABLE ORGANIC COMPOUNDS									
(M- and/or P-)Xylene	--	--	--	--	--	--	--	--	80J
1,2-Dichlorobenzene	--	--	--	--	--	--	--	33J	4,200J
1,3-Dichlorobenzene	--	--	--	--	--	--	--	--	260J
1,4-Dichlorobenzene	--	--	--	--	--	--	--	--	1,700
Chlorobenzene	--	--	--	--	--	--	--	--	5,400J
Toluene	--	--	--	49J	--	--	--	--	82J

TABLE 4-12
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
LEVEL 2
(all results are in mg/kg)

Parameter	GRID V12 6'	GRID V14 6'	GRID V15 6'	GRID V17 6'	GRID V18 5'
Aluminum	23,000	11,000	11,000	13,000	26,000
Arsenic	9.7	4.3	5.3	5.4	3.3
Barium	56	34	23	30	83
Beryllium	–	–	–	0.50	–
Calcium	410	160	170	190	3,500
Chromium	37	14	26	29	49
Cobalt	2.5	2.0	1.1	1.3	34
Copper	9.9	6.1	5.7	7.3	21
Iron	26,000	13,000	16,000	27,000	42,000
Lead	12	8.6	8.4	10	54
Magnesium	940	640	410	570	2,600
Manganese	30	47	31	32	500
Mercury	0.15	0.08	0.13	0.16	0.14
Nickel	6.9	5.4	3.6	3.8	91
Potassium	590	620	490	580	3,600
Strontium	5.6	4.0	3.1	5.0	25
Titanium	160	120	130	140	38
Vanadium	52	25	33	52	64
Yttrium	3.7	2.0	1.7	2.2	20
Zinc	19	15	11	9.9	250

TABLE 4-13
CALDWELL LACE LEATHER
LANDFILL AREA
SUBSURFACE SOIL RESULTS (8/91)
LEVEL 3
(all results are in mg/kg)

Parameter	GRID V5 9'	GRID V11 12'	GRID V12 9'
Aluminum	32,000	9,900	20,000
Arsenic	9.0	–	5.3
Barium	59	44	42
Calcium	200	330	530
Chromium	71	13	32
Cobalt	–	4.3	2.7
Copper	15	8.8	8.6
Iron	54,000	13,000	23,000
Lead	18	9.5	11
Magnesium	1,100	1,300	790
Manganese	37	160	25
Mercury	0.22	0.10	0.13
Nickel	8.1	6.8	6.3
Potassium	1,200	580	590
Sodium	–	260	–
Strontium	7.3	4.1	5.5
Titanium	160	160	140
Vanadium	88	22	46
Yttrium	7.8	2.5	2.6
Zinc	23	22	16

TABLE 4-14
CALDWELL LACE LEATHER
SINKHOLE AREA
SOIL RESULTS (8/91)

Parameter	SHA	SHB
Aluminum	10,000	9,100
Arsenic	4.0	2.2
Barium	150	130
Calcium	0.78	0.77
Chromium	1,400	890
Cobalt	41	9.5
Copper	10	8.7
Iron	6.4	5.5
Lead	10,000	8,100
Magnesium	17	9.9
Manganese	890	870
Mercury	960	970
Nickel	0.06	--
Potassium	9.4	10
Sodium	660	660
Strontium	9.8	8.5
Titanium	190	140
Vanadium	19	16
Yttrium	11	13
Zinc	27	29

TABLE 4-15
CALDWELL LACE LEATHER
GEOMETRIC MEANS AND UPPER CONFIDENCE INTERVAL ESTIMATES

Exposure Unit No.	Geometric Mean	No. of Composites	Upper 95% Confidence Limit	Upper 85% Confidence Limit
1	47	1	70	59
2	47	1	70	59
3	20	1	30	25
4	40	1	60	50
5	13	1	19	16
6	13	1	19	16
7	17	1	25	21
8	14	1	21	18
9	13	1	19	16
10	160	1	239	202
11	100	1	150	126
12	14	1	21	18
13	7	1	11	9
14	9	1	13	11
15	87	1	130	110
16	42	2	56	50
17	57	2	75	67
18	49	1	73	62
19	29	2	38	34
20, 21	120	1	180	151
22	220	1	329	277
23	165	2	219	194
24	154	2	205	182
25	120	1	180	151
26	44	1	66	55
27, 28	220	1	329	277
29, 30	180	1	269	227
MAX:	220		329	277

TABLE 4-16
CALDWELL LACE LEATHER
LANDFILL AREA
SOIL BORING RESULTS (12/92)
(all soil results are in mg/kg, except where noted)

Parameter	CL-SB-01 0 - 1½'	CL-SB-01 9 -10½'	CL-SB-01 45 -46'	CL-SB-02 0 - 1½'	CL-SB-02 9 - 10½'	CL-SB-02 15 -16½'	CL-SB-03 0 - 1½'	CL-SB-03 9 -10½'
Aluminum	6,400	7,200	1,900	5,300	5,200	5,300	7,400	6,000
Arsenic	4J	–	–	3.2J	8.3J	6.3J	3.7J	6.2J
Barium	44J	38J	6.5J	26J	17J	14J	59J	12J
Calcium	790	52	280	1,500	730	430	760	180
Chromium	12	7.4	8.2	70	11	12	20	10
Cobalt	3.6	1.2J	–	1.9	1.4J	15	5	2.6
Iron	11,000	8,200	7,500	8,700	7,400	6,500	9,800	17,000
Lead	8	8.1	3.6	5.1	7.7	6.5	7.9	23
Magnesium	570	260	130	340	350	620	640	340
Manganese	100	110	11	84	18	11	180	2.4
Nickel	–	–	–	–	–	19	–	–
Potassium	–	–	–	–	890	2,200	–	2,400
Sodium	–	140	–	–	560	–	–	620
Vanadium	19	18	9	16	16	6.8	17	10
Zinc	–	–	–	–	–	87	–	27
EXTRACTABLE ORGANIC COMPOUNDS								
1 Unidentified Compound*	500J	–	–	–	–	–	–	–
PURGEABLE ORGANIC COMPOUNDS								
Endrin*	–	0.94J	–	–	–	–	–	–

TABLE 4-16
CALDWELL LACE LEATHER
LANDFILL AREA
SOIL BORING RESULTS (12/92)
(all soil results are in mg/kg, except where noted)

Parameter	CL-SB-01 0 - 1½'	CL-SB-01 9 -10½'	CL-SB-01 45 -46'	CL-SB-02 0 - 1½'	CL-SB-02 9 - 10½'	CL-SB-02 15 -16½'	CL-SB-03 0 - 1½'	CL-SB-03 9 -10½'
Gamma-Chlordane/2*	--	.40J	--	--	--	--	--	--

* µg/kg

TABLE 4-16
CALDWELL LACE LEATHER
LANDFILL AREA
SOIL BORING RESULTS (12/92)
(all soil results are in mg/kg, except where noted)

Parameter	CL-SB-04 0 - 1½'	CL-SB-04 9 -10½'	CL-SB-04 35 - 36'	CL-SB-05 0 - 1½'	CL-SB-05 9 - 10½'	CL-SB-05 60 -61½'	CL-SB-06 0 - 1½'	CL-SB-06 9 - 10½	CL-SB-06 20 - 21½
Aluminum	8,000	4,600	8,700	9,900	8,100	3,100	4,900	5,200	12,000
Arsenic	5.4J	2.6J	4.6J	4.8J	3.3J	--	5.9J	5J	4J
Barium	67J	7.3J	40J	54J	30J	12J	24J	10J	43J
Beryllium	--	--	0.79	--	--	--	--	--	0.99
Calcium	260	140	1,600	410	170	320	420	180	3,000
Chromium	10	19	22	12	12	8.1	14	13	23
Cobalt	8.8	--	20	3.6	1.2J	1.2J	2J	--	8.1
Iron	11,000	13,000	26,000	14,000	13,000	7,700	8,900	13,000	15,000
Lead	9.2	6.0	18	8	8.3	3.6	5.8	4.5	17
Magnesium	680	150	450	810	340	120	320	290	850
Manganese	270	9.2	930	89	31	22	43	28	710
Mercury	--	--	--	--	--	--	--	--	0.18
Nickel	--	--	16	--	--	--	--	--	19
Potassium	--	--	1,300	--	--	--	--	--	1700
Sodium	--	--	--	--	--	--	--	--	--
Vanadium	19	26	27	23	27	14	15	20	14
Zinc	23	--	80	21	--	--	--	--	110
EXTRACTABLE ORGANIC COMPOUNDS									
Cedrol*	--	--	--	--	--	--	800JN	--	--

TABLE 4-16
CALDWELL LACE LEATHER
LANDFILL AREA
SOIL BORING RESULTS (12/92)
(all soil results are in mg/kg, except where noted)

Parameter	CL-SB-04 0 - 1½'	CL-SB-04 9 -10½'	CL-SB-04 35 - 36'	CL-SB-05 0 - 1½'	CL-SB-05 9 - 10½'	CL-SB-05 60 -61½'	CL-SB-06 0 - 1½'	CL-SB-06 9 - 10½	CL-SB-06 20 - 21½
1 Unidentified Compound*	--	--	--	--	--	1000J	--	--	--
11 Unidentified Compounds*	--	--	--	--	--	--	10,000J	--	--

* µg/kg

TABLE 4-16
CALDWELL LACE LEATHER
LANDFILL AREA
SOIL BORING RESULTS (12/92)
(all soil results are in mg/kg, except where noted)

Parameter	CL-SB-07 0 - 1½'	CL-SB-07 9 -10½'	CL-SB-07 20 - 21'	CL-SB-08 0 - 1½'	CL-SB-08 9 - 10½'	CL-SB-08 20 - 21½'	CL-SB-09 0 - 1½'	CL-SB-09 10 - 11½'	CL-SB-09 60 - 60½'
Aluminum	8,300	1,400	7,300	5,800	6,100	6,400	9,900	9,100	6,100
Arsenic	4.2J	–	2.9J	3.5J	2.5J	6.1J	6.6J	2.6J	3.8J
Barium	54J	3J	10J	36J	14J	28J	45J	41J	77J
Beryllium	–	–	0.25J	–	–	–	–	0.32	4.4
Cadmium	–	–	–	–	–	–	–	–	33
Calcium	11,000	54	640	610	240	2,800	490	71	1,800
Chromium	20	3.7	6.3	16	12	7	13	9.2	13
Cobalt	9.2	–	–	3.6	–	1.3J	3.9	2.5	15
Copper	–	–	–	–	–	–	–	5.7	–
Iron	12,000	3,300	5,600	9,900	9,700	6,200	14,000	9,100	23,000
Lead	9.4	1.9	14	7.6	5.5	8.4	11	7.9	15
Magnesium	1,300	110	390	420	280	590	670	280	430
Manganese	1,000	13	16	120	17	18	120	69	1,500
Nickel	–	–	–	–	–	–	–	–	42
Potassium	–	–	860	–	–	1,600	–	–	930
Sodium	–	160	–	–	120	–	–	–	–
Vanadium	22	5	8.9	18	21	10	21	18	17
Zinc	–	–	–	–	16	43	–	–	340

TABLE 4-16
CALDWELL LACE LEATHER
LANDFILL AREA
SOIL BORING RESULTS (12/92)
(all soil results are in mg/kg, except where noted)

Parameter	CL-SB-07 0 - 1½'	CL-SB-07 9 -10½'	CL-SB-07 20 - 21'	CL-SB-08 0 - 1½'	CL-SB-08 9 - 10½'	CL-SB-08 20 - 21½'	CL-SB-09 0 - 1½'	CL-SB-09 10 - 11½'	CL-SB-09 60 - 60½'
EXTRACTABLE ORGANIC COMPOUNDS									
1 Unidentified Compound*	--	--	--	700J	400J	--	--	--	--
2 Unidentified Compounds*	--	--	--	--	--	900J	--	--	--
PURGEABLE ORGANIC COMPOUNDS									
Acetone*	--	--	130U	--	--	--	--	--	--
Toluene*	--	--	16	--	--	--	--	--	--

* µg/kg

TABLE 4-17
CALDWELL LACE LEATHER
SURFACE WATER/SEDIMENT
JUNE 1990

Parameter	CL-011-SW	CL-006-SD	CL-011-SD	CL-012-SD	CL-016-SD
INORGANIC COMPOUNDS	ug/l	mg/kg	mg/kg	mg/kg	mg/kg
Barium	--	120J	50J	--	74J
Cobalt	--	6.3	6.3	6.8	8.8
Copper	--	4.7	54	9	7.2
Nickel	--	6.9	10	11	7.6
Vanadium	--	8.6	26	23	28
Aluminum	--	8,600J	14,000J	11,000J	16,000J
Manganese	--	920J	--	150J	450J
Calcium	8,900J	--	1,900	--	1,800
Magnesium	--	--	2,000	--	1,200
Iron	--	--	14,000J	16,000J	14,000J
Potassium	5,000	--	740	620	680
EXTRACTABLE ORGANIC COMPOUNDS					
(3- and/or 4-)Methylphenol	--	--	--	--	490
1 Unidentified Compound	--	400J	400J	500J	--
Tetramethylpiperidinone	--	--	--	--	1,000JN
Acetyloxyoctadecenoic Acid, Methylester	--	--	--	--	700JN
Hexadecanoic Acid	--	--	--	--	2,000JN
19 Unidentified Compounds	--	--	--	--	40,000J
PURGEABLE ORGANIC COMPOUNDS					
Toluene	--	--	--	--	5J
Total Xylenes	--	--	--	--	4J

TABLE 4-18
REGION IV WASTE MANAGEMENT DIVISION
FRESHWATER WATER QUALITY[1] AND SEDIMENT[2]
SCREENING VALUES FOR
HAZARDOUS WASTE SITES
(92 Version)

Compound	Acute Screening Value (ug/L)	Chronic Screening Value (ug/L)	NOAA ER-L Concentration (mg/kg)	NOAA ER-M Concentration (mg/kg)	Subjective Degree of Confidence ER-L/ER-M[3]
Barium	–	–	–	–	–
Cobalt	–	–	–	–	–
Copper[4]	9.22*	6.54*	70	390	H/H
Nickel[4]	789.00*	87.71*	30	50	M/M
Vanadium	–	–	–	–	–
Aluminum (pH 6.5 - 9.0)	750*	87*	–	–	–
Manganese	–	–	–	–	–
Calcium	–	–	–	–	–
Magnesium	–	–	–	–	–
Iron	–	1000*	–	–	–
Potassium	–	–	–	–	–
Toluene	1750 (5s)	175	–	–	–

[1] Based on Region IV Water Management Divison, Water Quality Standards Unit's Screening List. Hardness (mg/L as $CaCO_3$): 50.0; pH: 6

* Water Quality Criteria

s Number of Species

[2] Based on Effects Range - Low and Effects Range - High Values from:
Long, Edward R., and Lee G. Morgan, 1990. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. Office of Oceanography and Marine Assessment, Seattle, WA.

[3] L=Low
M=Moderate
H=High

[4] Hardness Dependent – Based on the following equations:

Compound	Acute Screening Value	Chronic Screening Value
Copper	$e^{(0.9422(\ln H)-1.464)}$	$e^{(0.8545(\ln H)-1.465)}$
Lead	$e^{(1.273(\ln H)-1.46)}$	$e^{(1.273(\ln H)-4.705)}$
Nickel	$e^{(0.846(\ln H)+3.3612)}$	$e^{(0.846(\ln H)+1.1645)}$
Silver	$e^{(1.72(\ln H)-6.52)}$	
Zinc	$e^{(0.8473(\ln H)+0.8604)}$	$e^{(0.8473(\ln H)+0.7614)}$

TABLE 4-19
CALDWELL LACE LEATHER
SEDIMENT
1/26/93
(Results in mg/kg, except where noted)

Parameter	Mud River Spring		Green Boiling Spring		Duncan Tile Spring		McPhearson Spring	
	A	B	A	B	A	B	A	B
Arsenic	8.8	–	4.1	3	4	4.6	9.1	–
Barium	28	17	38	35	24	56	67	51
Beryllium	0.34	0.27	0.56	0.65	0.33	0.50	.26J	0.62
Cobalt	6.6	3.1	4.5	6.2	3.9	7.6	11	2.4J
Chromium	78	13	14	13	10	14	20	5.7
Nickel	5.4	1.9	7.6	4.2	3.7	8.8	4.8	3.6J
Lead	12	5.1	7.8	7.1	9.4	16	14	9.7
Vanadium	27	–	16	20	14	24	25	–
Zinc	45	–	52	–	–	46	–	–
Aluminum	3,000	1,900	4,400	4,700	3,200	7,700	6,600	4,300
Managanese	600	220	350	330	300	420	520	54
Calcium	4,200	2,200	2,000	2,500	2,400	4,100	610	200
Magnesium	270	210	450	380	280	710	520	360
Iron	18,000	4,900	11,000	11,000	7,100	13,000	16,000	4,800
Sodium	19	12J	20J	22	22	43	32	24
Potassium	140	170	360	340	200J	540	310J	150

TABLE 4-19
CALDWELL LACE LEATHER
SEDIMENT
1/26/93
(Results in mg/kg, except where noted)

Parameter	Mossy Spring		Runoff/Long Southfork Spring		Lagoon Spring		Barnett-Karst Spring
	A	B	A	B	A	B	A
Arsenic	14	5.2	5	3.8	4.6	4	5.2
Barium	77	38	88	90	65	53	88
Beryllium	1.2	.53J	1	0.82	0.75	0.62	.60J
Cobalt	33	6.6	11	5.7	9.3	7.2	11
Copper	--	--	--	--	--	--	11
Chromium	160	13	30	17	19	8.2	18
Nickel	13	5	6.6	9.2	6.8	5.6	9.6
Lead	39J	17	15	9.8	15	14	15
Vanadium	59	16	42	32	17	15	32
Zinc	77	33	40	39	38	--	69
Aluminum	6,400	4,600	10,000	10,000	5,300	5,800	9,700
Managanese	2,600	500	1,100	630	660	430	1,300
Calcium	4,800	3,800	3,200	3,400	6,200	2,000	2,200
Magnesium	240	430	690	780	430	500	600
Iron	41,000	9,200	22,000	20,000	12,000	8,800	20,000
Silver	2.6	--	--	--	--	--	--
Sodium	21	23J	34	26	21J	26J	28
Potassium	85J	320	370J	420	520	410	580

TABLE 4-20
CALDWELL LACE LEATHER
LEACHATE SAMPLES
JUNE 1990

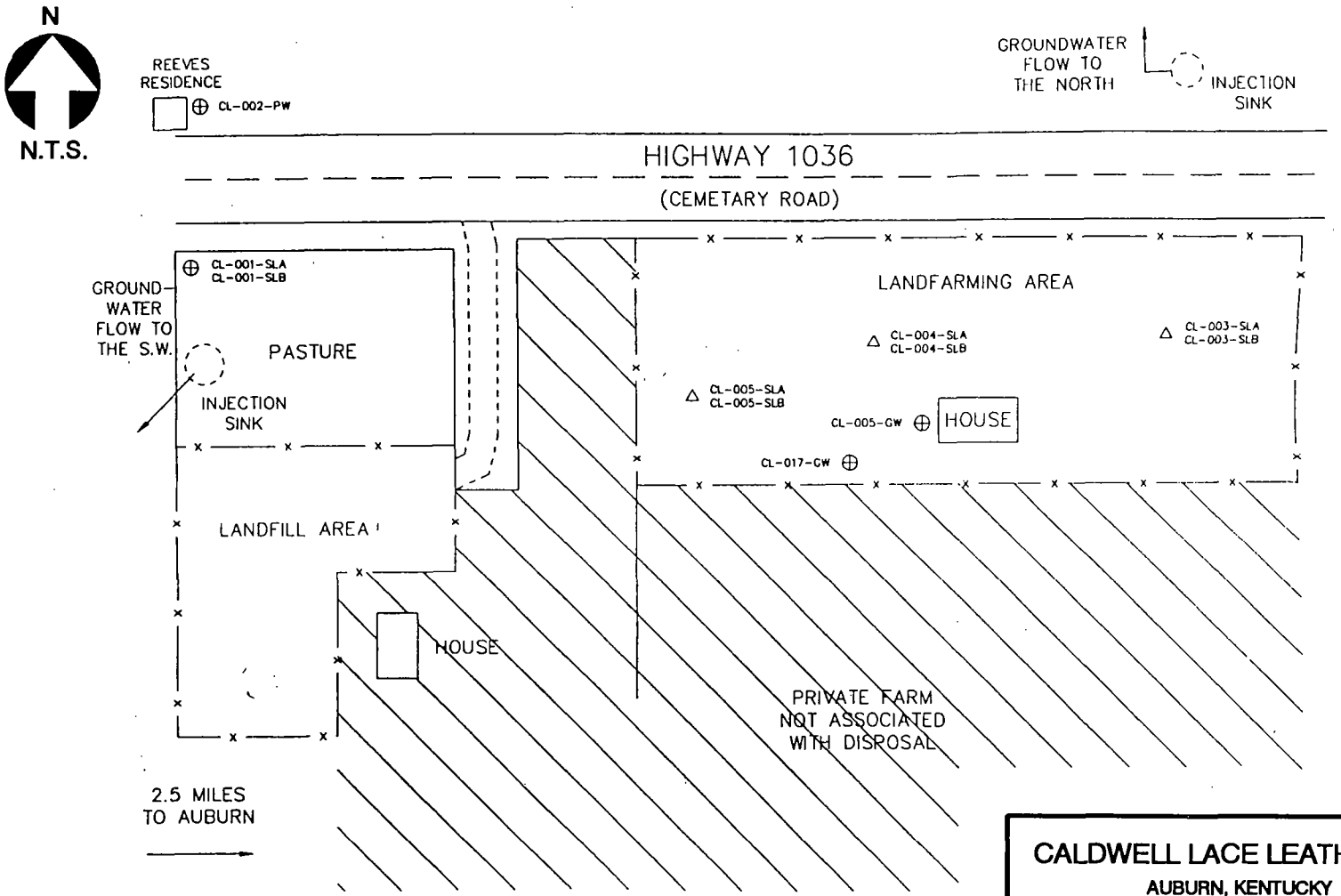
Parameter	CL-018GW	CL-016-LE
INORGANIC COMPOUNDS (ug/l)		
Silver	150JN	--
Barium	7400	380
Beryllium	97JN	--
Cadmium	9JN	--
Cobalt	660JN	29
Chromium	13,000J	710
Copper	810	--
Nickel	740	58
Lead	440J	--
Antimony	260JN	--
Vanadium	2,200	--
Zinc	3,200	--
Mercury	2.2	--
Aluminum	1,400,000J	--
Managanese	28,000J	2,300J
Calcium	91,000J	85,000J
Magnesium	160,000	52,000
Iron	1,700,000J	--
Sodium	100,000J	80,000J
Potassium	44,000	7,700
Cyanide	13	88
EXTRACTABLE ORGANIC COMPOUNDS (ug/l)		
Diethyl Pthalate	10J	3J
N-Nitrosodiphenylamine/Diphenylamine	14J	--

TABLE 4-20
CALDWELL LACE LEATHER
LEACHATE SAMPLES
JUNE 1990

Parameter	CL-018GW	CL-016-LE
(3-and/or 4-)Methylphenol	24J	--
Phenol	18J	--
Aniline	200JN	--
Dimethylethylphenol	80JN	--
Methylindole	70JN	--
Methylbenzenamine	1,000JN	100JN
Dimethylbenzenemethanol	--	10JN
Ethylbenzenamine	--	40JN
Dimethylbenzenamine 93 (isomers)	600JN	500JN
Chlorophenol (not 2)	700JN	300JN
Methylethylpehnol	200JN	20JN
Aminophenylethanone	--	80JN
Dichlorophenol	--	10JN
Hydroxymethylethylphenylethanone (2 isomers)	--	80JN
Methylthiobenzothiazole	--	20JN
Hexadecanoic Acid	--	30JN
Methylenebisphenol	--	10JN
Benzothiazolone	700JN	300JN
PURGEABLE ORGANIC COMPOUNDS (ug/l)		
Benzene	--	3J
Toluene	350	12
Ethyl Benzene	--	2J
Total Xylenes	--	7
Tetramethylpentanone	--	7JN

TABLE 4-20
CALDWELL LACE LEATHER
LEACHATE SAMPLES
JUNE 1990

Parameter	CL-018GW	CL-016-LE
7 Unidentified Compounds	--	300J
11 Unidentified Compounds	2,000J	--

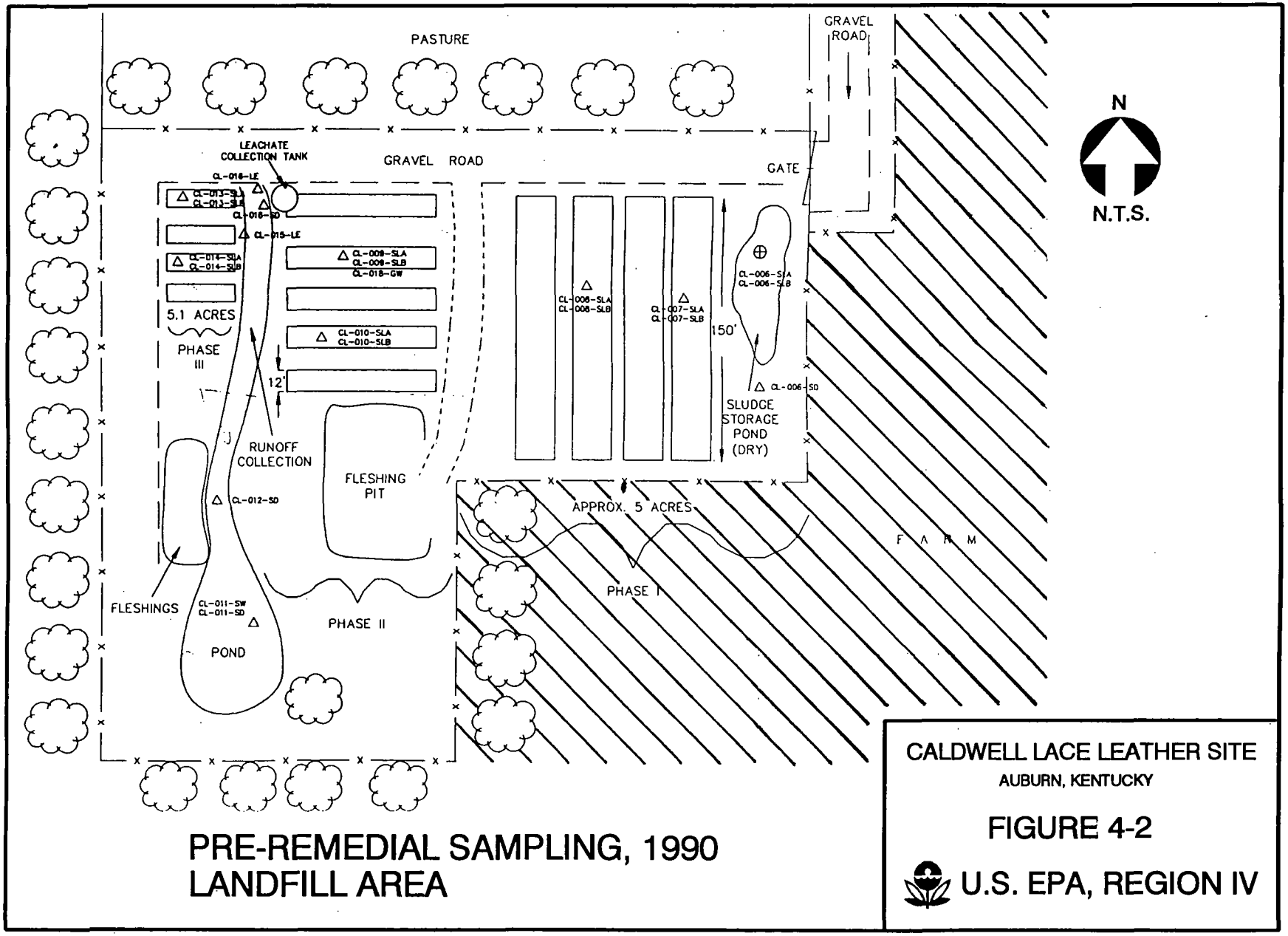


PRE-REMEDIAL SAMPLING, 1990
LANDFARM AREA

CALDWELL LACE LEATHER SITE
AUBURN, KENTUCKY

FIGURE 4-1

U.S. EPA, REGION IV

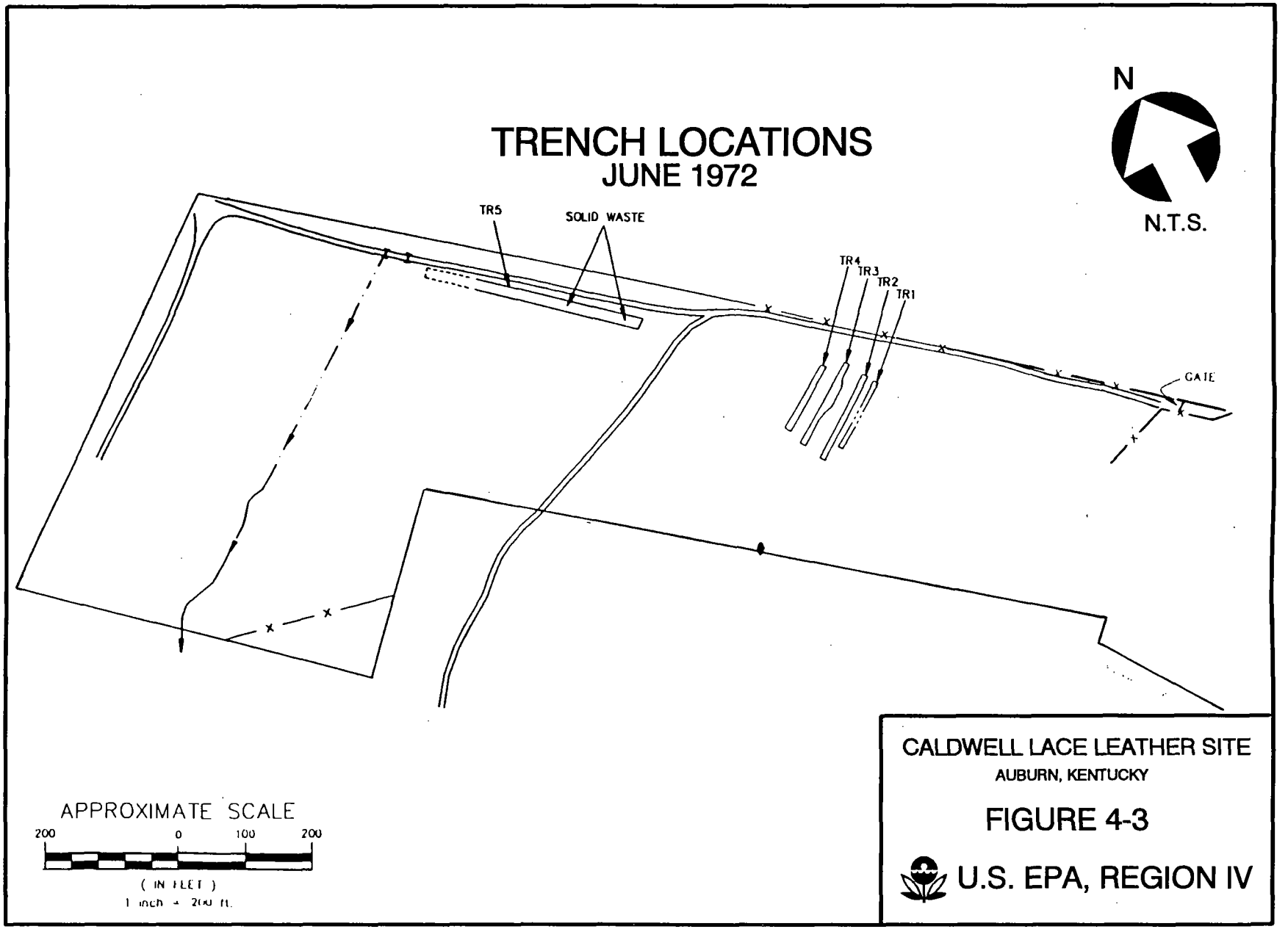


PRE-REMEDIAL SAMPLING, 1990
LANDFILL AREA

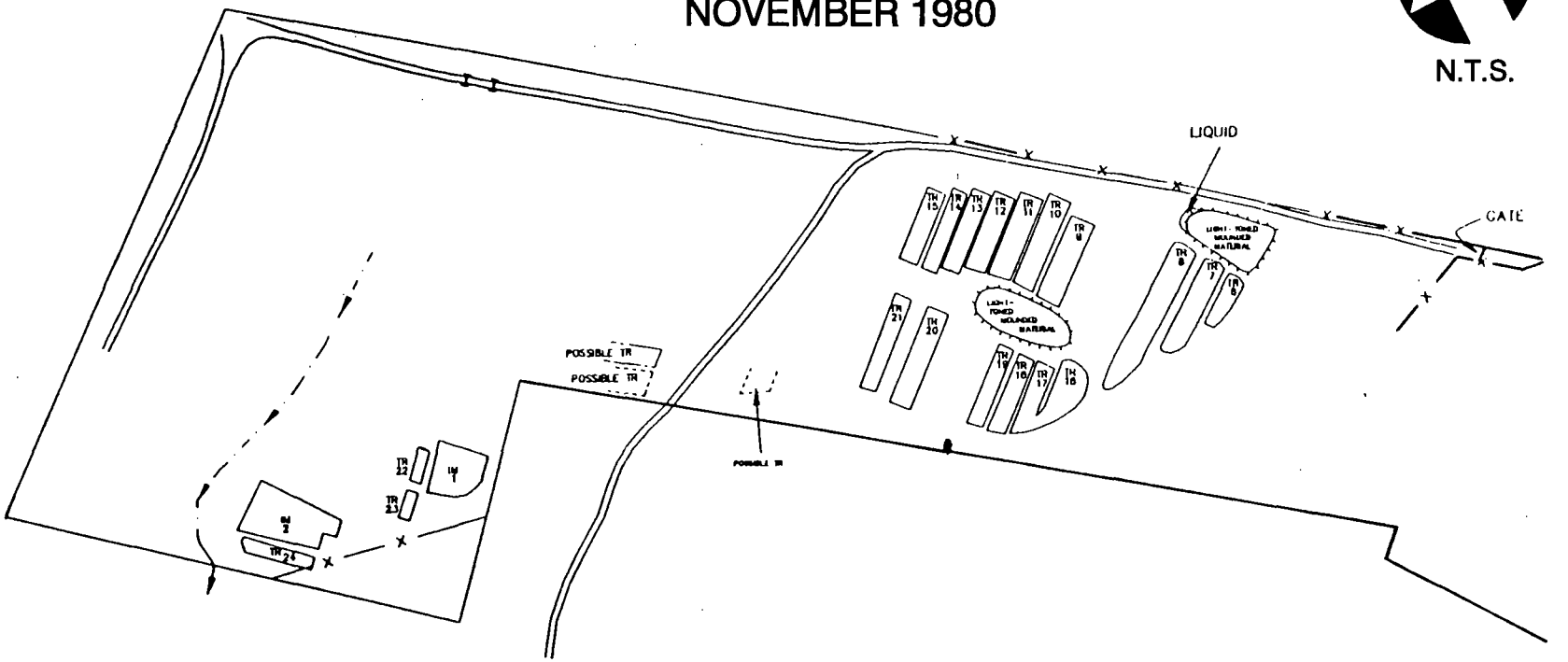
CALDWELL LACE LEATHER SITE
AUBURN, KENTUCKY

FIGURE 4-2

U.S. EPA, REGION IV


TRENCH LOCATIONS
JUNE 1972
N
N.T.S.
TR5
SOLID WASTE
TR4
TR3
TR2
TR1
GATE
APPROXIMATE SCALE
200
0
100
200
(IN FEET)
1 inch = 200 ft.
CALDWELL LACE LEATHER SITE
AUBURN, KENTUCKY
FIGURE 4-3
U.S. EPA, REGION IV

TRENCH LOCATIONS
NOVEMBER 1980



APPROXIMATE SCALE

200 0 100 200

(IN FEET)

1 inch = 200 ft.

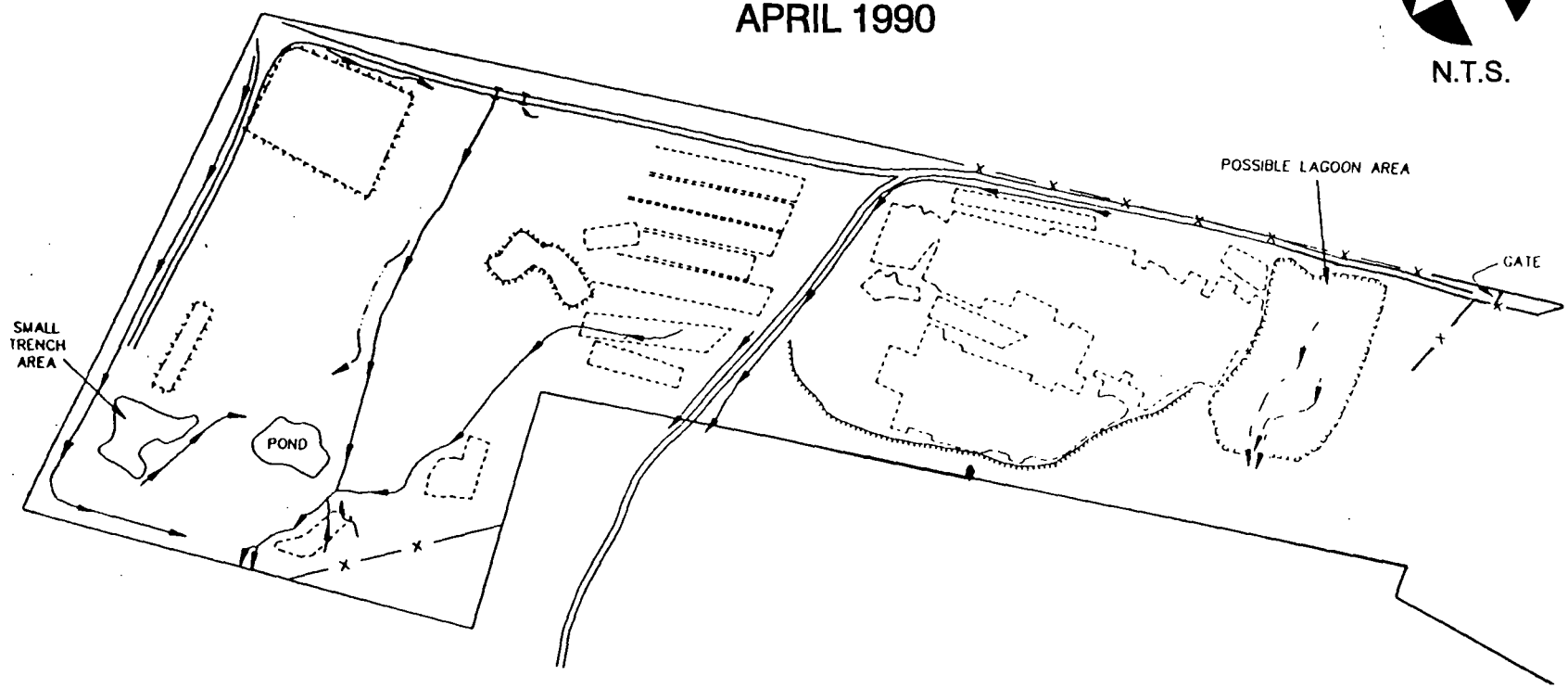
CALDWELL LACE LEATHER SITE

AUBURN, KENTUCKY

FIGURE 4-4

U.S. EPA, REGION IV

TRENCH LOCATIONS
APRIL 1990



APPROXIMATE SCALE

200 0 100 200

(IN FEET)

1 inch = 200 ft.

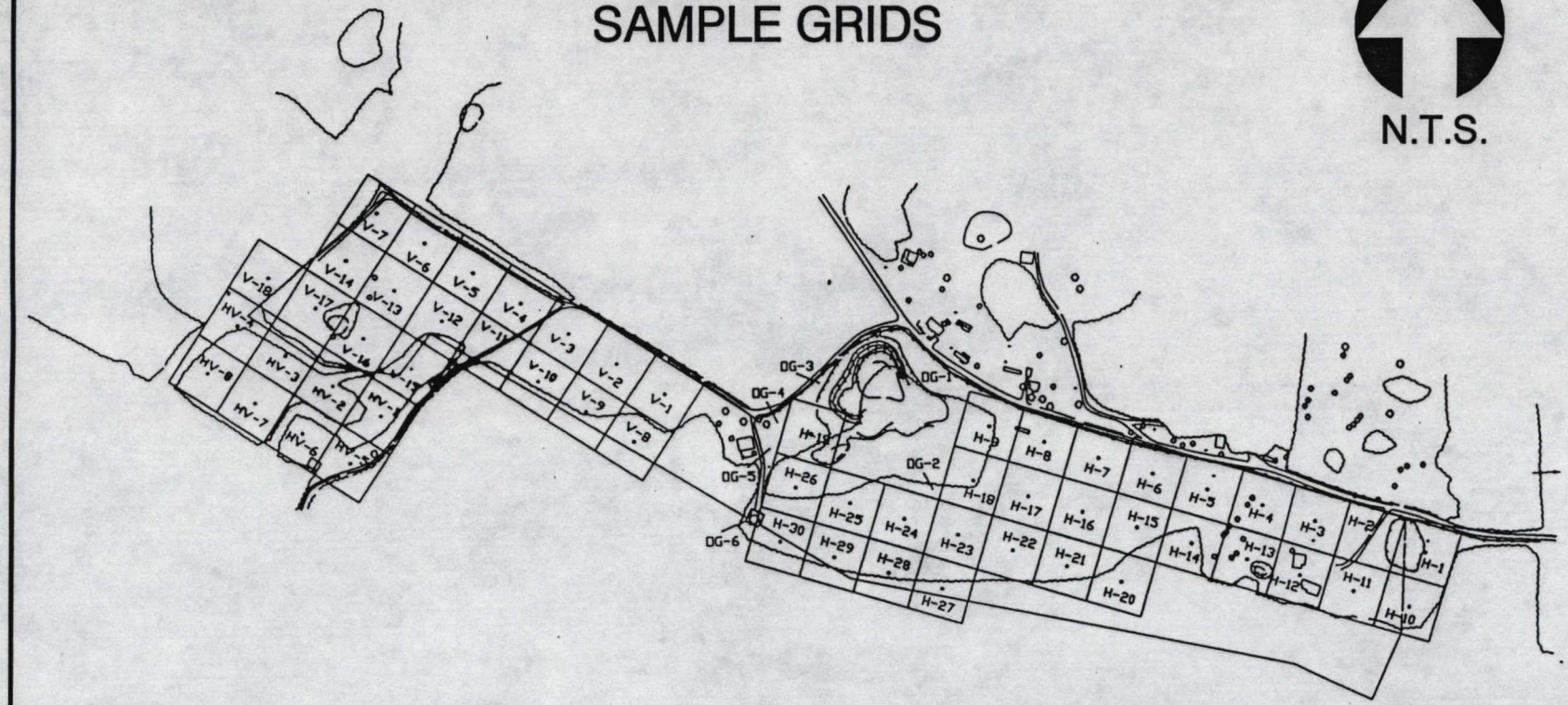
CALDWELL LACE LEATHER SITE

AUBURN, KENTUCKY

FIGURE 4-5

U.S. EPA, REGION IV

SAMPLE GRIDS



APPROXIMATE SCALE

548 0 274 548

(IN FEET)

1 Inch =548 ft.

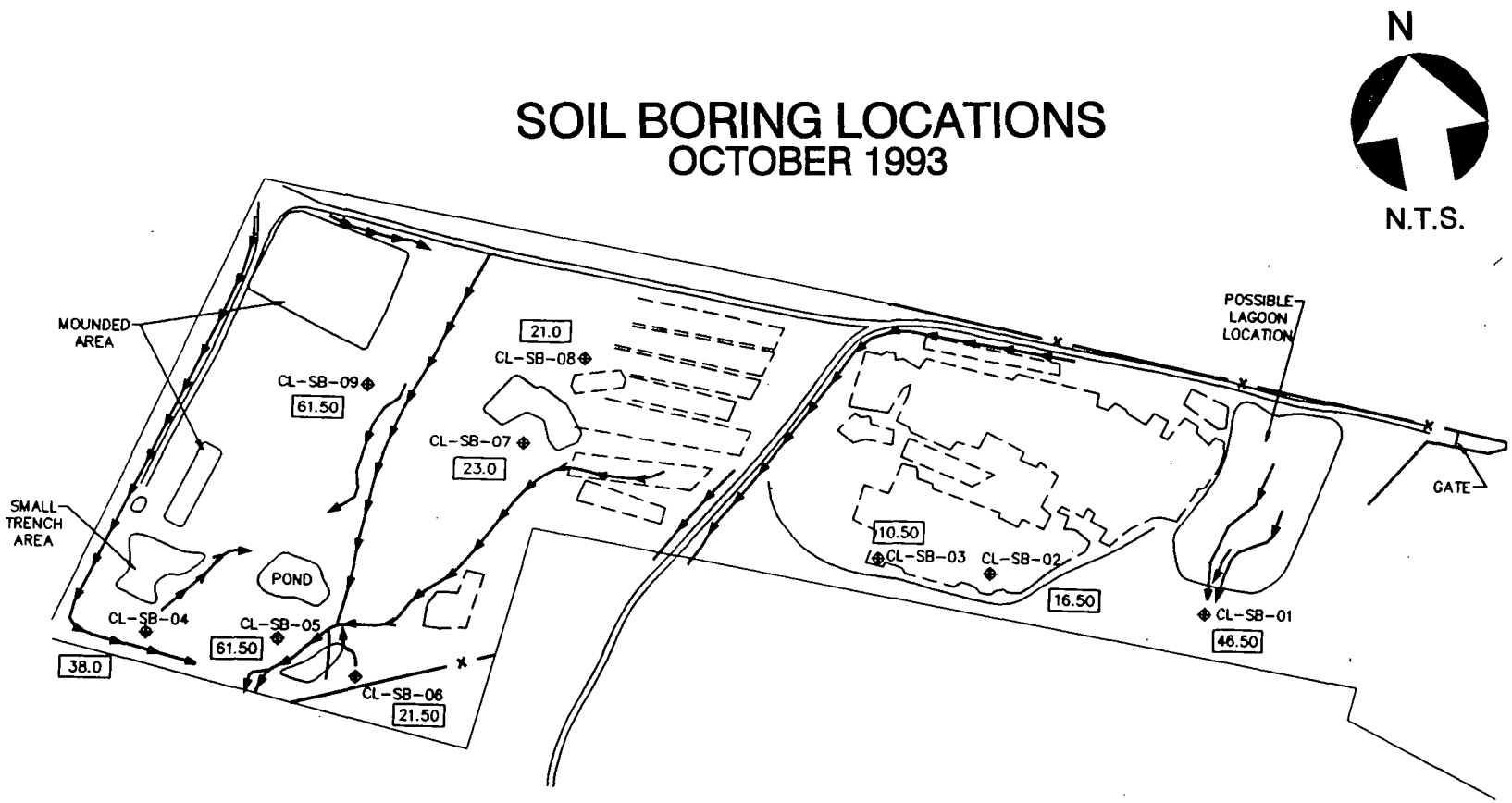
CALDWELL LACE LEATHER SITE

AUBURN, KENTUCKY

FIGURE 4-6

U.S. EPA, REGION IV

SOIL BORING LOCATIONS
OCTOBER 1993



LEGEND:

10.50	TOTAL DEPTH (FEET)
⊕	SOIL BORING LOCATION
→	DIRECTION OF SURFACE FLOW

100 0 100 200
SCALE IN FEET
1 INCH = 200 FT.

CALDWELL LACE LEATHER SITE
AUBURN, KENTUCKY

FIGURE 4-7

U.S. EPA, REGION IV

5

5.0 GROUND WATER

5.1 INTRODUCTION

5.1.1 DEFINITIONS AND CLASSIFICATION

Ground water is defined in CERCLA Section 101, Paragraph 12 as water in a saturated zone or stratum beneath the surface of land or water. EPA's regulatory approach to ground-water protection, as mandated by the National Contingency Plan (NCP), has been formulated in the EPA Ground-Water Protection Strategy. This guidance includes a classification system for ground waters as described in the document entitled Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy (EPA, Final Draft December, 1986). Under this guideline, the ground waters underlying the Caldwell Lace and Leather Site are classified as Class IIA, i.e., a current source of drinking water supply. This determination is based upon the observation that ground waters in potentially affected aquifers are used for domestic supply purposes within the Classification Review Area (CRA), which consists of an area within a two-mile radius from the Site. Class IIA ground waters generally receive a very high level of protection, based on the regulatory goal stated in the NCP of restoring affected ground waters to their highest beneficial use. In the case of Class IIA ground waters, this highest beneficial use is drinking water supply, and the remediation goals for Class IIA ground waters are generally based on protection of public health (e.g., drinking water standards).

The Commonwealth of Kentucky defines ground waters in Title 401 of the Kentucky Administrative Regulations (401 KAR). In 401 KAR Chapter 30.010, groundwater (sic) is defined as "...water which is in the zone of perennial saturation. It is differentiated from water held in the soil, from water in downward motion under the force of gravity in the perennially unsaturated zone, and from water held in chemical or electrostatic bondage. It is synonymous with the term 'phreatic water'...."

Kentucky has not developed a formal ground-water classification system similar to the Federal guidelines described above. Ground waters are included in the statutory definition of waters of the Commonwealth found in the Kentucky Revised Statutes Chapter 224 (KRS 224). KRS 224 Section 224.01-10 defines waters of the Commonwealth to "...mean and includes any and all rivers, streams, creeks, lakes, ponds, impounding reservoirs, springs, wells, marshes and all other bodies of surface or underground water, natural or artificial, situated wholly or partly within or bordering upon the Commonwealth or within its jurisdiction...." Kentucky regulations also contain a definition of the term "underground drinking water source" which is analogous to the EPA definition of underground source of drinking water (USDW) found in the Federal Safe Drinking Water Act (SDWA). Both of these definitions include essentially all ground

waters or aquifers that contain less than 10,000 milligrams per liter (mg/l) total dissolved solids and which are capable of supplying sufficient yield for drinking water supply.

Ground waters underlying the Site are subject to Kentucky jurisdiction as waters of the Commonwealth. They also meet the Federal SDWA definition of a USDW and the Kentucky definition of an underground drinking water source.

5.1.2 GEOLOGY/HDYROGEOLOGY

Site geology and hydrogeology are discussed in detail in Section 2 of this RI report. These subjects are therefore only briefly discussed in this Section.

Nearly all ground water at the Site is present at relatively shallow depths. The Site lies along the crest of an east-west trending ridge that is about 170 feet in elevation above the surrounding valley floors. In the vicinity of the Site, the bedrock is overlain by soils and residuum that is generally thin but variable in thickness. Soil depths range from 0 to 43 feet. The soils and residuum, where present, are underlain by limestones, shales and sandstone of the Mississippian age including, in descending order, (1) the Big Clifty Sandstone member of the Golconda Formation, (2) the Girkin Formation and (3) the Ste. Genevieve Limestone.

Most of the Site is underlain by as much as 70 feet of the Big Clifty Sandstone, which is the caprock for many of the ridges throughout the vicinity. The Big Clifty Sandstone is gray to light brown, fine-grained, cross bedded and locally shaley.

The Girkin Formation underlies the Big Clifty Sandstone and outcrops at the surface at the eastern and western ends of the Site. The Girkin Formation underlies the highly developed karst terrain lowlands that surround the Site. This Formation is approximately 170 feet thick and is comprised mostly of limestone that is medium-light gray to pale-yellow gray, aphanitic to coarsely detrital, and oolitic. Discontinuous shale and sandstone units up to five feet in thickness are present about 45 feet above the base of the Girkin Formation.

The Ste. Genevieve Limestone underlies the Girkin Formation. This limestone is light gray to light brown in color, fine to coarsely detrital, and oolitic. The Ste. Genevieve Limestone is approximately 200 feet thick in the vicinity of the Site and is the basal limestone in the area. The nearest outcrops of the Ste. Genevieve Limestone to the Site are at Mud Spring, about 4 miles southwest of the Site, and in the vicinity of the town of Auburn, located about 2 miles southeast of the Site. Auburn Spring, used by the city of Auburn for municipal water supply, is located near the outcrop of the Ste. Genevieve Limestone.

Ground-water hydrology in the vicinity of the Site is governed by the mature karst development of the Girkin Formation. Locally, the Big Clifty Sandstone is only present in the immediate vicinity of the Site and is not hydrologically significant with respect to the movement and occurrence of local ground waters. The Big Clifty member provides only temporary storage of infiltrated rain water that is relatively rapidly transmitted either to the underlying Girkin Formation or to surface discharge points in the form of small seeps and springs. Underlying the Girkin at considerable depth in the vicinity of the Site, the Ste. Genevieve Limestone is unlikely to be significantly affected by potential contamination from the Site. While the Girkin Formation undoubtedly transmits some recharge to the underlying Ste. Genevieve Limestone, the bulk of ground water that reaches the Girkin Formation will be diverted to surface water discharge points (springs) through discrete subsurface channel flow characteristic of karst terrains.

The hydrologically significant aquifer underlying the Site is therefore the Girkin Formation. As mentioned above, the Girkin Formation underlies the mature karst terrain of the areas surrounding the Site. Mature karst terrains are characterized by the presence of sinkholes, springs, disappearing streams and "karst windows", which are topographic depressions caused by the subsidence of the land surface resulting in the exposure of an underground stream. Ground-water flow in karst terrains is in turn characterized by conduit flow in subsurface channels, such as cave streams and other enlarged solution channels in the limestone. In the mature karst terrains such as those surrounding the Site, these conduits concentrate waters that enter the subsurface at either discrete points, such as sinkholes and karst windows, or by infiltration through overlying residuum or sandstone, into dendritic subsurface drainage patterns reminiscent of surface drainage patterns (i.e., creeks, streams and rivers). These subsurface conduits generally emerge to surface water discharge points in the form of springs.

Conduit flow in carbonate bedrock such as the Girkin Formation occurs in solution-enlarged openings that range in size from less than one inch to cave-size, such as the cave-like opening that forms Mossy Spring, a large volume discharge spring located approximately 2 miles northeast of the Site. These conduits develop along horizontal and vertical open fractures an bedding planes within the formation, resulting in the dendritic or trellised drainage network described above. Conduit flow predominates in the area surrounding the Site, and the hydrologic significance of this mature karst development is the rapid introduction of excess rainfall into the aquifer system, and subsequent rapid movement of ground water through the aquifer system.

5.2 OCCURRENCE OF GROUND WATER

Ground water can be found in the soils and residuum underlying portions of the Site; within the

Big Clifty Sandstone primarily within fractures and bedding planes that confer secondary porosity on the Sandstone medium; within the Girkin Formation primarily within solution-enlarged conduits that comprise the dendritic subsurface flow network characteristic of karst terrains; and similarly in characteristic karst conduits in the Ste. Genevieve Limestone.

Flow in major conduits converges to the springs that serve as the natural discharge points for these conduits. Flow within these conduits is typically turbulent, highly variable with respect to temperature and turbidity, and responds rapidly to precipitation events. The springs which serve as major discharge points for the conduit system draining the basin in which the Site lies (Mud River Spring, Mossy Spring) exhibit these flow characteristics.

Ground water occurring in the fractures and bedding planes of the Big Clifty sandstone are of little hydrologic significance, except in that they serve as recharge to the underlying Girkin Formation. Similarly, ground waters which are associated with primary porosity in the overlying soils and residuum, or with the pore space associated with the Big Clifty Sandstone, are likewise of little overall hydrologic significance at the Site except as routes of transport from contaminant source areas to the Girkin Formation. These ground waters are unlikely to be of sufficient yield to meet the Federal or state definition of underground sources of drinking water, and are unlikely to be of sufficient yield to classify as Class II ground waters under EPA guidelines. There are no known domestic supply wells screened in either the Big Clifty Sandstone or the soil/residuum strata in the vicinity of the Site. The Big Clifty member and the soil/residuum strata are of limited extent at the Site, likewise limiting the capability of these strata to store ground waters and transmit them to a hypothetical well.

Given the karstic nature of the ground water hydrology at this Site, the traditional measures of hydraulic characteristics are of little significance as well. Hydraulic conductivity will be highly variable, depending on whether or not a well intercepts a conduit bearing significant flow. Similarly, the concepts of transmissivity, storativity, porosity, etc, which govern the hydraulic behavior of aquifers in which the flow is predominantly laminar in nature, have little practical meaning in karst aquifers. Ground water will in all situations move in response to hydraulic gradients from points of recharge to points of discharge, and the general direction of flow even in karst aquifers can be estimated by drawing potentiometric contours on a Site map and assuming that flow occurs perpendicularly to the equipotential lines. Indeed, a potentiometric surface map was prepared by Quinlan as part of his dye-trace study of the Site, as discussed below (Quinlan, 1982). It is clear, however, that the local direction of ground-water flow at a specific location may be significantly different than the regional flow direction because that flow must follow available, discrete conduits whose orientation depends on the alignment of secondary solution channels in the limestone. These alignments are dependent upon structural features of the formation, including fractures, bedding planes, and dip of the rock strata. For these reasons,

dye-tracing was determined to be the most accurate method of determining the direction and rate of ground water flow in the karst aquifers underlying the Site.

5.3 MOVEMENT OF GROUND WATER

The movement of ground water at Caldwell is determined by the nature of the soil and rock matrix associated with the different lithologic strata underlying the Site. The types of ground-water movement range from laminar flow in the interstitial pore spaces of unconsolidated media (e.g., in the soils and residuum overlying the bedrock in portions of the Site) to turbulent flow in discrete conduits (e.g., flow in the solution-enlarged subsurface channels found in the Girkin Formation).

Ground-water will always flow in response to hydraulic gradients present in the aquifers in question. At the Caldwell Site, potentiometric equipotential lines radiate outward from the Site, which is located at a topographic as well as a local potentiometric "high point" or divide. Quinlan (1982) determined the potentiometric surface of the water table to be "...an elongate, sausage-shaped mound that is concave northward...." In addition to the determination of the potentiometric surface of the local water table, Quinlan conducted a series of dye traces. The dye trace studies conducted by Quinlan identified routes of dye movement to the southwest, towards the Mud River, from the old waste disposal areas. Other routes of flow were identified to the north, from the landspreading operations area, towards discharge points on the Gasper River, and flow routes to the west were inferred from the hydraulic gradient data.

Ewers (1983) conducted additional dye-trace studies at the Site. The results of this study were similar to those reported by Quinlan, and tend to confirm those observations.

The United States Geological Survey (USGS, 1993) also conducted dye-trace studies in 1992 at the Site (Appendix C). The results of the USGS study tended to confirm those of Quinlan by identifying points of discharge to the southwest and north. In addition, the USGS study confirmed the flow connection from the Site to points of discharge to the west, into the Long South Fork/Wiggington Creek drainage basin. The USGS study also confirmed the absence of a hydraulic connection between the Site and the spring used by the City of Auburn for public water supply. For the purposes of further discussion, the various springs used as monitoring points by Quinlan, Ewers, and the USGS will be identified by the nomenclature used in the 1993 USGS report.

During the course of the three separate studies, dye was injected into eight different points of entry to the subsurface conduit flow system either on the Site or in the immediate vicinity. These eight injection points, labelled A-H in the USGS report and on Figure 5-1, include

swallets, sinkholes and other karst windows that are naturally occurring. Detectors were placed during the course of the three studies in wells, springs, and surface streams surrounding the Site.

The results of the dye trace studies have delineated the movement of ground water in the karst aquifer underlying the Site. Dye injected at all injection points, with the exception of injection point G, was recovered at a series of connected recovery points southwest of the Site leading to eventual discharge into the Mud River surface water drainage. The dye recovery points along this pathway were springs numbers 2, 3, 6 and 8 (Green Boiling Spring, Duncan Tile Spring, Coy Wright Blue Hole Spring, and Mud River Spring, respectively). Mud River Spring (spring 8) is the final discharge point for this subsurface system, and is located approximately 4 miles southwest of the Site. Please refer to Figure 5-2, which has been reproduced from the USGS report, for identification of the dye-recovery points.

Dye injected at injection points A and B was also recovered at springs 9 and 11 (Mossy Spring and Cemetery Road Spring, respectively) and at surface water monitoring point 10 located in Long South Fork Creek. Springs 9 and 11 discharge to Long South Fork Creek. These springs and the surface water monitoring point are located approximately 1.8 miles northwest of the Site. This indicates that the subsurface system of solution channels in the Girkin Formation draining towards Mud River Spring and towards Mossy Spring is interconnected.

Dye was also injected into location G, which does not lie on the Site itself, but which is located north of the former landspreading operation area. Runoff from the landspreading operation area could enter the karst aquifer at this point. Dye injected at location G was recovered at springs 12, 13, and 16 (Barnett Spring, Barnett Karst Window, and Crawford Spring, respectively). Spring 16 is the ultimate discharge point for this portion of the karst system, and is located approximately 2.2 miles north of the Site. This spring discharges into Gasper River. These results indicate that storm water runoff from the Site can enter the subsurface karst system and be transported in a northerly direction, eventually discharging to Gasper River.

To summarize the findings of the dye trace studies, dye injected at all on-Site injection points used in the three separate studies was recovered from springs lying to the southwest, leading to the ultimate discharge point for this subsurface system, spring number 8 (Mud River Spring), which discharges into Mud River. Dye injected into on-Site injection point A and injection point B, lying just south of the eastern portion of the Site, was recovered from a system of interconnected springs leading to the northwest, culminating in spring number 9 (Mossy Spring), which discharges into Long South Fork Creek. Dye injected into injection point G, located north of the Site, was recovered from a series of interconnected springs lying north of the Site, culminating in spring number 16 (Crawford Spring) which discharges into Gasper River.

The rate of ground-water flow in subsurface karst conduits of the type present at this Site is highly variable, dependent upon rainfall, antecedent moisture conditions, and time of concentration. Rates of flow will increase dramatically in response to rainfall events, slowly tapering off to base flow conditions thereafter. Subsurface flow hydrographs would look essentially the same as surface water stream hydrographs following rainfall events; i.e., a rapidly rising limb followed by a more gradual falling limb returning to base flow rates and volumes.

The USGS (1993) estimated flow rates from the Site to points of discharge at downgradient springs to range from three to five days, and in the case of spring number 8 (Mud Spring) as much as eight days. Eight days travel time to spring number 8 is approximately equal to an average flow rate of two feet per minute. Flow rates in open solution channels in mature karst systems can be as high as 200 feet per minute under high flow conditions (e.g., in response to storm events).

5.4 GROUND-WATER RECHARGE/DISCHARGE

Ground-water recharge at the Site consists of infiltrated rainfall. Recharge occurs through the overlying soils and residuum, downward through fractures in the Big Clifty Sandstone, eventually reaching the open solution channels in the limestones of the Girkin Formation. Quantitative rates of recharge to the Girkin Formation (the primary aquifer of concern at the Site) have not been determined, but as in all karst terrains the rate of recharge will be relatively high, and the rapidity with which that recharge occurs will likewise be high. It is likely that as much as 25 inches per year of rainfall eventually serves as recharge to the Girkin Formation in the vicinity of the Site.

The primary points of discharge from the Girkin Formation were identified in the three dye trace studies discussed above. Discharge was identified into three separate drainage basins; to the southwest into the Mud River Basin, northwest into the Long South Fork Creek drainage basin, and north into the Gasper River drainage basin. Recharge from the Site, or runoff from the Site which is likely to enter nearby karst windows, will reach one or more of these discharge points.

5.5 GROUND-WATER QUALITY

The Pre-Remedial Sampling 1990 and the Groundwater Study 1991 were performed prior to the USGS dye-trace studies. The Groundwater Study involved sampling the discharge of various springs and potable wells. As a result of the USGS dye-trace studies, a number of these springs and wells were not identified as being in hydraulic connection to the Site. The following Section 5.5.2 regarding this sampling event is discussed in order to provide control data for comparison purposes.

5.5.1 PRE-REMEDIAL SAMPLING 1990

5.5.1.1 SAMPLING LOCATIONS AND RATIONALE

A sample of the drinking water (CL-002-PW) was collected from the Barry Reeves residence located approximately 1/4 mile northwest of the landfill area of the Site (Figure 5-3). This sample represented the closest residential well to the source of contamination.

The proposed sample CL-001-GW was not collected. After advancing a borehole to a depth of 27 feet at the location proposed in the Pre-Remedial Sampling Study Plan, ground water was not encountered. The purpose of this sample which was to characterize ground water upgradient of the Site, was adequately addressed by the drinking water sample from location CL-002-PW.

CL-005-GW was a sample of the ground water from an existing well on the east side of the landfarming area of the Site (Figure 5-3). The purpose of the sample was to characterize any ground water contamination caused by the waste disposal reported to have occurred on the landfarm.

Ground water sample CL-006-GW was not collected as proposed in the Study Plan, since ground water could not be encountered within the drilling range of the power auger used during this study.

CL-017-GW was not collected as proposed in the study plan since the existing well located on the southwest corner of the "Phase I" closure portion of the landfill area was dry at the time of the sampling study. However, the sample was collected from a spring located in a sinkhole on the south side of the landfarming area (Figure 5-3). The purpose of this sample was to characterize any impact on the ground water from the wastes reportedly disposed in the landfarming area.

5.5.1.2 DATA DISCUSSION

Complete analytical results are presented in Appendix F. A summary of the data is presented in Table 5-1.

The sample of drinking water from CL-002-PW showed the presence of nothing other than the typical levels of copper and zinc due to plumbing lines. The sample collected from the well at CL-005-GW showed high levels of barium, calcium, magnesium, sodium and potassium. Potassium detected at CL-017-GW is believed to be an indication of the tanning waste. A

summary of analytical data for groundwater is presented in Table 5-1.

5.5.2 GROUNDWATER SAMPLING AND GEOPHYSICAL REPORT 1991

5.5.2.1 SAMPLING LOCATIONS AND RATIONALE

Five private water wells and four naturally occurring springs were sampled. The locations of the sample collection points are as follows:

CL028PW (2.3 in Figure 5.4)

This sample was collected from the kitchen faucet of a residence located at 3919 Cemetery Road. The residence is owned by Mr. Bob Appling of Bowling Green, Kentucky who was renting the property to Mr. Jimmy Thompson at the time of sampling. The water is drawn from a well on the property. A sample could not be collected at the well since there was no faucet. Therefore, the sample was collected from the closest outlet which was a faucet located in the kitchen of the house. Due to a heavy sulphur odor in the water, the residents do no use it for drinking, but do use it for cleaning and bathing.

CL029PW (1.1 in Figure 5.4)

This sample was collected from a well on the property of Mr. Barry Reeves at 2642 Cemetery Road. Due to the lack of a faucet at the well, the sample was collected from a faucet in the kitchen of the residence. The water is normally used for drinking by the residents.

CL030PW (1.12 in Figure 5.4)

This sample was collected from a well located on the property of H.T. Hulse at 384 Duncan Chapel Road. The sample point was a faucet located adjacent to the well house. The water from this well is normally used for drinking by the residents.

CL031PW (2.35 in Figure 5.4)

This sample was collected from a well on the property of Mr. Albert Summers of 314 Summers Road. A faucet located at the well house was used as the sample point. The water from this well is normally used for drinking by the residents.

CL032PW (2.26 in Figure 5.4)

This sample was collected from a well on the property of Mr. Bobby Poor located at 566 Lashley Road. The point of sample collection was a faucet located at the well house. The water from this well is normally used for drinking by the residents.

CL034GW (1.19 in Figure 5.4)

This sample was collected from a naturally occurring spring located to the west and downgradient from the Site.

CL035GW (1.15 in Figure 5.4)

This sample was collected from a naturally occurring spring located to the south and downgradient from the landfarm portion of the Site.

CL036GW (1.17 in Figure 5.4)

This sample location is a naturally occurring spring located to the north and downgradient of the Site.

CL037GW (1.18 in Figure 5.4)

This sample was collected from the Site of a naturally occurring spring located to the northeast and downgradient of the Site.

5.5.2.2 DATA DISCUSSION

Complete analytical results may be found in Appendix I. A summary of the data is presented in Tables 5-2 and 5-3.

Analytical results of the ground water samples showed the presence of chromium in two private wells and in one naturally occurring spring. The well belonging to H.T. Hulse showed the presence of 20 μg/l of chromium. When the well was resampled, chromium was not detected. The well belonging to Bobby Poor showed chromium present at 22 μg/l and when resampled, chromium was present at 6.5 μg/l. Additionally, samples from these same two well contained lead at concentrations of 12 μg/l for the Hulse well and 18 μg/l for the Poor's well. Upon resampling, lead was not detected in either well. Chromium was also detected in the sample from the naturally occurring spring shown as 1.18 in Figure 5-4.

5.5.3 RAIN EVENT AND QUARTERLY MONITORING

5.5.3.1 SAMPLING LOCATIONS AND RATIONALE

As a result of the dye trace studies conducted at the Site, the investigation regarding ground-water quality was performed by sampling the discharge from the various springs identified as being hydraulically connected to the Site. No monitoring wells have been installed on the Site for the purpose of ground-water quality evaluation. Although a number of private drinking water wells and springs were sampled as part of the RI, it has not been established that any of those wells or springs are hydraulically connected to the Site (Tables 5-2 and 5-3). The results from the sampling of the latter set of springs provided control data for comparison with the former set. It was assumed that the springs identified as being in hydraulic connection were potentially affected by contaminant transport from the waste disposal activities conducted at the Site, while the springs not so identified would be unaffected by contaminant transport.

5.5.3.2 DATA DISCUSSION

Water quality sampling was conducted by EPA ESD and Region IV personnel and by an EPA contractor, Roy F. Weston, Inc. 28 chemicals were detected during the RI sampling and analysis of ground water (Table 5-4 through 5-9). Of these, five are naturally occurring essential nutrients that are not considered to be Site-related; they are calcium, iron, magnesium, potassium and sodium. Another seven contaminants were eliminated from the risk assessment process by means of the contaminant concentration/toxicity screening process; these contaminants were carbon disulfide, diethyl phthalate, phenol, toluene, molybdenum, bromomethane, and cyanide. The sixteen remaining contaminants were selected as contaminants of concern in ground water for the Caldwell Site. These sixteen contaminants are discussed individually below.

Each contaminant is discussed in terms of its occurrence, concentration, comparison to regulatory criteria and to background or control samples. Sample concentrations are compared to two sets of regulatory criteria; criteria that are designed to be protective of human health via consumption of drinking water and criteria designed to be protective of aquatic life in ambient surface water streams (Table 5-10). In most cases, a single set of criteria is established for comparisons of this type, depending on the most relevant and appropriate circumstances of the site in question. In this case, however, the samples taken from the springs used as monitoring points represent both ground-water quality (since they are the only samples obtained for ground-water characterization) and discharges to surface streams (since the springs are the points at which ground-water emerges from the subsurface and is discharged into surface water habitats). The sample results represent, therefore, both ground-water quality and potential surface water

quality.

Another unique aspect of ground-water characterization at sites where karst solution conduits dominate subsurface hydrology is that each discharge point (i.e., spring) represents flow from a distinct drainage basin. It is difficult, therefore, to find one spring to serve as the single sampling point to determine control or background ground-water quality conditions; the water quality from one spring to another is highly variable and dependent upon the characteristics of each individual drainage basin. Water quality in potentially affected springs should be compared to that found in a set of unaffected springs, rather than one such spring, in the vicinity of the Site. In this manner, positive results that are not uncharacteristic of naturally-occurring water quality in the vicinity of the Site will not be mistakenly attributed to contaminant transport from the Site. It is also important to note that all the springs are located in intensively farmed area.

Aluminum

Aluminum was detected in ground-water samples taken from the springs used as sampling points in concentrations ranging from 120 parts per billion (ppb) to 25 parts per million (ppm). The higher concentration exceeds both ambient water quality criteria (AWQC) for the protection of aquatic life and the EPA secondary Maximum Contaminant Level (MCL). The AWQC for aluminum for protection of aquatic life from chronically toxic effects is 87 ppb, and the secondary MCL is 50 ppb. It should be noted, however, that the highest concentration was in a sample taken in association with a rainfall event, when the sediment load carried by turbulent flow in open solution channels is likely to have been very high. In karst flow conduits, sampling during response to rainfall events yields results analogous to sampling surface water streams in similar circumstances.

It should also be noted that samples taken from Duncan Tile Spring shown to be unaffected by the Site during the dye-trace studies yielded comparable results when analyzed for aluminum as those from the spring shown to contain the highest concentrations. Samples taken from McPherson Spring on the same date as that taken from Duncan Tile Spring which was shown to have 25 ppm of aluminum contained 5.5 ppm of aluminum. On another sampling date associated with rainfall events, Duncan Tile Spring samples contained 5.1 ppm and samples from McPherson Spring contained 6.6 ppm of aluminum.

Samples taken from Green Boiling Spring, which is located in very close proximity to Duncan Tile Spring and which was likewise shown to be in hydraulic connection to the Site, on the same date as the sample found to contain 25 ppm, contained only 0.73 ppm of aluminum. Finally, samples taken from Duncan Tile Spring in January 1993, which

were not associated with a rainfall event were shown to contain only 0.51 ppm of aluminum.

A number of unaffected springs were sampled in February and May 1993. The results of these sampling efforts are presented in Table 5-3. Aluminum was detected in these springs (numbers 1.14, 1.16, 1.17 and 2.25 in the USGS report) at concentrations ranging from 330 ppb to 4.6 ppm. While the concentrations are less than the maximum concentration observed in Duncan Tile Spring, they are similar in magnitude and in the fact that they exceed regulatory criteria. Therefore, even though the maximum aluminum concentration observed was in an affected spring, comparison of aluminum concentrations from that spring with those from a number, or set, of unaffected streams does not reveal a great discrepancy.

Barium

Concentrations of barium found in spring samples ranged from 28 ppb to 180 ppb. No AWQC have been established for barium, and no samples exceeded the primary MCL for barium of 2.0 ppm. The highest concentration was again found in Duncan Tile Spring, from the same sampling event that the highest aluminum result was obtained. On the same date, a sample from McPherson Spring contained 110 ppb of barium.

Barium concentrations in the set of unaffected wells samples ranged from 29 ppb to 34 ppb.

Chromium

Samples taken from the springs used as monitoring points for the RI were sampled for both trivalent and hexavalent chromium. Hexavalent chromium, the more toxic form, was detected in concentrations ranging from 1 ppb to 10 ppb. All reported concentrations were less than the AWQC for hexavalent chromium for protection of aquatic life from chronic toxicity, which is 11 ppb.

Trivalent chromium was detected in concentrations ranging from 17 ppb to 21 ppb. All reported concentrations were below the AWQC of 117 ppb for chronic toxicity resulting from exposure to trivalent chromium.

The primary MCL for chromium is based on total chromium, without regard to its valence state. The primary MCL for chromium is 100 ppb. All samples for either trivalent or hexavalent chromium were below the primary MCL, and even adding the

highest trivalent result to the highest reported hexavalent result yields a combined concentration of only 31 ppb, also well below the primary chromium MCL.

Only one spring sampled for chromium by ESD contained 6.1 ppb of total chromium. Wells sampled showed total chromium at 20 and 22 ppb.

Cobalt

Cobalt was reported in only one sample at a concentration of 11 ppb. This sample was taken from Duncan Tile Spring in association with a rainfall event. No regulatory criteria for drinking water or for protection of aquatic life have been established.

Copper

Copper was reported in only one sample at a concentration of 14 ppb. This sample was also taken from Duncan Tile Spring in association with a rainfall event. This concentration is above the chronic AWQC for protection of aquatic life, which is 9.22 ppb. The Maximum Contaminant Level Goal (MCLG) for copper is 1300 ppb.

Lead

Positive results for lead were reported in only one spring, which was McPherson Spring, which was shown in the dye-trace studies to be unaffected by ground-water flow from the Site. Concentrations ranged from 6.3-7.2 ppb, which is below the concentration established by CERCLA guidance for the protection of human health via drinking water consumption (15 ppb). There is no numerical MCL for lead. The chronic AWQC for lead as established by EPA is dependent upon the hardness of the water; at 100 ppm hardness, the chronic AWQC is 1.32 ppb. It is likely, therefore, that the samples from McPherson Spring exceeded the AWQC for lead. The reported lead concentrations should be considered to be naturally occurring, however, since the water quality in McPherson Spring is not affected by contaminant transport from the Site.

Manganese

Manganese was detected in spring samples in concentrations ranging from 18 ppb to 4,200 ppb. The highest concentration was found in a sample obtained from Lagoon Spring. The next two highest concentrations, 2,500 and 1,100 ppb were detected at McPherson Spring, which is assumed to be unaffected by contaminant transport from the Site. In fact, in three out of the five sampling events, the highest concentration of

manganese was found in McPherson Spring. Lagoon Spring and Duncan Tile had the highest manganese concentrations in the other two sampling events.

No AWQC have been established for manganese for the protection of aquatic life. EPA has established a secondary MCL of 50 ppb, which was exceeded by a number of spring samples taken during the RI, including samples taken from Lagoon Spring, Mossy Spring, and Barnett Karst Window, as well as McPherson Spring and Duncan Tile Spring. Of more significance, however, is the fact that many of these samples also exceed EPA's health-based criterion for the protection of public health via consumption of drinking water, which is 180 ppb, based upon an EPA-approved reference dose.

The set of unaffected wells sampled contained manganese in concentrations ranging from nondetectable levels to 740 ppb.

Nickel

Nickel was present in detectable quantities from potentially affected springs in samples taken from Green Boiling Spring and Duncan Tile Spring, in concentrations ranging from 8 ppb to 22 ppb. All concentrations observed are less than the chronic AWQC of 88 ppb and the primary MCL of 100 ppb.

Strontium

Strontium was detected in spring samples in concentrations ranging from 35 ppb to 350 ppb. No regulatory criteria have been established for strontium.

Unaffected spring sampling identified strontium concentrations ranging from 140 ppb to 220 ppb. These results are consistent with those found in the potentially affected wells.

Titanium

Titanium was detected in samples from potentially affected springs at concentrations ranging from 10 ppb to 350 ppb. The highest concentration was once again in a sample taken from Duncan Tile Spring in association with a rainfall event. No regulatory criteria have been established for titanium.

Samples obtained from unaffected springs were found to contain titanium in concentrations ranging from 14 ppb to 81 ppb. Titanium was also found in a sample from McPherson Spring at a concentration of 120 ppb in association with a rainfall event;

the concentration of titanium in Duncan Tile Spring on that sampling date was 83 ppb. The highest concentrations were therefore observed in the potentially affected spring (Duncan Tile Spring), but this spring was not consistently found to contain the highest concentrations of titanium in all sampling events.

Vanadium

Vanadium was detected in samples from potentially affected springs in concentrations ranging from 27 ppb to 42 ppb. the highest concentration was again observed in a sample from Duncan Tiled Spring on a date associated with a rainfall event. No regulatory criteria have been established for vanadium.

The unaffected springs sampled contained vanadium in concentrations ranging from 2.9 ppb to 7.9 ppb.

Yttrium

Yttrium was found in only one sample, taken from Duncan Tile Spring, at a concentration of 21 ppb. No regulatory criteria have been established for yttrium, and the unaffected springs were not analyzed for this contaminant.

Zinc

Zinc was detected in samples from potentially affected springs at concentrations ranging from 6 ppb to 61 ppb. The chronic AWQC for zinc is 59 ppb, and the secondary MCL is 5 ppm. The highest concentration observed, obtained from Duncan Tile Spring in association with a rainfall event, marginally exceeds the chronic AWQC for zinc.

The unaffected springs sampled by ESD contained zinc in concentrations ranging from 5 ppb to 12 ppb.

5.6 SUMMARY OF WATER QUALITY DATA

Of the contaminants of concern discussed above, barium, chromium, copper, and nickel were present in concentration that were below AWQC or MCLs, while zinc was present in only one sample marginally exceeding the chronic AWQC for that contaminant. These contaminants are not therefore present in concentrations that are significant from either an environmental or human health perspective.

The concentrations of lead observed in samples from potentially affected streams were all below the drinking water criterion established by CERCLA policy (15 ppb). While the concentrations observed exceeded the chronic AWQC established for lead, the concentrations found in samples taken from McPherson Spring were the highest; McPherson Spring was shown by the dye trace studies to be unaffected by contaminant transport from the Site. It is therefore likely that the lead concentrations observed were naturally-occurring.

Aluminum and manganese are the two contaminants that appear to be found in elevated concentrations in potentially affected springs (particularly Duncan Tile Spring). Aluminum was found at its highest concentration in Duncan Tile Spring during sampling designed to show the effects of rainfall events on ground-water quality. It is likely that increased flow in the karst conduit system resulted in an increased sediment/suspended solids load in this sample, perhaps contributing to anomalously high results. On other sampling dates, the aluminum concentration observed in McPherson Spring, unaffected by contaminant transport from the Site, was greater than that observed in Duncan Tile Spring. Manganese was found consistently in greater concentrations in McPherson Spring than in Duncan Tile Spring, indicating that manganese concentrations observed during the RI are likely to be naturally occurring.

Titanium was elevated in samples taken from potentially affected springs when compared to those taken from unaffected springs. The difference between the two data sets is not great, however, and on at least one sampling event McPherson Spring concentrations of titanium exceeded those in Duncan Tile Spring, indicating that the affected spring (Duncan Tile) is not consistently contaminated to levels greater than the unaffected spring (McPherson).

5.7 REFERENCES

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TABLE 5-1
CALDWELL LACE LEATHER
GROUNDWATER SAMPLES
JUNE 1990

Parameter	CL-002-PW	CL-005-PW	CL-017-GW
FIELD MEASUREMENT RESULTS			
pH (SU)	5.7	6.67	6.05
Conductivity (μmhos/cm)	50	603	60
Temperature (°C)	17.0	15.6	23.0
INORGANIC COMPOUNDS (ug/l)			
Barium	--	340	--
Cobalt	--	--	--
Copper	67	--	--
Zinc	710	--	--
Calcium	--	100,000J	--
Magnesium	--	31,000	--
Sodium	--	12,000J	--
Potassium	--	1,700	510
EXTRACTABLE ORGANIC COMPOUNDS (ug/l)			
Caprolactam	--	10JN	--

TABLE 5-2
CALDWELL LACE LEATHER
POTABLE WELL SAMPLES
FEBRUARY and MAY 1991
(Results in µg/l, except where noted)

Parameter	Appling CL028PW 2/91	Reeves CL029PW 2/91	Hulse CL030PW 2/91	Hulse WW-01 5/91	Summers CL031PW 2/91	Poor CL032PW 2/91	Poor WW-01 5/91
FIELD MEASUREMENT RESULTS							
pH (SU)	7.3	6.5	7.3	NA	7.7	7.3	NA
Conductivity (µmhos/cm)	350	125	301	NA	321	346	NA
Temperature (°C)	14.5	14.9	13.1	NA	15.1	14.1	NA
INORGANIC COMPOUNDS							
Barium	960	12	97	46	30	120	5.3
Cobalt	–	–	6.2	–	–	7.5	2.7
Chromium	–	–	20	–	–	22	6.5
Copper	92	6.1	20	17	3.8	70	13
Molybdenum	5.3	–	–	–	–	–	10
Nickel	–	–	14	–	–	20	11
Lead	–	–	12	–	–	18	–
Strontium	3700	62	270	2,000	140	210	810
Titanium	13	10	220	30	19	240	110
Vanadium	–	–	31	–	–	33	12
Yttrium	–	–	12	–	–	14	4.0
Zinc	5.9	6.7	82	84	13	100	72
Aluminum	56	88	16,000	1,400	440	18,000	7,100
Managanese	–	–	740	71	7.5	710	340
Calcium*	15	24	65	72	53	55	68
Magnesium*	16	1.1	6.2	16	4.1	10	14
Iron*	0.18	0.16	15	1.1	0.29	18	5.9
Sodium*	88	1.7	1.2	2.6	2.6	7.4	6.4
Potassium*	2.6	–	1.6	0.77	–	6.9	5.4
PURGEABLE ORGANIC COMPOUNDS							
Carbon Disulfide	1.3J	–	–		–	–	

TABLE 5-3
CALDWELL LACE LEATHER
SPRING SAMPLING EVENT
FEBRUARY, MAY and AUGUST 1991
(Results in µg/l, except where noted)

Parameter	Spring 1.19 CL034GW 2/5/91	Spring 1.15 CL035GW 2/5/91	Spring 1.17 CL036GW 2/5/91	Spring 1.18 CL037GW 2/5/91	Spring 2.25 SW-01 5/20/91	Moore Spring SW-SPG-001 08/10/91
INORGANIC COMPOUNDS						
Barium	39	34	29	39	29	34
Chromium	--	--	--	6.1	--	--
Strontium	84	160	180	140	220	220
Titanium	42	66	21	81	14	--
Vanadium	2.9	5.2	--	7.9	--	2.8
Zinc	5.0	8.1	--	12	--	2.8
Aluminum	1,800	3,400	600	4,600	330	290
Managanese	36	36	16	34	13	7.0
Calcium*	35	52	53	40	74	77
Magnesium*	1.8	3.4	3.4	4.0	4.4	4.6
Iron*	1.6	2.8	0.46	4.0	0.22	0.18
Sodium*	1.4	2.3	1.5	1.3	3.4	2.5
Potassium*	2.2	--	0.71	1.4	--	0.76

TABLE 5-4
CALDWELL LACE LEATHER
RAIN EVENT SAMPLING
6/3/92
(Results in µg/l, except where noted)

Parameter	Mud River Spring	Green Boiling Spring	Duncan Tile Spring	McPherson Spring	Mossy Spring	Runoff	Lagoon	Barnett-Karst Spring
INORGANIC COMPOUNDS								
Barium	41	35	180	110	32	81	39	45
Cobalt	–	–	11	–	–	–	–	–
Copper	–	–	14	–	–	–	–	–
Chromium	–	–	21	–	–	17	–	–
Nickel	–	–	22	–	–	–	–	–
Lead	–	–	20	7.2	–	12	–	–
Strontium	250	190	140	38	220	100	140	250
Titanium	10	16	350	67	–	240	16	52
Vanadium	–	–	42	–	–	27	–	–
Yttrium	–	–	21	–	–	–	–	–
Zinc	–	43	61	12	–	39	–	26
Aluminum	420	730	25,000	5,500	150	16,000	720	2,200
Manganese	25	23	960	570	–	170	24	85
Calcium*	79	65	50	6.1	76	39	56	83
Magnesium*	5.3	4.2	4.8	2.4	4.9	4.0	2.7	5.6
Iron*	0.31	0.51	21	5.9	.093	16	0.50	1.7
Sodium*	2.6	770	2.0	4.1	3.1	–	2.0	3.8
Potassium*	–	–	4.1	–	–	5.8	–	–

* mg/l

TABLE 5-5
CALDWELL LACE LEATHER
QUARTERLY SAMPLING EVENT
7/29/92
(Results in µg/l, except where noted)

Parameter	Mud River Spring	Green Boiling Spring	Duncan Tile Spring	McPherson Spring	Mossy Spring	Runoff	Lagoon	Barnett-Karst Spring
Barium	47	NA	44	49	33	40	120	31
Cobalt	–	NA	–	–	–	–	–	–
Chromium	–	NA	–	–	–	–	–	–
Nickel	–	NA	–	–	–	–	–	–
Lead	–	NA	–	–	–	–	–	–
Strontium	270	NA	240	35	230	220	170	280
Titanium	18	NA	74	16	–	25	32	12
Vanadium	–	NA	–	–	–	–	–	–
Yttrium	–	NA	–	–	–	–	–	–
Zinc	–	NA	15	–	–	11	33	–
Aluminum	730	NA	3,600	1,200	120	1,000	1,900	170
Manganese	18	NA	120	170	–	29	4,200	–
Calcium*	82	NA	80	9	80	83	66	86
Magnesium*	5.5	NA	5.4	2.1	5.2	5.4	3.2	5.6
Iron*	0.48	NA	2.6	1.2	0.052	0.71	3.5	0.076
Sodium*	3.0	NA	5.0	5.4	3.6	2.9	2.8	6.7
Potassium*	–	NA	–	–	–	–	4.3	–

* mg/l

TABLE 5-6
CALDWELL LACE LEATHER
RAIN EVENT SAMPLING
9/23/92
(Results in µg/l, except where noted)

Parameter	Mud River Spring	Green Boiling Spring	Duncan Tile Spring	McPherson Spring	Mossy Spring	Runoff	Lagoon	Barnett-Karst Spring
Barium	55	NA	55	110	55	55	77	56
Cobalt	–	NA	–	–	–	NA	–	–
Chromium	–	NA	–	–	–	NA	–	–
Nickel	–	NA	–	–	–	NA	–	–
Lead	–	NA	–	6.3	–	NA	–	–
Strontium	210	NA	230	68	150	180	96	220
Titanium	43	NA	83	120	86	36	92	52
Vanadium	–	NA	–	–	–	NA	–	–
Yttrium	–	NA	–	–	–	NA	–	–
Zinc	13	NA	18	16	15	15	19	13
Aluminum	2,600	NA	5,100	6,600	5,500	2,300	6,500	2,900
Manganese	50	NA	130	2,500	98	32	250	79
Calcium*	61	NA	77	12	53	67	40	76
Magnesium*	4.3	NA	5.0	3.1	4.0	5.0	2.3	4.8
Iron*	2.0	NA	3.8	8.9	4.4	17	5.0	2.2
Sodium*	1.9	NA	2.9	4.6	2.2	2.3	–	2.4
Potassium*	4.7	NA	–	–	5.2	3.4	8.3	2.7

* mg/l

TABLE 5-7
CALDWELL LACE LEATHER
QUARTERLY SAMPLING EVENT
11/11/92
(Results in µg/l, except where noted)

Parameter	Mud River Spring	Green Boiling Spring	Duncan Tile Spring	McPhearson Spring	Mossy Spring	Runoff/Long Southfork Spring	Lagoon Spring	Barnett-Karst Window Spring
INORGANIC COMPOUNDS								
Barium	48		44	68	31	54		37
Cobalt	–		–	–	–	–		–
Chromium	–		–	–	–	–		–
Nickel	–		–	–	–	–		–
Lead	5.9		–	–	–	–		–
Strontium	350		260	38	210	240		300
Titanium	11		53	–	–	11		11
Vanadium	–		–	–	–	–		–
Yttrium	–		–	–	–	–		–
Zinc	–		–	–	–	–		–
Aluminum	200		2,800	420	130	230		200
Managanese	15		81	1,100	–	38		14
Calcium*	95		90	4.0	73	89		92
Magnesium*	6.9		6.1	3.5	5.1	5.8		6.6
Iron*	0.13		2.2	5.0	0.088	.20		0.088
Sodium*	3.6		3.6	3.0	3.5	3.0		4.9
Potassium*	–		–	–	–	–		–
PURGEABLE ORGANIC COMPOUNDS								
Bromomethane	–	–	–	0.55J	–	–		–

TABLE 5-8
CALDWELL LACE LEATHER
QUARTERLY SAMPLING EVENT
1/26/93
(Results in µg/l, except where noted)

Parameter	Mud River Spring	Green Boiling Spring	Duncan Tile Spring	McPhearson Spring	Mossy Spring	Runoff/Long Southfork Spring	Lagoon Spring	Barnett-Karst Window Spring
INORGANIC COMPOUNDS								
Barium	37J	30J	32J	44	30J	28J	32J	33J
Cobalt	–	–	–	–	–	–	–	–
Chromium	–	14J	–	–	–	–	–	–
Nickel	–	8J	–	–	–	–	–	–
Lead	–	–	–	–	–	–	–	–
Strontium	NA	NA	NA	NA	NA	NA	NA	NA
Titanium	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	–	–	–	–	–	–	–	–
Yttrium	NA	NA	NA	NA	NA	NA	NA	NA
Zinc	6J	–	42J	8J	–	–	–	–
Aluminum	430J	190J	510J	600J	84J	100J	450J	320J
Managanese	–	–	35J	800J	–	–	–	19J
Calcium*	87J	76J	85J	7.6J	77J	72J	54J	83J
Magnesium*	5.1J	4.5J	4.9J	3J	4.5J	4.5J	2.4J	5J
Iron*	5J	.25J	.59J	.98J	.091J	.094J	.55J	.32J
Sodium*	23J	5.5J	2.3J	3.6J	2.3J	2.9J	1.4J	2.7
Potassium*	1.3J	.84J	.78J	.82J	.79J	.75J	1.8J	1.1J
PURGEABLE ORGANIC COMPOUNDS								
Bromomethane	–	–	–	0.55J	–	–	–	–

TABLE 5-9
CALDWELL LACE LEATHER
HEXAVALENT CHROMIUM CONCENTRATIONS

Sampling Date	6-4-92	7-30-92	9-24-92	11-12-92	1-27-93
Detection Limit	1 µg/l	.01 mg/l	.01 mg/l	.01 mg/l	.01 mg/l
Mud River Spring	10 µg/l	–	–	–	–
Green Boiling Spring	8 µg/l	–	–	–	–
Duncan Tile Spring	9 µg/l	–	–	–	–
McPherson Spring	5 µg/l	–	–	–	–
Mossy Spring	1 µg/l	–	–	–	–
Runoff	7 µg/l	–	–	–	–
Lagoon Spring	3 µg/l	–	–	–	–
Barnett-Karst Spring	4 µg/l	–	–	–	–

Table 5-10
EPA Regulatory Criteria

Parameter	National Primary Drinking Water Regulations (9/92)			Freshwater Quality Criteria (12/92)	
	MCL (ppm)	MCL (ppm)	SMCL (ppm)	Criterion Maximum Conc. (μg/l)	Criterion Continuous Conc. (μg/l)
				Hardness (mg/l as $CaCO_3$): 50; pH: 6	
Barium	2	2			
Cobalt					
Copper	TT	1.3		9.22*	6.54*
Chromium (Total)	0.1	0.1			
Chromium III				984.32*	117.32*
Chromium VI				16	11
Nickel	0.1	0.1		789*	87.71*
Lead	0.015 (Action Level)			33.78*	1.32*
Strontium					
Titanium					
Vanadium					
Yttrium					
Zinc			5	65.04*	58.91*
Aluminum			0.05-0.2	750	87
Manganese			0.05		
Iron			0.3		

Manganese SMCL .05

* Hardness Dependent.

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY

WATER-RESOURCES INVESTIGATIONS
REPORT 92-4195, PLATE 1

86°49' 47' 45' 43' 86°41'

36°55'30"

54'

52'30"

51'

36°49'30"

Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator Projection, Zone 16
Contours from U.S. Geological Survey
Auburn 1951, Dennis 1952, Homer 1951, and
South Union 1951.

SCALE 1:24,000

1 0 1 MILES
1 0 1 KILOMETERS

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

DYE-TRACER TEST AND IDENTIFIER

- T-1,3 — 1-3 THIS STUDY
- T-QE-4 — Q QUINLAN(1982), E EWERS(1983)

LOCATION OF DYE-INJECTION SITE AND IDENTIFIER

- A — DYE-INJECTION SITE

LOCATION OF DYE-RECOVERY SITE AND IDENTIFIER

- 4 — WELL
- 6 — SPRING
- 10 — STREAM

LOCATION OF DYE-MONITORING SITE AND IDENTIFIER

- 14 — SPRING
- 5 — STREAM

LOCATION OF SELECTED WELLS AND SPRINGS AND IDENTIFIERS

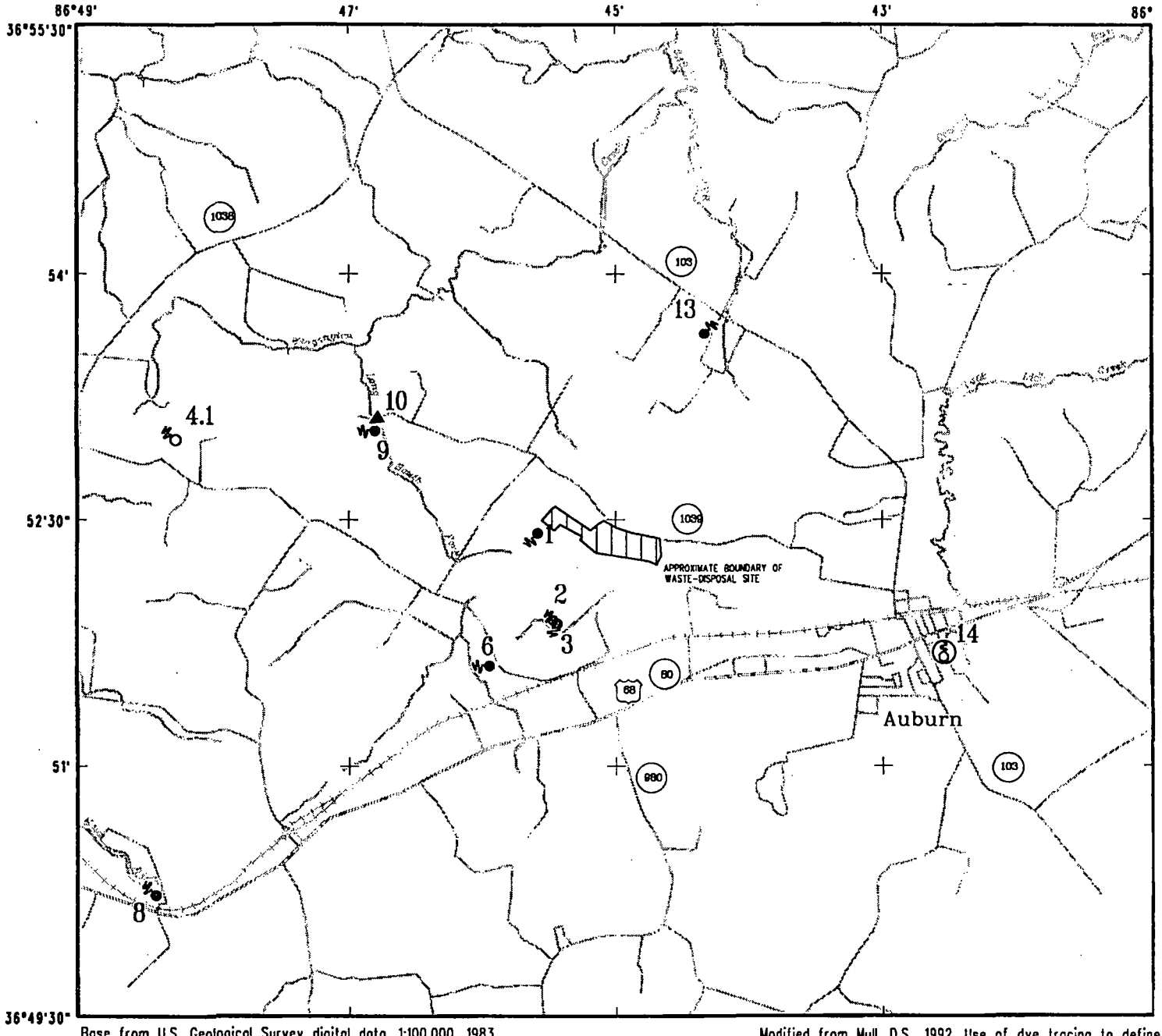
- 2.43 — WATER WELL
- 3.10 — SPRING

DYE-TRACER TESTS, SPRINGS, AND WELLS IN THE VICINITY OF A SUPERFUND WASTE-DISPOSAL SITE, NEAR AUBURN, KENTUCKY

by
D.S. Mull
1992

FIGURE 5-1

Mull, D.S., 1992, Use of dye tracing to define the direction of ground-water flow from a superfund waste-disposal site in karst terrane, near Auburn, Kentucky: U.S. Geological Survey Water-Resources Investigations Report 92-4195

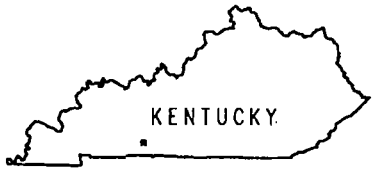


Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator Projection, Zone 16
Contours from U.S. Geological Survey
Auburn 1951, Dennis 1952, Homer 1951, and
South Union 1951.

Modified from Mull, D.S., 1992, Use of dye tracing to define the direction of ground-water flow from a superfund waste-disposal site in korst terrane, near Auburn, Kentucky: U.S. Geological Survey Water-Resources Investigations Report 92-4195

1 0 1 MILES

1 0 1 KILOMETERS

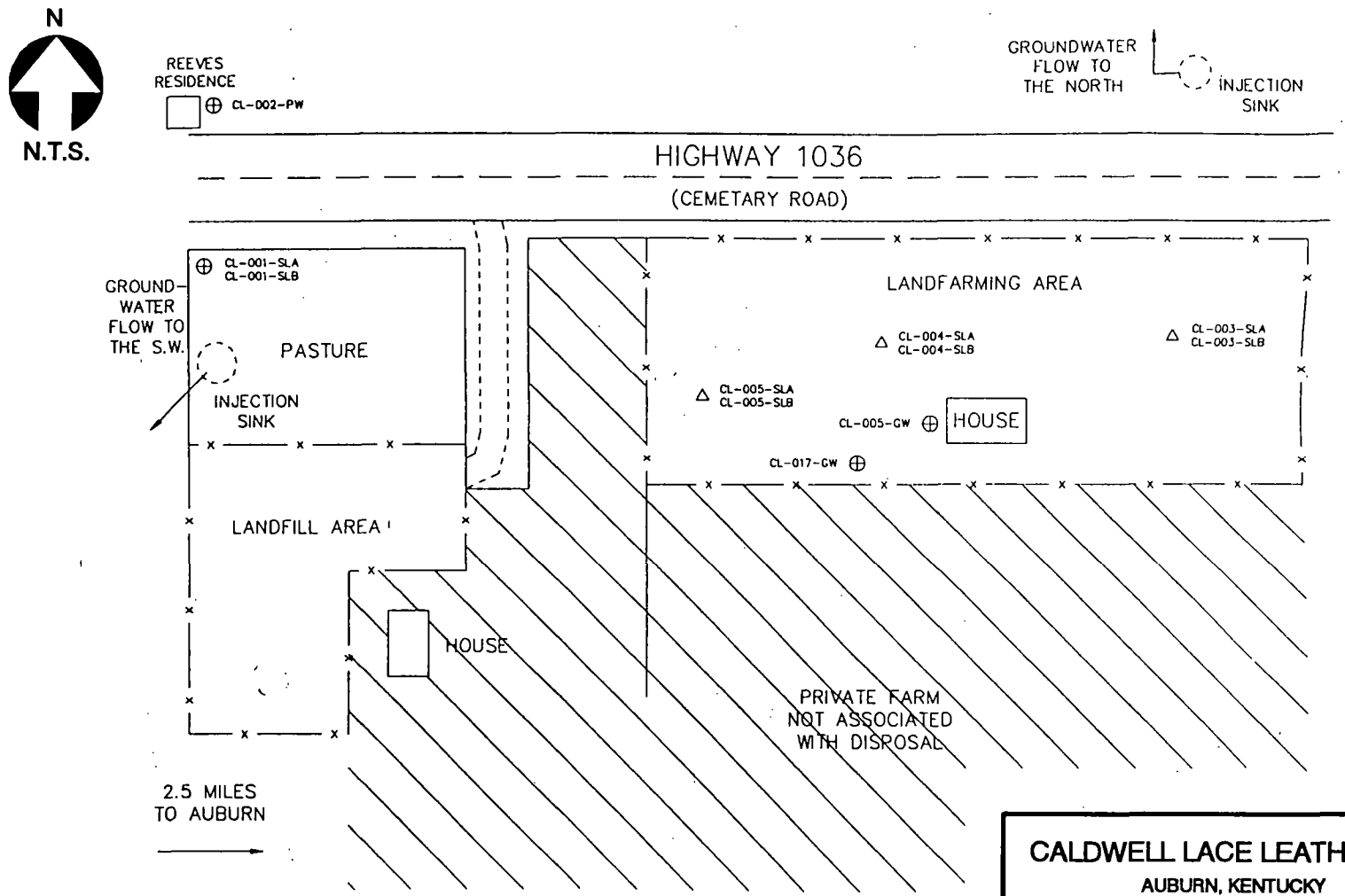


Location of Study Area

EXPLANATION

- 6 DYE-RECOVERY SITES AND IDENTIFIER
- SPRING
- 10 STREAM
- 14 DYE-MONITORING SPRING AND IDENTIFIER
- 4.1 SELECTED SPRING AND IDENTIFIER

FIGURE 5-2 SELECTED MONITORING SITES

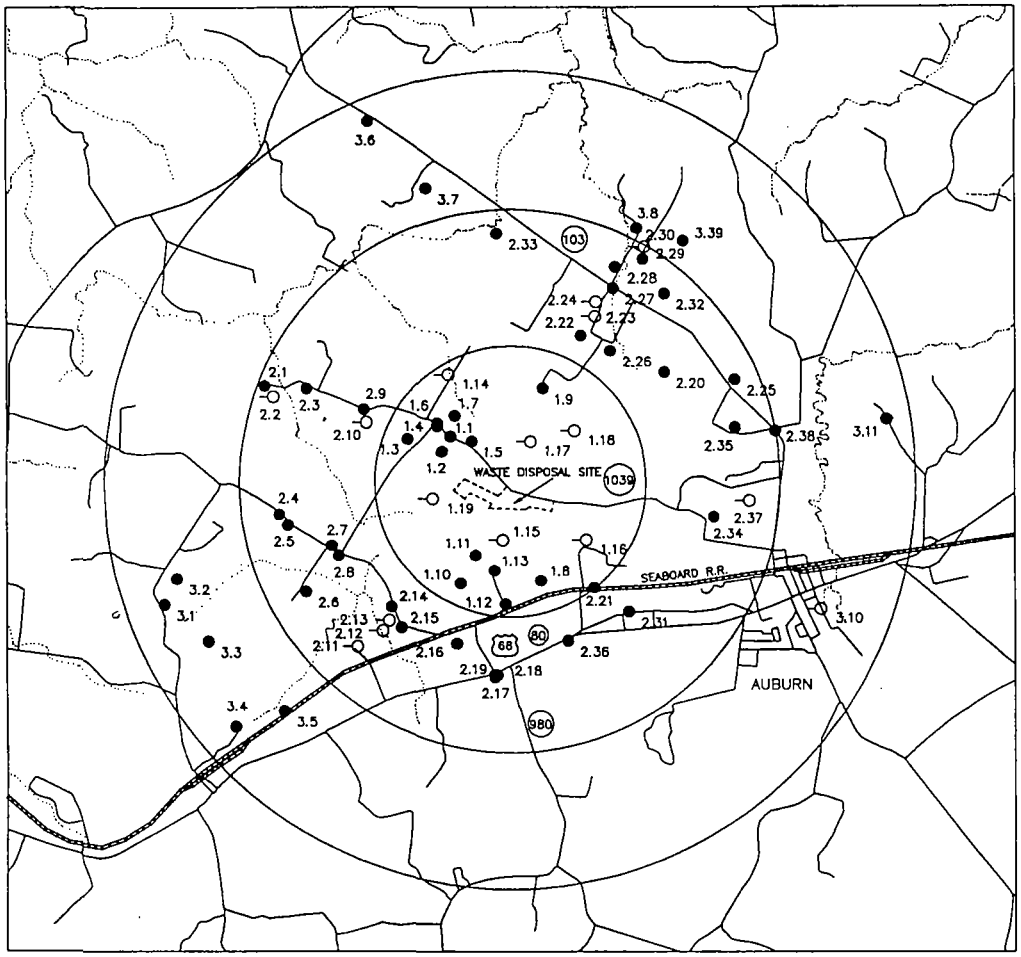


PRE-REMEDIAL SAMPLING, 1990
LANDFARM AREA

CALDWELL LACE LEATHER SITE
AUBURN, KENTUCKY

FIGURE 5-3

U.S. EPA, REGION IV



N

N.T.S.

LEGEND:
- WELL
- SPRING
- ROADS
- STREAMS

APPROXIMATE SCALE
6000 0 3000 6000
(IN FEET)
1 inch = 6000ft.

WELLS AND SPRINGS IN 1,2 AND 3 MILE RADIUS JUNE 1990

CALDWELL LACE LEATHER SITE
AUBURN, KENTUCKY

FIGURE 5-4

U.S. EPA, REGION IV

6

6.0 CONTAMINANT FATE AND TRANSPORT

6.1 POTENTIAL ROUTES OF MIGRATION

The fate and transport of contaminants are related to the contaminants present, the soil type, hydrogeologic features, and other site characteristics. The following discussion describes the site-specific conditions that may affect contaminant transport.

The Caldwell Lace Leather Site was used for disposal of tanning wastes which were buried in the landfill area and tilled into soils in the landfarm. As a result, the surface and subsurface soils were impacted. Also, due to the karst topography of the area, it is probable that releases of the wastes in soil have migrated to the groundwater, surface water (springs) and sediments.

The Auburn, Kentucky area is typified by karst terrain involving underground streams, intermittent springs, and sinkholes. These sinkholes and subsurface features result from solution of channels which are formed by surface water percolating through the soil and eroding sandstone and limestone formations, eventually allowing the permeable soils above to subside. Most karst features are hydrogeologically significant because of their unique relation to the groundwater system. They collect and discharge water into, store and transmit, or discharge water from the groundwater system. Initially, flow diffuses through a large number of small fractures. With time, a network of conduits begins to develop that carries an increasing proportion of the flow. The development of sinkholes also contributes to the development of the conduit system because surface water will begin to flow directly into the conduits. In a mature karst system, runoff proceeds directly into tributary conduits and moves rapidly to the spring or springs at the downstream end of the basin (Quinlan and Ewers, 1985).

The geology underlying the site consists of the Big Clifty sandstone, the Girkin limestone, and the St. Genevieve limestone. The beds dip north-northwest at about 40 feet per mile. Soils in the area are typical of those weathered from parent rock of sandstone and limestone. The site is located on an east-west trending limestone ridge capped at the higher elevations by sandstone. The ridge is both a topographic and a groundwater divide in the immediate area. The two distinct groundwater basins discharge to two different rivers, the Mud River, which is located 4 miles southwest of the site, and the Gasper River which is located 2.4 miles northeast of the site. The Mud River discharges into Lake Hancock approximately 5 miles from the point of its origin. It was found that the depth to groundwater beneath the landfill and landfarm areas is estimated to be 60 feet below land surface. At this depth, unless fractures and/or sinkholes are encountered, leaching may be a reduced concern.

Two separate groundwater studies for the area have been performed by consulting hydrogeologists. The first study was completed and reported by James F. Quinlan, PhD, in November 1982 (Quinlan, 1982), and the second by Ralph O. Ewers, PhD, in March 1983 (Ewers, 1983). Quinlan determined through dye tracing that groundwater from the old Caldwell Lace Landfill area traveled to Wiggington Creek, a tributary to the Gasper River, via springs, sinking streams, and overland streams. Quinlan also inferred the possibility that groundwater from the landfill area may, in part, flow toward the southwest to one or more of the springs that eventually flow to the Mud River. The Quinlan (1982) and Ewers (1983) studies confirmed that the groundwater flow direction from the adjoining landfarming area was in a southwest direction toward Mud River. Ewers' study mentioned the possibility that some infiltration from the extreme eastern portion of the land-spreading site may flow northward to the source of the Gasper River.

6.2 CONTAMINANT PERSISTENCE

6.2.1 PROPERTIES AFFECTING THE CONTAMINANTS' PERSISTENCE

The range of concentrations for the contaminants of potential concern are presented in Table 6-1. The physicochemical properties for the contaminants of potential concern are presented in Table 6-2. A discussion follows on the relevance of the physicochemical parameters most frequently used to evaluate persistence of organic and inorganic chemicals.

Biodegradation is the biological process by which aerobic microbes or anaerobic microbes break down organic chemicals to either a higher- or a lower-molecular-weight chemical(s). This is a very important process by which soil microbes or aquatic microbes can detoxify chemicals (Ney, 1981). The process could also result in the formation of a more toxic chemical.

Many factors may affect the rate of biodegradation such as pH, temperature, sorption, populations of microbes, moisture, the presence of other chemicals, and the concentrations of chemicals present. Chemicals that are highly water-soluble can biodegrade, but those with low water solubility usually will not.

Bioaccumulation is the key consideration to be able to predict whether food-chain contamination can occur. It may happen in two ways: (1) contaminated plants eaten by animals cause contamination in animals, and (2) contaminated animals eaten by animals move the contaminants up the food chain. Some of the predictive indicators are water solubility (WS) and the octanol water partition coefficient (K_{ow}).

Hydrolysis is one of the most important mechanisms in the environment for the breakdown of a parent chemical (Ney, 1981). It occurs in soils, water, plants, animals, and possibly air because water exists in all of these environments. The hydrolysis of pesticides has even occurred on plant surfaces. Hydrolysis is the chemical interaction of water with the contaminant which alters the chemical's structure and, in turn, altering its transport in the environment. Many environmental factors influence the rate of hydrolytic degradation, such as temperature, pH, solubility, sunlight, ad- or absorption, and volatility. The rate of hydrolyzation of a chemical is the time that it takes to reach one-half of its original amount ($t_{½}$).

Photolysis of a chemical can occur as long as it can absorb sunlight. Phototransformation of a chemical can occur in air, soil, or water and on surfaces of water, soil, plants, and animals. Environmental influences can have an effect on the rate of phototransformation, such as depth of the chemical in soil and water, sorption to soil, sensitizers, and pH. The rate of phototransformation is the time that it takes for a parent chemical to be transformed to one-half (the half-life, $t_{½}$) of its original amount. This rate could differ in soil, in water, and on surfaces. The faster the photolytic rate is, the less likelihood of continued exposure in the environment. If the photolytic half-life is <30 days, then accumulation, bioaccumulation, or food-chain contamination is unlikely; if it is 30 to 90 days, some food-chain contamination is possible; and if it is >90 days, food-chain contamination is likely.

For example, the log K_{ow} for N-nitrosodiphenylamine was estimated to range from 2.57 to 3.13, indicating a low potential for bioaccumulation. Bis(2-ethylhexyl)phthalate also has a long photolytic half-life of 144 to 200 days, making it difficult to dissipate in order to prevent bioaccumulation (ATSDR, 1992). Over time, this persistence will cause bioaccumulation and possible biomagnification.

In order to fully understand the processes of adsorption, precipitation, and complexation, it is important to recognize certain chemical characteristics which affect the magnitude and manner of these processes. These characteristics include the pH of the surrounding environment, the redox potential between chemical and substrate, ionic strength in a body of water, and the concentration of complexing ions in the water.

The pH of an area is simply how basic or acidic it is. In essence, the concentration of the hydrogen ion is a measure of the acidity or basicity of a solution. The pH is important because it dramatically affects the direction of a reaction (i.e., at a high pH two agents might bond while surrounded by a lower pH they might repel one another).

When an atom, molecule, or ion loses electrons, it is oxidized; when electrons are gained, it is reduced. These reactions are referred to as oxidation-reduction, or redox, reactions. All metals

are reducing agents, while nonmetals are all oxidizing agents (except for the noble gases). As a result, metals and nonmetals often undergo redox reactions forming complexations. A common example of this is the formation of table salt (NaCl). Therefore, the potential for a redox reaction is important for migration because it dictates which chemicals will associate or dissociate and either form or dissipate colloidal particles, respectively.

The ionic strength in a body of water and the concentration of complexing ions in water are very important to colloidal formation and deformation. When metals react with nonmetals, electrons are transferred from the metals to the nonmetals and ionic compounds are formed (compounds containing ions). The electrostatic attraction between ions in a bond is very strong; it takes a lot of force for dissociation. Thus, the ionization potential (strength) in water and ionic compound concentrations are very important for determining associations and dissociations.

6.3 CONTAMINANT MIGRATION

The migration of contaminants of potential concern listed in Table 6-1 are discussed below.

6.3.1 INORGANICS

The fate of inorganics in aquatic systems depends on partitioning between soluble and particulate solid phases. Adsorption, precipitation (with the exception of chromium as it does not precipitate), and complexation are processes affecting partitioning. These same processes, which are influenced by pH, the redox potential, the ionic strength of the water, the concentration of complexing ions in the water, and the metal concentration and type, affect the adsorption of metals.

When inorganic material is discharged into waterways in the form of particulate matter, it typically settles out, precipitates out, or adsorbs to organic matter and clay in the water column (however, the variant chemical forms of zinc (zinc hydroxide, zinc carbonate) and arsenic (arsenate, As(+5), As(+3)) allow them to be either very soluble in water or likely to adsorb to sediments). Thus, as the amount of organic content increases so does the mobility of the chemical adsorbed to particulate matter.

However, because of the generally low water solubility and highly adsorptive nature of inorganics, they are likely to be immobilized in slower moving bodies of groundwater and surface water. This immobilization makes the contaminant more accumulative or bioaccumulative, persistent in environmental compartments, slightly prone to biodegradation, and available for metabolism in plants and animals.

The Caldwell Lace Leather Site groundwater medium, being controlled by a karst terrain, moves too rapidly through subterranean channels and conduits for any significant inorganic chemical-particulate adsorption. Hence, the majority of inorganics introduced into the groundwater medium are flushed from the site.

Sediments and soils are the probable repositories for most metals emitted into the environment. The transport of these inorganics in soil and sediment is quite limited due to many factors involving the physical and chemical characteristics of the media and the contaminant. Adsorption and desorption are the two most important factors influencing an inorganic migration through the soil and sediment media. Inorganic molecules have a high affinity for adsorption under the right conditions. This, in turn, restricts the molecule's mobility through media considerably. As a result, in soil and sediment, once adsorption has taken place the inorganic will not migrate substantially except during erosion and heavy runoff periods. The most important factor affecting the adsorbance rate of inorganics in soil and sediment is the concentration of particulate matter, especially in an organic form (e.g., plant decay material). As the amount of organic particulate increases in soil and sediment, the rate of adsorption increases. When the presence of organic matter is low, the mineral content or frequency of iron, manganese, and aluminum oxides become important for adsorption. Zinc, arsenic, barium, and beryllium particularly sorb well to cationic (positively charged) sites on soils and clay hydroxides. This will retard movement through the medium.

Another important factor affecting adsorbance is pH of the soil or sediment. Inorganic adsorption is higher at elevated soil pHs. This occurs because the higher pH causes hydroxide ions to have a greater affinity to associate. (Copper is an exception. Adsorption is not influenced by pH; it is primarily influenced by the quantity of organic matter present). Thus, at higher pH levels in soil, inorganic migration is restricted because of increased adsorption.

At the Caldwell Site, most contamination from the inorganics would be expected to be present in the soils and sediments due to their retentive properties. Exceptions to this general trend would be expected when sinkholes develop and feed the free-flowing groundwater channels. Once these eroded soils reach these channels, the hydrogeology of the karst network present at the site may transport soils off-site.

In general, inorganics tend to bioaccumulate at the low end of trophic levels. With plants, inorganics tend to remain adsorbed to the soil rather than being taken up by the plant. However, when uptake does occur, the inorganic tends to remain in the plant root system.

Benthic animals (especially filter feeders) at the low trophic levels tend to bioaccumulate inorganic contaminants. For example, the soluble form of mercury, methylmercury readily

enters the aquatic food chain when introduced into that medium. Methylmercury is rapidly bioaccumulated and biomagnified by aquatic animals and plants, and it tends to remain a hazard due to its relatively long bio-half-life of 1,000 days.

Beryllium is another exception in that it is highly toxic to aquatic life in soft water. As the water hardens, the toxic effects of beryllium is reduced significantly. Once again, benthic organisms are at primary risk due to intake of contaminated sediment.

The potential migration of chromium at the site is discussed in Subsection 6.3.3, Modeling.

6.3.2 ORGANICS

Water solubility of a substance is a critical property affecting environmental fate; highly soluble chemicals can be leached from wastes and soils and are mobile in surface water and groundwater. The higher the water solubility of a chemical, the more likely it is to be mobile, and the less likely it is to be accumulative, bioaccumulative, volatile, and persistent. A highly soluble chemical is prone to biodegradation and metabolism that may detoxify the parent chemical. The lower the water solubility of a chemical, the more likely it is that it will be immobilized via adsorption; thus, it would be less mobile, but more bioaccumulative. Those compounds which range between high and low water solubilities could go either way, and will be influenced by additional parameters.

Volatilization of a compound from environmental media will depend on its vapor pressure, water solubility, and diffusion coefficient. For estimating releases from water to air, the Henry's Law constant (the partition coefficient that expresses the ratio of the chemical concentration between air and water at equilibrium) is more appropriate than vapor pressure alone. Compounds with Henry's Law constants exceeding 10^{-3} atm m^3/mole will undergo significant volatization. Compounds with Henry's Law constants in the range of 10^{-3} to 10^{-5} atm m^3/mole are associated with moderate volatilization, while compounds with values less than 10^{-5} atm m^3/mole volatize from water only to a limited extent (Lyman et al., 1982).

The octanol-water partition coefficient (K_{ow}) is often used to estimate the extent to which an organic chemical will partition from water into octane. The higher the K_{ow} value, the greater is a compound's tendency to partition adhere to a surface (i.e., surface soil). Similarly, the organic carbon partition coefficient (K_{oc}) reflects the propensity of a compound to adsorb to the organic carbon found in soil. The higher the K_{oc} value, the greater is a chemical's tendency to adsorb to soil organic carbon instead of migrating through groundwater. For example, large nonpolar compounds such as DDT and PCBs have high K_{oc} values (exceeding 10^5) and are

relatively immobile. By contrast, small or more polar organic compounds such as toluene and vinyl chloride have low K_{oc} values (less than 10^3) and are relatively mobile.

Adsorption is the physical-chemical process by which soil binds with chemicals so that they are not released or are very slowly released in the environment. Water provides the release mechanism for the contaminant to become available in nature. Plant root systems have been shown to cause desorption through chemical-particle uptake. This, in turn, allows the chemical to migrate easier to other plant parts. Animals ingesting soil have also released the adsorbed chemical(s) for easier uptake.

The mobility of adsorbed chemicals is prevented only in those soils that can adsorb chemicals. Sandy soils and low-organic soils do not readily adsorb chemicals. The movement of soil or soil particles containing an adsorbed chemical can contaminate other environments (e.g., as soil runoff or airborne particulates). Soil sorption, chemical sorption, or bound chemical(s) in soil may be described as the extent that an organic chemical partitions between a solid phase and a liquid phase. This value is better known as the adsorption coefficient (K_{oc}), and is expressed as the micrograms adsorbed per unit organic carbon (soil solid phase) divided by micrograms per milliliter of solution (liquid base). The organic carbon content of soil at the Caldwell site has not been measured, so the importance of soil adsorption in mitigating containment transport cannot be confirmed.

Leaching is the movement of a chemical downward through soil by water. It is of concern because of the possibility that the chemical will move through the soil and contaminate the groundwater. Many factors affect whether or not a chemical leaches in soil, including solubility, biodegradation, hydrolysis, dissociation, sorption, volatility, rainfall, and evapo-transpiration. A chemical that is water-soluble can leach in soil and is likely to be biodegraded by soil microbes. If biodegradation is rapid, then leaching may be minimal. A chemical that is insoluble in water can be adsorbed in soil, moved with soil particles, and perhaps very slowly biodegraded, if at all. The more precipitation, the greater the chance is for chemicals to leach.

Surface runoff may spread contamination to a more widespread area. This can occur when (1) a water-soluble chemical can be solubilized in rainwater and snow melt, and as the water runs off the contaminated area, so does the soluble chemical; (2) chemicals that are ad- or absorbed by soil can migrate as soil erosion occurs; and (3) solvents other than water may solubilize and transport chemicals.

When a chemical does run off or is moved with soil to a noncontaminated area, contamination of air, soil, plants, animals, and aquatic environmental compartments can result. If the land slopes, resulting in water runoff, it is likely that soil and any chemicals that are present will

migrate. Moreover, the amount of rainfall and snow strongly influences the amount and distance of such movement.

6.3.2.1 PESTICIDES

In general, the pesticides identified in Table 6-2 tend to adsorb tightly to soil particles and organic material. As a result of this strong adsorption tendency, pesticide leaching from soils into water systems is not common. Therefore at the Caldwell Site, most pesticide contamination should remain primarily in the soil medium, as has been observed.

However, in view of the extensive sinkhole system throughout the Caldwell Site, pesticide contamination could potentially reach the groundwater system via direct vertical transport through these sinkholes. Rainwater runoff could transport chemicals to these sinkholes where vertical migration into the groundwater medium might occur. However, none of these pesticides have been detected in site groundwater.

There is a large body of information concerning the transport and partitioning of chlordane in the environment. In outdoor air, chlordane exists predominantly in the vapor phase, whereas particle-adsorbed chlordane will contribute relatively minor amounts to the environmental burden.

Chlordane in water will both adsorb to grounded and suspended sediments and volatilize. The partitioning of chlordane to sediment correlates with the organic carbon content of the sediment. The mean log K_{oc} for trans-chlordane to samples of suspended particulate matter from the St. Clair and Detroit Rivers was 6.2 (ATSDR, 1993). The rate of volatilization of chlordane from water depends to a large extent on the amount, size, and percent of organic matter of the suspended material in the water body since adsorption to suspended solids and sediments attenuates the rate of volatilization. The rate of volatilization is also affected by temperature, wind, and water turbulence. The majority of chlordane, however, probably enters water as runoff from soils, and is adsorbed by particulates before entering a body of water. The chlordane repartitions in the water and volatilizes rapidly near the water surface. Understandably, chlordane has not been detected in site surface water.

In soil, chlordane adsorbs to the organic matter and volatilizes slowly over time. Chlordane does not leach significantly. In general, chlordane remains in the top 20 cm of most soils (ATSDR, 1993), and for some soils, it stays at this level for over twenty years. Volatilization from soil is a major loss mechanism for chlordane. Sandy soils and soils with small amounts of organic matter retain chlordane less than soils with high clay and/or organic content. Soil moisture, however, is the most important factor. The wetter the soil, the weaker the adsorption

bond. In dry soil, the organic vapors are much more strongly adsorbed with a resulting decrease in volatilization. Volatilization in some cases will continue for many years, as evidenced by the detection of indoor air concentrations of chlordane 15 years after application. Crop cover does not markedly alter the rate of volatilization. In a 3-year field experiment on chlordane volatilization it was determined that the highest residues of chlordane were in the top ten cm of soil for both the cropped and fallow plots (ATSDR, 1993).

Specific information for migration of transnonachlor and the chlordenes was not available. It is assumed they will follow the trends of the other pesticides.

6.3.2.2 DICHLOROBENZENES

1,4- and 1,3-dichlorobenzene are manufactured insecticides with very similar chemical characteristics. Even though 1,4-dichlorobenzene is a solid and 1,3-dichlorobenzene is a liquid, they behave in much the same manner in differing media because of their similar chemical traits.

Dichlorobenzenes tend to volatilize to the atmosphere from soil and water at a relatively rapid rate. The estimated volatilization half-life for 1,4-dichlorobenzene in a model river was 4.3 hours (ATSDR, 1993). Volatilization from surface soil may be an important transport mechanism for dichlorobenzenes, but adsorption to soil particulates may inhibit volatilization by an order of magnitude compared to volatilization from water. However, due to their relatively high vapor pressures (0.4 mmHg for 1,4- and 1.9 mmHg for 1,3-) it seems that the rate of adsorption would be quite low compared to the rate of volatility.

6.3.2.3 POLYNUCLEAR AROMATIC HYDROCARBON COMPOUNDS (PAHs)

There are four PAHs of concern at Caldwell: benzo(a)anthracene, chrysene, benzo(a)pyrene, and benzo(b and/or k)fluoranthene. PAHs were only detected in the landfill surface soil.

High molecular weight PAHs, such as the ones found at the Caldwell site, have K_{oc} values in the range of 1×10^5 to 1×10^6, which indicates strong tendencies to adsorb to organic carbon. Sorption of PAHs to soil and sediments increases with increasing organic carbon content and is also directly dependent on particle size. Volatilization from soil and sediments is not a significant process for the higher molecular weight PAHs.

6.3.2.4 OTHER SEMIVOLATILE ORGANIC COMPOUNDS

N-nitrosodiphenylamine has a vapor pressure of 0.1 mmHg at 25 C; therefore, it should exist almost entirely in the vapor phase. It is also soluble in water (35 mg/L), but with a Henry's law

constant of 1.4E-1 atm-m3/mol, there is strong indication that volatilization from water will be a slow but significant transport process. The soil sorption coefficient (K_{oc}) for N-nitrosodiphenylamine was estimated to range from 830 to 1,830. This K_{oc} is indicative of low moderate mobility in soil; therefore, significant leaching is not expected to occur in most types of soil.

Bis(2-ethylhexyl)phthalate was detected in groundwater, surface water, and landfill subsurface soil. Since it has a relatively low Henry's law constant (1.1E-5 atm-m^3/mol) and vapor pressure (6.2E-8 mmHg), bis(2-ethylhexyl)phthalate has a low volatility rate. Thus, it is not likely to escape from any medium via this route. It also has a low solubility in water and a high adsorption rate. Thus, it is likely to persist in the soil and sediments, with some release via a rapidly moving groundwater system like the one at the Caldwell Site.

6.3.3 MODELING

The potential mobility of chromium III, which was disposed at the Site, was modeled using a geochemical speciation model call MINTEQA2. The purpose of the modeling was to determine whether dissolved levels of Cr(III) could exceed the chromium drinking water standard (0.1 mg\L) in water in direct contact with chromium-contaminated waste.

Two calculations using MINTEOQA2 were performed at the U.S. EPA Center for Exposure Assessment Modeling (CEAM, 1991). In the first evaluation, water containing elevated levels of organic acid and ionic strength were assumed to contact an infinite source of amorphous $Cr(OH)_3$. The organic acid level was fixed at 0.1 mM, roughly 100 times the highest total level of organic acids found in groundwater samples from the site. As an added safety factor, the organic acid was assumed to be phthalic acid instead of the monocarboxylic acids that probably predominate in this waste. The ionic strength was also conservatively elevated. The modeling results indicated that dissolved Cr(III) levels are not expected to exceed the current drinking water standard except at low pH values. The pH at the site exceeds 7 due to the abundance of lime. Therefore, the mobility of dissolved Cr(III) is not an issue at the present time.

The second calculation was performed to estimate the partition coefficient (K_d) for Cr(III) using background conditions at the Site (i.e., no organic acids or elevated ionic strength). To conservatively calculate K_d, the dissolved Cr(III) levels were fixed at the levels predicted in water in contact with an infinite source of amorphous $Cr(OH)_3$. Sorption was modeled using the MIT diffuse-layer methodology. The average concentration of iron in a number of soils from around the country was employed to establish the sorbent concentration at this site, since data for this parameter were unavailable. This is not necessarily a conservative value; however, decreasing the predicted K_d value by a factor of ten should provide a conservative estimate. The

K_d values, which vary based on pH, are presented in Table 6-3. At pH 7, the K_d value is 260,000 L/kg, indicating that essentially all of the Cr(III) present would be sorbed to soil particles.

6.3.4 SUMMARY

Based on the physical and hydrogeological features present at the Caldwell Lace Leather Site, the potential exists for migration of some of the more mobile contaminants already detected in site groundwater and surface water. Due to the site hydrogeology, chemicals entering the groundwater system may be flushed from the groundwater system and discharged off-site. The depth of the groundwater table (30 to 40 ft.) in the area may help to slow the process of contaminant leaching, and the extensive system of sinkholes and fractures helps dilute and disperse any contaminant which does reach the groundwater medium. Important chemical factors in the water such as the pH, redox potential, ionic strength of the water, and the concentration of ionic complexes in the water all contribute to the fate of individual chemicals within the physical terrain.

The pH of the soil, adsorption rates, organic content in the soil, redox potentials, and the presence of sinkholes at the site play significant roles in determining fate and transport. Adsorption renders some chemicals relatively immobile, making transport unlikely. However, the presence of sinkholes and/or fractures in the karst terrain may provide avenues for contaminant migration into the groundwater medium as runoff waters feed into them.

Based upon the survey of the physicochemical, geological, and hydrogeological features at the Caldwell Lace Leather Site, we would expect to find the majority of contamination to reside in the soil medium. Most of the organics detected in Site soil are relatively immobile and have not migrated to groundwater or surface water. In addition, modeling indicated that chromium will not significantly leach from Site soil, a conclusion supported by the fact that groundwater chromium concentrators are well below MCLs. However, the potential does exist for some contaminants to migrate into groundwater through sinkholes, runoff and leaching. Thus, while contamination may occur in all media at this Site, their persistence in each medium is directly related to the present physical and chemical properties as addressed in this section.

6.4 REFERENCES

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Table 6-1
Caldwell Lace Leather Site
Ranges of Concentrations for Contaminants of Concern

	Groundwater µg/L	Surface Water µg/L	Sediment mg/kg	Subsurface Soil mg/kg	Landfarming Surface Soil (mg/kg)	Landfill Surface Soil (mg/kg)
INORGANICS						
Aluminum	56-25,000	84-25,000	2,450-14,000	--	--	--
Arsenic	--	--	--	1.2-18	1.6-18	1.8-8.4
Barium	5.3-960	28-180	--	8.9-89	32-160	29-210
Beryllium	--	--	--	0.54-0.63	0.5-1.5	0.51-2.2
Cadmium	--	--	--	--	0.6	1.7
Chromium (Total)	6.1-22	6.1-21	12-160	4.9-5,000	7.4-1,100	5-5,600
Cobalt	2.7-11	11	5.4-33	1.6-12	2.2-14	17
Copper	3.8-92	--	4.7-54	1.5-16	3.8-18	1.7-28
Lead	5.9-20	5.9-20	7.5-39	2.4-45	6.5-52	8.2-280
Manganese	7.5-4,200	14-4,200	150-2,600	10-740	57.0-800	80-2,000
Mercury	--	--	--	0.06-0.18	0.07-0.11	0.07-0.46
Molybdenum	5.3-10	--	--	--	--	--
Nickel	11-22	8-22	5.4-13	3.7-49	3.5-25	2.5-22
Strontium	62-3,700	--	--	2.0-200	--	2.2-210
Tin	--	--	--	--	2.6-26	--

Table 6-1 ((Continued)
Caldwell Lace Leather Site
Ranges of Concentrations for Contaminants of Concern

	Groundwater µg/L	Surface Water µg/L	Sediment mg/kg	Subsurface Soil mg/kg	Landfarming Surface Soil (mg/kg)	Landfill Surface Soil (mg/kg)
Titanium	10-350	10-350	--	50-220	86-190	81-210
Vanadium	2.9-42	2.9-42	8.6-59	7.2-47	--	8.2-48
Yttrium	12-21	21	--	1.8-10	--	2.2-20
Zinc	5.0-710	--	33-77	2.9-91	15-270	9.4-200
PESTICIDES/PCBs						
Chlordene	--	--	--	0.062	--	--
Trans-Nonachlor	--	--	--	0.054	--	--
Gamma-Chlordane	--	--	--	0.15	--	--
Alpha-Chlordene	--	--	--	0.058	--	--
Alpha-Chlordane	--	--	--	0.13	--	--
SEMI-VOLATILE ORGANICS						
1,3-Dichlorobenzene	--	--	--	0.042	--	--
1,4-Dichlorobenzene	--	--	--	0.62	--	--
N-Nitrosodiphenylamine	--	--	--	1.2	--	--
Benzo(a)anthracene	--	--	--	--	--	0.13
Chrysene	--	--	--	--	--	0.073-0.14
Benzo(b and/or k)fluoranthene	--	--	--	--	--	0.087

Table 6-1 (Continued)
Caldwell Lace Leather Site
Ranges of Concentrations for Contaminants of Concern

	Groundwater µg/L	Surface Water µg/L	Sediment mg/kg	Subsurface Soil mg/kg	Landfarming Surface Soil (mg/kg)	Landfill Surface Soil (mg/kg)
Benzo(a)pyrene	--	--	--	--	--	0.053
Bis(2-ethylhexyl)phthalate	14-59	14-59	--	42	--	--
VOLATILE ORGANICS						
Bromomethane	0.56	--	--	--	--	--

Table 6-2
Caldwell Lace Leather
Physical Constants and Coefficients

	log K_{ow}	Reference	log K_{oc}	Reference	Molecular Weight (g/mol)	Solubility in Water 20-25°C (mg/L)	Reference	Vapor Pressure 20-25°C (mmHg)	Reference	Henry's Law Constant 20-25°C (atm-m^3/mol)	Reference
INORGANICS											
Aluminum	NA		NA		27	--		NA		NA	
Arsenic	NA		NA		75	Insoluble	EPA, 1992	NA		NA	
Barium	NA		NA		137	Hydrolyzes	EPA, 1992	NA		NA	
Beryllium	NA		NA		9.01	Insoluble	EPA, 1992	NA		NA	
Chromium	NA		NA		51.9	Insoluble	EPA, 1992	NA		NA	
Cobalt	NA		NA		59	Insoluble	EPA, 1992	NA		NA	
Copper	NA		NA		63.5	Insoluble	EPA, 1992	NA		NA	
Lead	NA		NA		207.2	Insoluble	EPA, 1992	NA		NA	
Manganese	NA		NA		200	--		NA		NA	
Mercury	NA		NA		201	5.6E-2	EPA, 1992	NA		1E-2	EPA, 1992
Molybdenum	NA		NA		95.9	Insoluble	EPA, 1992	NA		NA	
Nickel	NA		NA		58.7	Insoluble	EPA, 1992	NA		NA	
Strontium	NA		NA		87.6	Insoluble	EPA, 1992	NA		NA	
Tin	NA		NA		118.7	Insoluble	EPA, 1992	NA		NA	
Titanium	NA		NA		47.8	Insoluble	EPA, 1992	NA		NA	
Vanadium	NA		NA		50.9	Insoluble	EPA, 1992	NA		NA	
Yttrium	NA		NA		88.9	Insoluble	EPA, 1992	NA		NA	

Table 6-2 (Continued)
Caldwell Lace Leather
Physical Constants and Coefficients

	log K_{ow}	Reference	log K_{oc}	Reference	Molecular Weight (g/mol)	Solubility in Water 20-25°C (mg/L)	Reference	Vapor Pressure 20-25°C (mmHg)	Reference	Henry's Law Constant 20-25°C (atm-m^3/mol)	Reference
Zinc	NA		NA		65.3	Insoluble	EPA, 1992	NA		NA	
PESTICIDES/PCBs											
Chlordene	--		--		--	--		--		--	
Gamma-Chlordane	2.78	EPA, 1992	5.15	EPA, 1986	410	5.6E-2	EPA, 1992	1E-5	Montgomery & Welkom	4.79E-5	EPA, 1992
Alpha-Chlordane	2.78	EPA, 1992	5.15	EPA, 1986	410	5.6E-2	EPA, 1992	1E-5	Montgomery & Welkom	4.79E-5	EPA, 1992
Alpha-Chlordene	2.78	EPA, 1992	5.15	EPA, 1986	410	--	Montgomery & Welkom	--	Montgomery & Welkom	4.79E-5	EPA, 1992
Trans Nonachlor	--	--	--		--	--		--		--	
SEMI-VOLATILE ORGANICS											
1,3-Dichlorobenzene	3.38	EPA, 1992	2.23	Montgomery & Welkom	147	123	Montgomery & Welkom	2.3	Montgomery & Welkom	3.2E-3	EPA, 1992
1,4-Dichlorobenzene	3.39	EPA, 1992	2.20	Montgomery & Welkom	147	79	EPA, 1992	0.6	Montgomery & Welkom	4.3E-3	EPA, 1992
N-Nitrosodiphenylamine	3.13	Montgomery & Welkom	2.76	Montgomery & Welkom	198	35.1	Montgomery & Welkom	0.1	Montgomery & Welkom	3.13	EPA, 1992
Benzo(a)anthracene	5.66	EPA, 1986	6.14	Montgomery & Welkom	228	0.014	Montgomery & Welkom	1.1E-7	Montgomery & Welkom	6.6E-7	EPA, 1986
Chrysene	5.66	EPA, 1986	5.30	EPA, 1986	228	0.006	Montgomery & Welkom	6.3E-9	Montgomery & Welkom	1E-6	EPA, 1992
Benzo(b and/or k)fluoranthene	6.12	EPA, 1986	5.74	EPA, 1986	252	0.014	Montgomery & Welkom	5.0E-7	Montgomery & Welkom	1.2E-5	EPA, 1986

Table 6-2 (Continued)
Caldwell Lace Leather
Physical Constants and Coefficients

	log K_{ow}	Reference	log K_{oc}	Reference	Molecular Weight (g/mol)	Solubility in Water 20-25°C (mg/L)	Reference	Vapor Pressure 20-25°C (mmHg)	Reference	Henry's Law Constant 20-25°C (atm-m^3/mol)	Reference
Benzo(a)pyrene	6.1	EPA, 1986	5.74	EPA, 1986	252	0.004	Montgomery & Welkom	5.49E-9	Montgomery & Welkom	5E-7	EPA, 1992
Bis(2-ethylhexyl)phthalate	5.3	EPA, 1992	5.0	Howard, 1984	391	0.4	Montgomery & Welkom	6.2E-8	Montgomery & Welkom	3E-7	EPA, 1992

REFERENCES AND FOOTNOTE VALUES

EPA, 1986 = EPA (Environmental Protection Agency), 1986 Superfund Public Health Evaluation Manual. Office of Emergency and Remedial Response. Washington, DC, EPA/340/1-86/060.

EPA, 1992 = EPA, 1992, *Handbook of RCRA Groundwawer Monitoring Constituents Chemical Physical Properties*, Washington, D.C. (40 CFR Part 264, Appendix 9).

Howard, 1984 = Howard, P.M., 1990. Handbook of Environmental Chemicals, Vol. II: Solvents. Lewis Publishers, Inc., Chelsea, Michigan.

Montgomery & Welkom = John H. Montgomery and Linda M. Welkom, 1990. Groundwater Chemicals Desk Reference. Lewis Publishers, Inc. Chelsea, Michigan.

NA = No Values Available.

Table 6-3
Caldwell Lace Leather
Speciation Results of Cr(III) Modeling Using MINTEQA2

pH	Dissolved ppm	% Dissolved	Adsorbed ppm	% Adsorbed	K_d L/kg	log(K_d)
4	1.65e+02	15.4	910	84.6	2.60e+00	0.41
4.25	3.50e+01	3.7	910	96.3	1.22e+01	1.09
4.5	8.11e+00	0.9	910	99.1	5.27e+01	1.72
4.75	2.09e+00	0.2	910	99.8	2.05e+02	2.31
5	6.03e+01	0.1	910	99.9	7.09e+02	2.85
5.25	1.97e-01	0	910	100	2.17e+03	3.34
5.5	7.23e-02	0	910	100	5.92e+03	3.77
5.75	3.00e-02	0	910	100	1.43e+04	4.15
6	1.39e-02	0	910	100	3.07e+04	4.49
6.25	7.12e-03	0	910	100	6.01e+04	4.78
6.5	4.00e-03	0	910	100	1.07e+05	5.03
6.75	2.45e-03	0	910	100	1.74e+05	5.24
7	1.65e-03	0	910	100	2.60e+05	5.41
7.25	1.22e-03	0	910	100	3.52e+05	5.55
7.5	9.83e-04	0	910	100	4.35e+05	5.64
7.75	8.53e-04	0	910	100	5.02e+05	5.70
8	7.80e-04	0	910	100	5.49e+05	5.74
8.25	7.44e-04	0	910	100	5.75e+05	5.76
8.5	7.23e-04	0	910	100	5.92e+05	5.77
8.75	7.12e-04	0	910	100	6.01e+05	5.78

7.0 ECOLOGICAL FIELD INVESTIGATION AND RESULTS

Ecological field investigations were conducted to verify either the presence or absence of ecological receptor and indicator species. An additional aim was to furnish environmental risk assessment personnel with qualitative data on broad-scale Site attributes such as specialized habitats, biotic populations, and community associations. The information was used to evaluate the potential magnitude and frequency of species contact with contaminants through various exposure pathways. This information will ultimately be used to derive ecological exposure assessments which are attempts to evaluate the potential magnitude and frequency of species contact with contaminants through various exposure pathways.

This section is divided into three subsections: an off-season ecological survey, a supplementary survey, and a limited field study.

7.1 OFF-SEASON ECOLOGICAL FIELD SURVEY

Field efforts were focused in a very specific way on characterizing the biota of the Site and describing the communities which they occupy. Tasks were formulated to identify general site and community boundaries and to determine whether or not the various habitats had the capacity for supporting both receptor and indicators species. Additional procedures were instituted to locate state and federal threatened and endangered (T&E) species. Informational needs in this regard were augmented through literature reviews and contact with appropriate natural resource trustees.

7.1.1 METHODS

On November 12, 1992 a WESTON biologist conducted a field investigation of the CLL Site. Prior to initiating qualitative inventories, a site reconnaissance was undertaken to locate site boundaries, occurrence and extent of major community types, presence of surface water and associated drainage patterns, potential wetlands, and signs of gross surface contamination. U.S.G.S. 1:24000 topographic maps and maps from Revision 2 of the Work Plan were used in this effort. A reconnaissance of off-Site springs and seepage areas, which dye-trace studies had indicated might be impacted by pollutant disposal activities, was also undertaken.

Field methods used during floristic and faunistic investigations employed both systematic walk-through surveys and specialized habitat surveys. Each of these methodologies is briefly described below.

Walk-Through Survey

Walk-through surveys involved the establishment of a series of evenly spaced parallel transect lines running in the direction of the short axis of each study site. In the current study, a 25m spacing between lines was used. An approximate 2m wide corridor on either side of each transect line was scanned for T&E occurrences and potential target/receptor species. Quantitative information was also gathered at this time in order to generate comprehensive species and species abundance checklists.

This same methodology proved useful in defining large-scale community associations and locating unique ecological habitats.

Habitat Survey

Habitat surveys consisted of intensive visual screening of specialized habitats recognized as having the greatest potential for supporting T&E species. At Caldwell these included mesic limestone hillsides in boundary woodlands, small rock outcrops, sinkholes, moist depressions, and pond margins. Field work was also conducted in the immediate vicinity of the eight off site spring-seep areas.

7.1.2 RESULTS

Past land use history at the site including logging, farming, grazing, and industrial activities have created a mosaic of seral communities including species characteristic of pioneer, intermediate, and subclimax successional stages. Since the level of successional development within a given geographic location typically determines which plants and animals associate together as biotic communities, successional types are a logical framework from which to present floristic and faunistic characterizations.

During the course of ecological investigation three predominant community types were identified. (The three are also readily discernible on the latest aerial photography.) Together these types encompass the full range of successional development present at the site. The various plant and animal species associated with each are summarized in the following sections.

Early Successional Grassland-Pasture

Grassland-pasture habitat dominates the Caldwell site and constitutes about 80 percent of the total area or approximately 18 hectares (ha). It consists of gently rolling topography ranging in elevation from about 225 to 250 meters (m). Lower elevation sites

tend to have high water availability and contain moist ravines, sinkhole depressions and pond margins. The upper elevation ridgetops that are underlain by Big Clifty sandstone are apparently well drained and may be classified as subxeric.

Flora

Of the 128 species of plants identified site-wide (Table 7-1), 72 (56.3 percent) occur in the grassland-pasture type. Although occasional woody vines, shrubs, and tree seedlings have encroached into the open fields, greater than 85 percent of the plant species there are herbaceous. Exotics too are well represented and constitute slightly over 36 percent of the extant taxa (Table 7-2).

Not unexpectedly, by far the most conspicuous elements in the flora are several species of exotic and native grasses. These include the native broomsedge and purpletop, and the introduced meadow fescue and orchard grass. Both fescue and orchard grass are common forage species native to Europe, and both appear to have been planted for grazing or soil stabilization purposes.

Dominant non-grass forbs within the grassland-pasture type are Canada goldenrod, Queen Anne's lace, and tall ironweed. Sericea lespedeza also occurs with notable frequency particularly in the vicinity of the access road which bisects Tract 1. Sericea, which is a perennial legume of Asian origin, was likely planted on site as a soil stabilizer and nitrate former.

Several obligate/facultative wetland entities were noted within the grassland even though these constituted only a very minor portion of the site vegetation in terms of frequency and areal coverage. They include various sedges, rushes, and bulrushes. Precise species identification was impossible on all but a few because of the time of year that the site investigation was conducted. All were restricted to pond margins and moist depressions.

Fauna

Field surveys indicate the use of the grassland-pasture type by several species of important game animals (Table 7-3). Whitetail deer droppings and tracks were found community wide and bedding locations were frequent in the northwest corner of the property. Eastern cottontail rabbit droppings were also detected throughout the area and numerous tracks were observed around the muddy edges of the drained pond on Tract 1. Direct sightings were made on both northern bob-white quail and mourning dove. The quail were flushed from an open area near the common boundary between Tracts 1 and

2 and consisted of a large resident covey of approximately 20 birds. Mourning dove were found foraging or gathering gravel several times during the day along the site access road.

Seven species of non-game birds were sighted within the grassland community during the course of site investigations. These included common songbirds such as mockingbird, robin, bluebird, white throated sparrow, and house sparrow. Various raptor/predators were also noted.

American kestrel and loggerhead shrike were observed perch hunting throughout the day and, though not directly associated with the site, several sightings of red-tail hawk were made as they circled overhead (Table 7-4).

The relatively low number of bird observations can be attributed directly to the time of the year which the study took place and to weather related factors. The vast majority of migrant and summer breeding species had likely departed in the weeks prior to initiation of the surveys. The only birds therefore remaining were winter residents. Also, the weather on the day the surveys took place was extremely unsettled. A major cold front was passing through the area causing rain squalls and wind gusts in excess of 40 miles per hour. Many resident species were likely holding close in deep cover for protection.

The pond associated with marginal grasslands on Tract 2 was surveyed from its banks in order to determine if fish were currently present. The turbidity of the water, however, made them impossible to detect.

Scrub-Shrub

Scrub-shrub communities are grasslands, pastures, and other previously disturbed areas which have been undisturbed for long enough periods of time to allow successional invasion by shrubs and small sapling sized trees. The scrub-shrub type is limited to an estimated 5 percent of the land area or only about 1 ha. It is most evident along the moist drainage area southwest of the drained pond on Tract 1.

Flora

Because scrub-shrub associations represent a transitional stage between grasslands and woodlands they contain elements of both.

Dominant forbs include broomsedge, common ragweed, ironweed, and chickweed while

invading tree species are exemplified by eastern redcedar, black cherry, blackgum, and American elm (Table 7-1).

Somewhat unexpectedly, the scrub-shrub type exhibited the lowest diversity of all the communities examined. A total of only 35 plant taxa were inventoried. This represented a mere 27.3 percent of cumulative plant species occurrence site wide (Table 7-2). Although much of this lack of diversity can be explained in terms of the limited area occupied by the type, a much more important factor is the intense competition from highly colonial elements such as blackberry, raspberry, and smooth sumac. While not important on a site wide basis, these species dominate within the scrub-shrub and tend to effectively suppress subordinates. Additionally, the presence of Japanese honeysuckle vine has had a deleterious effect on associated species because of its constricting, smothering growth habit.

Fauna

No direct sightings of any game animals were made during the walk-through survey. There was, however, much evidence in the form of tracks and droppings to indicate that this is a preferred location for whitetail deer and cottontail rabbit. Rabbit droppings were especially plentiful around dense blackberry thickets (Table 7-3).

Despite the limited areal coverage of the scrub-shrub community more species of birds were found here than in any other type. The protective nature of the cover and an abundant food supply in the form of sumac drupes and dried honeysuckle berries are likely explanations for this site preference. A total of 15 species were observed (Table 7-4). Exclusive to the site were American goldfinch, song sparrow, tufted titmouse, golden-crowned kinglet, and Carolina wren.

Woodland Border

The border forests which ring the property represent the most successionally advanced community type. Collectively they encompass approximately 15 percent of the site area or about 3.5 ha. Trees here commonly range from 15 to 60 centimeters in diameter and attain a maximum height in excess of 20 m. The largest specimens are likely to be at least 60 years old. The presence of cut stumps in the moist ravine just south of Tract 1 indicates that selective hardwood logging has taken place within the last 5 years.

Flora

The overstory forest is best characterized as a mixed hardwood type, although certain restricted areas contain a strong occurrence of eastern redcedar. Tree species diversity is moderately high at 38 taxa but fully 42 percent of these fall within only three genera; Quercus (oak) with 9 species, Carya (hickory) with 4 species, and Ulmus (elm) with 3 species (Table 7-1). The most dominant elements in approximate order of occurrence are southern red oak, sassafras, eastern redcedar, white oak, yellow-poplar, blackgum, and mockernut hickory.

Overall community makeup is 85.3 percent woody and 14.7 percent herbaceous (Table 7-2). Herb coverage is generally inconsequential and the only species encountered with any regularity are field garlic and white snakeroot. These tend to avoid well drained side slopes and were most frequent in moist lowlands, depressions, and ravines. It is worthy of mention that the only fern species found on site inhabited woodland situations. These were Christmas fern and ebony spleenwort. No grasses were found inhabiting the community.

Fauna

As in other types, deer sign was present in the border woodlands. In addition to droppings and tracks, antler rubbings were in evidence on various small trees and shrubs including smooth sumac, redcedar, and eastern redbud. One deer stand was found positioned in a tree near the extreme west end of the property and provided evidence of the use of this animal for recreational purposes.

Other field observations related to game species included raccoon droppings containing persimmon seeds found in a wooded sinkhole depression at the west end of the site, a single gray squirrel feeding on post oak acorns, a flock of 8 to 10 mourning dove roosting in mature redcedars, and two American woodcock flushed from the logged ravine area (Table 7-3).

Eleven species of non-game birds were spotted inhabiting the woodland type. These included species such as cardinal, American crow, blue jay, mockingbird, Carolina chickadee, brown thrasher, and robin. Exclusive to this community were hairy woodpecker and white-breasted nuthatch (Table 6-4). A single Cooper's hawk was seen diving from its perch in a dominant oak tree and flying in persuit of prey in the scrub-shrub area. This food item most likely would have been a song bird, a small rodent such as a white-footed or deer mouse, or perhaps something as large as a rabbit.

Springs

Eight off-Site springs were scanned during specialized habitat surveys to provide risk assessment personnel with information on T&E and potential indicator/receptor species. These sites were thought to have the greatest likelihood of supporting uncommon entities because they tend to offer unique site attributes.

Although most locations contained varying amounts of facultative and obligate wetland vegetation such as sedges and rushes (not identifiable to species), very few additional terrestrial species were inventoried. These included such common plants as poison hemlock (Conium maculatum), water speedwell (Veronica anagallis-aquatica), cattail (Typha latifolia), dwarf St. Johnswort (Hypericum mutilum), and bugleweed (Lycopus virginicus).

Only three of the sites appeared to contain perennial waterflow levels significant enough to support fish populations. These were Mossy Spring (location 8B), Long South Fork or "Runoff" (location 8C), and Mud River (location 14). Despite intensive searches from the bank, however, no fish were observed. The only aquatic or semi-aquatic life forms clearly evident at the time of the survey were water striders (Gerris sp.), caddis larvae (Hydropsychidae), and tadpoles of unknown species. Two frogs were seen very briefly at Mossy Spring but identification could not be made. Based on range and habitat, however, they likely were pickerel frogs (Rana palustris).

7.1.3 SUMMARY

From the ecological perspective the Caldwell Lace Leather Site is typical of most culturally impacted areas within the Western Escarpment Physiographic Province. Land use practices have resulted in a wide range of disturbance regimes that span all stages of successional development. Community associations therefore contain elements characteristic of each of these successional types. The purposeful and accidental introduction of exotic plant species has also had a profound influence on regional floristic diversity.

The varied plant life observed at the site offers the indigenous fauna many habitat opportunities and a bountiful food supply. Though beyond the scope of this report, the numerous mast, browse, seed, and forage species signals a potentially complex pollutant exposure pathway.

No rare, threatened, or endangered species were encountered on the Caldwell property or in conjunction with any of the outlying spring-seep areas. It must be cautioned, however, that the field evaluations took place during the dormant season when much of biota was inactive or in

a non-emergent state.

7.2 SUPPLEMENTARY ECOLOGICAL FIELD SURVEY

The off-season ecological survey place during the dormant season constituting only a partial accounting of species on site. An approximate 30 percent increase in plant species and a 50 to 100 percent increase in avifauna could be found on the Site should a supplementary investigation be conducted during the growing season. To that end, a subsequent survey was conducted to fully assess the occurrence of receptor organisms as well as threatened and endangered species. This supplementary survey was conducted on 30 June and 1 July 1993. Results of that effort are presented herein.

7.2.1 METHODS

Field methods used in the inventory of plants during the supplementary investigation were essentially the same as those used initially and therefore are not repeated here. Sampling protocols used to inventory the presence of bird species at the former disposal site and off-site springs generally followed those of the plant survey in that each habitat type was visually delineated and then systematically examined to determine the species of birds which were occupying that habitat based on sight and song/call identification. Unlike plants and avifauna which are generally conspicuous and readily observed, many mammalian species, by virtue of their secretive nature, nocturnal habits, small size, and the like, are extremely difficult to inventory. Therefore, a short term qualitative site assessment is not adequate to determine the identity of all mammals that potentially occur on a given site. Instead, for the purposes of the current study, a combined methodology was developed to make use of both on site observation and literature review. The presence of an animal was considered confirmed when an individual of a given species was directly observed or when indirect "signs" of a species such as nests, tracks, rubbings, scats, and paths were in evidence. An expanded list of mammals likely or unlikely to occur at each site was developed by assessing habitat availability and comparing that to the habitat preference of each taxon known to inhabit the Pennyroyal Plain subsection of the Highland Rim physiographic province and/or more specifically, Logan County. Several standard reference works were employed in this effort. This list is presented in Section 7-4.

7.2.2 RESULTS

7.2.2.1 ON-SITE LOCATIONS

Figure 7-1 outlines the following habitats identified on and surrounding the site.

Early Successional Grassland-Pasture

The supplemental floristic survey increased the number of species present in the grassland-pasture community from 72 reported species to 128 in 102 genera (Table 7-5). The greatest increase occurred in the herbaceous category which now stands at 115 species or nearly 90 percent of the taxa within the community type (Table 7-6). Notable increases were observed in abundance ratings for introduced forage species such as white clover and Japanese clover which became much more conspicuous during the growing season, particularly on the Landfarm. Although 12 new exotics were added, their percentage of community occurrence actually decreased from 36.1 percent to 29.7 percent. This off-setting effect was due to the discovery of 44 new native elements.

The recent survey has proven useful in clarifying the identity of several species within the Cyperaceae. This was considered critical since many Kentucky rare, threatened, and endangered (RTE) species are contained within this family. It is now possible to state with a high degree of certainty that none of these plants occur on the Caldwell site. Only more common elements such as flat and head-bearing sedge and green bulrush were present.

A total of six birds were added to the list of species inhabiting the grassland pasture community. These include common species such as eastern kingbird, house finch, and song and field sparrows. The only one of these exclusive to the community was the kingbird. Barn swallow and turkey vulture were also observed flying overhead, but their specific association with the site is unknown.

During the fall 1992 survey several bird species were observed that were absent during the present study. Many of the birds seen in November were either winter visitors or are migratory and may have stopped at the site for a brief period coincidental with the field investigation. Together, the list of birds from the November 1992 investigation along with Table 7-7 in the present report represents most of the common species that could be expected to occur at the site on an annual basis.

Presented in Table 7-8 is a regional listing of mammals expected to occur within the study area based on habitat preference. Table 7-9 lists those species which are most likely to inhabit the various community types found at the Caldwell disposal site itself. Within the grassland-pasture type, field observation and review of literature suggests that 12 species could be anticipated. Only two of these, however, white-tailed deer and woodchuck were confirmed in the field.

The small farm pond situated in the grassland-pasture area near the boundary between the Landfill and Landfarm was originally expected to contain a number of previously undocumented elements because of the uniqueness of such a habitat on site. However, upon close examination it was discovered that heavy usage by horses and beef cattle precluded this from occurring. The pond margin was found to be completely devoid of any vegetation due to trampling and heavy grazing. The water itself was suffused with algae and appeared entirely eutrophied. No signs of fish or aquatic macroinvertebrates were readily apparent although it is highly likely that intensive screening would reveal the presence of midges (Chironomidae) and other Dipteran taxa typical of enriched lentic habitats.

Scrub-Shrub

Floristically, the scrub-shrub type continued to exhibit the lowest diversity of all the on-site communities examined with only 45 species. This represents slightly over 20 percent of cumulative plant species occurrence site wide (Table 7-6). While ten additional species were tallied in the most recent survey, the general lack of diversity can still be attributed to the intense competition of highly colonial plants such as blackberry, raspberry, and smooth sumac.

The same colonial elements responsible for lowering plant species richness ironically are those which provide the tight, protective cover and abundant food supply that many native birds find so attractive. As in the fall 1992 inventory the scrub-shrub once again supported more species of birds than any other on-site community. Added to the 15 birds tallied in November were 10 new species (Table 7-7). Exclusive to the type were willow flycatcher, white-eyed vireo, yellow breasted chat, common yellowthroat, and American goldfinch.

While limited in areal extent, the unique habitat structure afforded by the scrub-shrub has the potential for harboring as many as 15 mammalian species (Table 7-9). Recent efforts directly confirmed the presence only of white-tailed deer.

Woodland Border

Nearly 47 percent of the total plant species identified on site occur within the mixed deciduous forests which ring the old disposal area (Tables 7-5 and 7-6). Current surveys indicate the presence of 100 taxa in 69 genera. Sixty one percent are classified as woody while 39 percent are understory herbaceous plants. These figures indicate a sharp increase in the number of herbaceous elements since the dormant season investigation

when herbs constituted only 14.7 percent of total community occurrence. Most notable were native forest mesophytes such as enchanter's nightshade, fragrant bedstraw, white avens, mayapple, and black snake root. Also well represented was common chickweed, the ubiquitous Eurasian introduction.

Field surveys revealed the addition of seven species of birds to the community. All are common summer breeders in the central Kentucky area. The only birds found exclusively in the woodland border forest were the chipping sparrow and yellow-billed cuckoo (Table 7-7).

Seventeen species of mammals are considered likely inhabitants of the border forest. Three occurrences confirmed by direct sighting or indirect means were white-tailed deer, eastern grey squirrel, and short-tailed shrew.

7.2.2.2 OFF-SITE LOCATIONS

Eight off-Site springs and seepage areas were inventoried to provide risk assessment personnel with a better understanding of the biological diversity associated with areas that are either hydrologically connected to the Caldwell Disposal Site or which may serve as control locations for comparative impact sampling at some time in the future (Figure 7-2). The unique array of site attributes in these areas such as canopied and uncanopied wetlands, riparian terraces, and rock outcrops provide habitats for vegetation not available on the disposal site itself. Furthermore, the perennial waterflow evidenced at some of the larger springs offered the potential for habitation by a completely different assemblage of aquatic organisms also not likely to be found in on-site locations.

The following text is a discussion of the most salient biological features observed at each of the off-site locations. Support data for this section of the report are presented in Tables 7-10 through 7-13.

Lagoon Spring

Lagoon Spring lies approximately 1000 meters south of Caldwell Landfill. The spring emanates from a prominent limestone rock outcrop and flows for only a short distance before discharging into a cultivated field that, in the Spring of 1993, had been planted in corn. The runoff channel, which was dry at the time of the investigation, is narrow and completely canopied. There was evidence that the channel itself had recently been impacted by road construction activities. Because limestone parent material is at or close to the surface the overstory, middlestory, and understory are dominated by obligate or

facultative calciphytes. Such species include chinkapin oak, hackberry, coralberry, and bladder-nut. Poison ivy and Virginia creeper were common vines while dominant herbs included clearweed and bedstraw.

Little bird activity was observed or heard at the time of the investigation probably because of the proximity of the site to the vast monoculture of corn. On the wooded slope above the spring robins and cardinals were common. This was also the location of the only woodthrush heard either on or off-site.

During survey activities at Lagoon Spring a previously overlooked sediment pond was discovered. The pond lies approximately 300 meters east northeast of the area described above. Examination of the area revealed the presence of a biota rich in aquatic and riparian organisms. Along the forested margin were found black willow, sycamore, and cottonwood and various herbaceous plants such as Engelmann's spikerush, hedge-hyssop, and water-hyssop. In the pond itself were common snailseed and water-meal. Dozens of adult odonates including *Boyeria vinosa* along with other dragonflies of the families Aeshnidae and Libellulidae were observed as they hunted prey over the pond's surface. Several small whirly-gig beetles (Gyrinidae) could be seen as they moved across the water. Numerous frogs of unknown identity were also observed.

Because this biotically rich water body lies directly down gradient of the Landfill of the former disposal area and appears to be surficially connected to it, further investigation in the form of surface water and/or sediment sampling may be advisable.

McPherson Spring

McPherson Spring, a low volume seepage site not hydrologically connected to the Caldwell Site, is located in a small woodland surrounded by open fields. Within the woodlands there are indications of perennial soil saturation and the site may be best characterized as palustrine. Many of the dominant trees, including red maple, American elm, and blackgum possessed buttressed trunks. The understory herbaceous plants were further indicative of a wetland situation and included white grass, touch-me-not, false nettle, brown sedge, and sallow sedge.

No fish were observed below the spring and based on the small size of the runoff channel it is unlikely that fish are ever present. Numerous burrowing crayfish chimneys and a single northern red salamander (*Pseudotriton ruber ruber*) however, were found adjacent to the channel. The predominant substrate matrix is silt with a moderate covering of yellowish-orange precipitate, indicating a ferrous contribution.

A single nest of an eastern gray squirrel was observed in the canopy confirming the presence of this game species at the spring. A total of 17 species of birds were documented at or in the vicinity of the spring. The only grasshopper sparrow documented during the present investigation was heard singing in some tall grass adjacent to a pond approximately 100 meters southwest of the spring.

Duncan Tile Spring

Duncan Tile Spring emanates within a small woodland area and flows approximately 200 meters before discharging into a small farm pond. For nearly its entire length the channel is non-canopied and is bracketed by cultivated fields. Consequently, the vegetation associated with the channel contains an admixture of shade intolerant hydrophytes and introduced forage grass species able to withstand periodically saturated soil conditions. Typical native entities included frogfruit, winged loosestrife, fox sedge, lined bulrush, and various species of spikerush. Dominant forage grasses included meadow fescue, velvet grass, and redtop.

No fish were observed in the runoff channel of Duncan Tile Spring but the size of the flow carried in the channel appears large enough to support a population. The presence of fish in the pond, although unconfirmed, would serve as an occasional source of fish in the upstream channel.

Both sides of the runoff channel are in permanent or semi-permanent cultivation and thus provide little in the way of wildlife habitat. A large, mixed group of barn swallows and rough-winged swallows were observed as they worked the air over the pond. Numerous mourning doves, a popular game species, were seen perched on wires in the vicinity of the spring.

Green Boiling Spring

Green Boiling Spring occurs approximately 300 meters from Duncan Tile Spring and is also surrounded by tilled, agricultural land. The runoff channel from Green Boiling Spring flows generally south before issuing into the main Duncan Tile drainage. The head of Green Boiling Spring is surrounded by a small wooded island of trees five to seven meters tall and contain species such as red mulberry, sycamore, persimmon, and black cherry. Herbaceous plants found in association with the spring included Allegheny blackberry, poison ivy, Japanese honeysuckle, and fox grape. Downstream towards the confluence with the runoff from Duncan Tile Spring, redtop grass was extremely conspicuous and in some places completely covered the channel.

At the time of the present investigation, Green Boiling Spring contained only a very small amount of water which could only be seen after the grass lining the runoff channel had been pulled back. Based on the small size of the channel, it is unlikely that fish ever occur between this spring source and the confluence with Duncan Tile Spring.

Because of the proximity of the two springs, bird species associated with Duncan Tile Spring were also found at Green Boiling Spring.

Mossy Spring

Mossy Spring is a moderately high volume water source which flows from a rocky opening in a narrow corridor woodland which is surrounded by cultivated fields. The head of the spring and runoff channel were found to be well canopied with hackberry and bitternut hickory capturing the overstory. Middle and understory strata were somewhat sparse containing only small amounts of panicled dogwood, hackberry, and coralberry. Vine species were dominated by Japanese honeysuckle and poison ivy. The most common herbaceous species were yellow wingstem, creamy violet, and clearweed. It is worthy of note that the Mossy Spring site contained the only documented occurrence of moonseed vine and bigleaf waterleaf.

Although no fish were observed in the canopied runoff channel, the spring provides adequate flow to support one or more species. The channel substrate was composed of angular cobbles, covered with an aquatic herbaceous species tentatively identified as *Podostemon ceratophyllum*. Numerous taxa of aquatic macroinvertebrates were found in association with the vegetated substrate, including river snails (Pleuroceridae), caddisflies (Trichoptera), stoneflies (Plecoptera), and mayflies (Ephemeroptera).

Several species of birds were observed or heard in the riparian area, including white-eyed vireo, ruby-throated hummingbird, blue-gray gnatcatcher, yellow-breasted chat, and tufted titmouse.

Long South Fork or "Runoff"

The Long South Fork is located near Mossy Spring and, similarly, is surrounded on both sides by cultivated fields. Because of time constraints, the team of investigators did not visit the spring source but rather concentrated on a short reach of the runoff channel and riparian zone several hundred meters downstream. In this area the canopy structure paralleled that of Mossy Spring except for the significant addition of sycamore. Understory herbs were diverse and well developed. The most frequently tallied species

included enchanter's nightshade, clearweed, and yellow wingstem.

The canopied channel was found to contain many bedrock outcrops, occasional patches of cobble, and silty pools. The source of the silt is presumably from erosion off the nearby agricultural fields. As expected, the bird species observed or heard at Long South Fork Spring were the same as at nearby Mossy Spring. Several small mosquitofish (*Gambusia affinis*) were observed in the runoff channel. A common snapping turtle (*Chelydra serpentina*) with a carapace length of approximately 20 centimeters was observed moving across the bottom of one of the pools. Aquatic macroinvertebrates found on the channel bottom included several larval damselflies (Odonata: Coenagrionidae) and river snails (Pleuroceridae).

Barnett Karst Window

Barnett Karst Window occurs at the bottom of a wooded sinkhole near the edge of cultivated field which at the time of the investigation was planted in soybean. The surrounding overstory vegetation is dominated by mature sugar maple, bitternut hickory, black cherry, and northern red oak. Understory tree regeneration, shrubs, and herbs were found to be sparse. The opening of the window itself is approximately one meter square through which can be seen an underground stream that is approximately 15 centimeters deep and of unknown width. The substrate of this subterranean channel is composed of bright, angular gravel. No aquatic life was observed through the opening. Near the rim of the sinkhole the opening of an active groundhog den was found. No birds were found in the immediate vicinity of the sinkhole, but numerous species were observed in association with the open areas surrounding the soybean field, including blue grosbeak, loggerhead shrike, brown thrasher, purple martin, eastern meadowlark, and others.

Mud River Spring

The Mud River Spring is actually two hydrologically unrelated springs which emanate out of a limestone rock face. The two springs converge approximately ten meters downstream from their respective sources. Vegetative diversity at this location was greater than at any other off-site area. This is due in part to a wide range in substrate availability such as rock faces, gravel bars, downstream mud flats, and riparian terraces. Close proximity to residential and agricultural areas also represent likely sources for a number of exotic forb and grass species such as common chickweed and Japanese grass. The mature deciduous overstory is composed primarily of hackberry, sugar maple, and white oak while the shrub layer is dominated by calciphytic entities such as coralberry.

Both springs have similar substrate and aquatic life characteristics. The channel substrate is composed of eroded limestone, angular gravel, and occasional patches of vegetated cobbles. Abundant river snails (Pleuroceridae), caddisflies (Trichoptera), and mayflies (Ephemeroptera: Heptageniidae) were found in association with the substrate. Numerous side-scuds (Amphipoda) were also observed. A dead banded sculpin (*Cottus carolinae*) was found in the channel of one of the springs. A woodduck box had been placed on the side of a tree adjacent to the spring but indications of usage were not evident. Bird species observed in association with the Mud River Spring included a spotted sandpiper, Carolina wren, yellow-billed cuckoo, and summer tanager.

7.2.3 SUMMARY

A supplemental investigation was performed at the Caldwell Lace Leather Site and at eight off-site springs on 30 June and 1 July. The purpose of the investigation was to obtain additional information on the ecological attributes of the site and certain off-site locations which had been shown through previous geological testing to be hydrologically connected to the disposal area. This supplemental investigation was recommended in the trip report submitted to EPA following the initial ecological survey of 12 November 1992. Because that work took place during the dormant season, it was reasoned that only a partial accounting of species had been determined and that a large increase in species of plants and animals could be inventoried with an investigation during the growing season.

As anticipated, a large increase in floristic elements were revealed during the supplemental investigation. The list of on-site plant species grew from 128 to 213 representing an increase of over 65 percent. Unique off-site habitats were responsible for the addition of 50 others making a grand total of 253 distinct taxa for all locations.

Increases in faunistic diversity followed similar patterns. Fifteen new species of birds were added to the on-site tally raising that total to 41. Based on habitat and the known range of Kentucky's mammals, it was projected that 21 species could potentially occur on the site and/or off-site springs either as permanent residents or occasional visitors. Numerous species of herptiles and aquatic macroinvertebrates were observed at nearly all off-site spring locations.

No rare, threatened, or endangered species were encountered on the Caldwell property or in conjunction with any of the outlying spring-seep areas during the supplemental investigation.

7.3 LIMITED FIELD STUDY

This section reports the findings of a limited field study conducted by EPA and contract

personnel in July, 1993 at eight sample locations around the CLL Site. The objectives of the study were to:

- document the habitat available in aquatic systems;
- document ambient water quality parameters;
- document the aquatic biota present;
- determine the likelihood of impairment of the aquatic systems as a result of activities at the Caldwell Site;
- perform biological toxicity tests on samples of sediment.

Previously, a dye study conducted by the USGS, in cooperation with the USEPA, demonstrated movement of groundwater from the Site to surrounding springs to the south and northwest of the Site, and that the groundwater flow occurred primarily through solution enlarged openings or conduits in the carbonate bedrock. In addition, chemical analyses were performed on water and sediment samples from eight of these off-site Springs and seeps and identified five chemicals of concern (COCs) -- aluminum, chromium, lead, manganese, and bis(2-ethylhexyl)phthalate. The study identifies Mossy Spring as the "worse case" with respect to sediment contamination having chromium, lead, and silver levels exceeding NOAA ER-L and NOAA ER-M sediment screening values. Also conducted were terrestrial animal and plant surveys and cursory aquatic organism surveys at the same eight locations.

Based on these previous studies and on a reconnaissance survey conducted on June 30, 1993, by EPA Region IV personnel, the following eight springs were selected as sampling locations for the current study (Figure 7-2):

- Lagoon Spring
- Lagoon Spring Pond (approximately 200' SE of Lagoon Spring)
- Green Boiling Spring
- Duncan Tile Spring
- McPherson Spring

- Mud River Spring
- Mossy Spring
- Long South Fork

7.3.1 METHODS

The eight sampling locations selected for this study were visited over a two-day period starting July 13, 1993.

Habitat Quality Evaluation - At each sampling location a habitat quality evaluation was conducted (when applicable) which consisted of a habitat assessment and physical characterization. The evaluation were conducted according to EPA Rapid Bioassessment Protocols For Use in Streams and Rivers (USEPA 1989).

Ambient Water Quality Measurements - Standard ambient water quality parameters (Ph, dissolved oxygen, temperature, and specific conductance.) were measured on-location with a YSI/Grant 3800® multi-probe sonde and recorded. At three locations considered to be permanent water bodies, (Lagoon Spring Pond, Mossy Spring, and Mud River), a 500 ml sample of water was collected for analysis of alkalinity and hardness which was performed later in the laboratory. All measurements were made according to EPA Region IV guidelines (USEPA 1990).

Biosurveys - At each sampling location at which standing or flowing water was encountered, a modified Rapid Bioassessment Protocol I was conducted according to EPA Bioassessment Protocols For Use in Streams and Rivers (USEPA 1989). Aquatic biota was observed or sampled at each location for a total of one man-hour. Larger biota such as fish, frog, and crayfish were simply observed and recorded. Benthic macroinvertebrates were sampled by carefully picking through leaf packs, algae mats, and other clumps of aquatic vegetation, and by examining the underside of rocks. A sample of invertebrates representative of the location was preserved in 70% alcohol and transported back to Athens for closer examination and identification.

Toxicity Tests - A 1-liter sample of sediment was collected from Lagoon Spring Pond, Mossy Spring and Mud River Spring, labeled, packed in wet ice, and transported to the Athens, Ga laboratory. There, whole-sediment toxicity tests were conducted using the amphipod *Hyalella azteca* as the test organism in a 10-day, static, non-renewal test. Sediment samples were collected, handled, shipped, and tested according to EPA Region

IV Ecological Support Branch Standard Operating Procedures for Hazardous Waste Site Investigations (USEPA 1992).

7.3.2 RESULTS

Habitat Quality Evaluations - were conducted at all but two sampling locations, Green Boiling Springs and Lagoon Spring Pond, both of which lacked a channel (i.e. habitat assessment not possible). Copies of field data sheets for completed evaluations can be found with the tables at the end of this section.

Water Quality Measurements - are summarized in Table 7-14. Measurements were recorded for all but two locations, Lagoon Springs and Green Boiling Springs, both of which contained no water at the time of the study.

Biological Surveys - Table 7-15 summarizes the Macrobenthos Qualitative Sample List for five locations that contained standing or flowing water at the time of the study. Copies of the Rapid Bioassessment (Protocol I) field data sheets can be found in with the tables at the end of this section.

Toxicity Tests - No toxicity was detected in any of the three sediment samples tested. Copies of the laboratory bench sheets for these tests can be found in at the end of this section. The poor performance of the control animals and the animals in the Lagoon Spring Pond test sample may be attributed to starvation. Test animals were fed a 1 cm square of "conditioned" brown paper toweling. Apparently, in the control tests the microflora which colonized the paper toweling was not enough to sustain the test animals for 10 days. Control animals had no other source of food. The sediment used in the control test was washed silica sand. In contrast, field-collected sediment was visibly rich in organic particulate matter, algae, and other microorganism which could supplement the diet of test animals. However, in the Lagoon Springs Pond sample, the sediment was also visibly infested with ostracods which are omnivorous scavengers feeding on bacteria, molds, algae, and fine detritus. So, even though there was supplemental food in this sediment sample, much of it could have been scavenged by the endemic microcrustaceans to the detriment of the introduced test amphipods.

7.3.3 SUMMARY

Of the eight sample locations visited on July 13 and 14, 1993, only two (Mossy Spring and Mud River Spring) were good candidates for determining impairment of these surface waters by the activities at the Cll site. All other locations have physical impairments, either an intermittent

lack of water (Lagoon Spring, Green Boiling Spring, and Long South Fork) or poor stream structure (Boiling Spring, Lagoon Spring Pond, Duncan Tile Spring, and McPherson Spring), that can easily obscure impairments inflicted by Site activities. Fortunately, the sampling locations chosen as good candidates, Mossy Spring and Mud River Spring, seem to be a well-matched set of streams. Both scored equally well on the habitat assessment, 113 and 114 respectively. Both support similar aquatic communities, that is, an abundance of a limited number of species of gastropods (1 species) and microcrustaceans (2 species) along with rarer pollution-sensitive stream organisms such as Plecoptera (1 species), Ephemeroptera (2 species), and Trichoptera (1 species). The relatively low biotic diversity of both streams is characteristic of a stenothermal environment and not necessarily indicative of impairment. The temperature of the water is about 14 °C, the temperature of the subterranean water system from which both springs are derived. The species of Plecoptera, Ephemeroptera, and Trichoptera identified from the springs (see Table 7-16) are species which characteristically inhabit cold (< 15 °C) water. Both springs receive water draining the Caldwell Site (USGS/USEPA 1993). However, that report identifies Mossy Spring as the "worse case" with respect to the presence of site-derived contaminants in the sediment, while Mud River Spring may be considered "clean." Considering the similarity in biotic composition between the two sample locations and the presence of pollution sensitive taxon at both locations, it appears that the COCs derived from the Site do not noticeably impair these spring-fed aquatic systems. Also, toxicity test results for both locations demonstrated no lethal effects related to the locations sampled following a ten-day exposure of test animals to whole sediments.

From our inspection of the Site and surrounding areas in June and July of this year, and from field and laboratory biological studies that we conducted, we were not able to detect biological differences in selected, similar sample locations in the vicinity of the disposal site, regardless of differences in the level of chemical contamination that exists in the sediments. It is likely that subtle biological differences that may exist between similar locations sampled that are attributable to contamination from the Caldwell Lace Leather area may well be masked by contamination or alteration of local aquatic habitats by the intense level of agriculture that is characteristic of this area.

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Table 7-1
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Boxelder	*Acer negundo*	Tree	S	X	X	X	N
Sugar maple	*Acer saccharum*	Tree	R			X	N
Ebony spleenwort	*Asplenium platyneuron*	Fern	S			X	N
False foxglove	*Aureolaria virginica*	Herb	R			X	N
Field garlic	*Allium vineale*	Herb	O	X		X	E-Europe
Common ragweed	*Ambrosia artemisiifolia*	Herb	I	X	X		N
Giant ragweed	*Ambrosia trifida*	Herb	S	X			N
Broomsedge	*Andropogon virginicus*	Grass	C	X	X		N
Indian-hemp	*Apocynum cannibinum*	Herb	S	X			N
Devil's walkingstick	*Aralia spinosa*	Tree	R			X	N
Downy aster	*Aster pilosus*	Herb	S	X			N
Paw paw	*Asimina triloba*	Tree	S			X	N
Spanish needles	*Bidens bipinnata*	Herb	S	X			N
Beggar's ticks	*Bidens frondosa*	Herb	S	X	X		N
Trumpet creeper	*Campsis radicans*	Vine	I	X	X	X	N
Wild senna	*Cassia marilandica*	Herb	S	X			N
Nodding thistle	*Carduus nutans*	Herb	I	X			E-Europe

Table 7-1 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Sedge[3]	*Carex sp.*	Herb	I	X			N
Bitternut hickory	*Carya cordiformis*	Tree	S			X	N
Pignut hickory	*Carya glabra*	Tree	I			X	N
Red hickory	*Carya ovalis*	Tree	S			X	N
Mockernut hickory	*Carya tomentosa*	Tree	O		X	X	N
Hackberry	*Celtis occidentalis*	Tree	I		X	X	N
Mouse-ear chickweed	*Cerastium glomeratum*	Herb	O	X	X	X	E-Europe
Eastern redbud	*Cercis canadensis*	Tree	S		X	X	N
Chickory	*Cichorium intybus*	Herb	S	X			E-Europe
Virgin's-bower	*Clematis virginiana*	Vine	R			X	N
Horseweed	*Conyza canadensis*	Herb	I	X			N
Tall coreopsis	*Coreopsis tripteris*	Herb	I	X			N
Flowering dogwood	*Cornus florida*	Tree	O		X	X	N
Panicled dogwood[3]	*Cornus racemosa*	Shrub	S		X	X	N
American hazel	*Corylus americana*	Shrub	S			X	N
Umbrella sedge[3]	*Cyperus strigosus*	Herb	S	X			N

Table 7-1 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Orchard grass	*Dactylis glomerata*	Grass	F	X			E-Europe (planted)
Queen Anne's lace	*Daucus carota*	Herb	O	X			E-Europe
Wooly panic grass	*Dichanthelium accuminatum*	Grass	I	X	X		N
Buttonweed	*Diodia teres*	Herb	S	X			N
Wild yam	*Dioscorea villosa*	Vine	R			X	N
Persimmon	*Diospyros virginiana*	Tree	I	X	X	X	N
Wild rye	*Elymus virginicus*	Grass	R	X			N
Silver plume grass	*Erianthus alopecuroides*	Grass	O	X			N
Tall thoroughwort	*Eupatorium altissimum*	Herb	O	X			N
White snakeroot	*Eupatorium rugosum*	Herb	S			X	N
Flat-topped goldenrod	*Euthamia graminifolia*	Herb	S	X			N
Meadow fescue	*Festuca arundinacea*	Grass	F	X			E-Eurasia (planted)
White ash	*Fraxinus americana*	Tree	R			X	N
Bedstraw	*Galium aparine*	Herb	S	X		X	N
Wild-licorice	*Galium circaezans*	Herb	R			X	N

Table 7-1 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Honeylocust	*Gleditsia triacanthos*	Tree	S	X	X	X	N
Purple cudweed	*Gnapthalium purpureum*	Herb	S	X			N
Shrubby St. John's-wort	*Hypericum prolificum*	Shrub	R			X	N
Touch-me-not[3]	*Impatiens capensis*	Herb	R	X			N
Black walnut	*Juglans nigra*	Tree	S			X	N
Rush[3]	*Juncus sp.*	Herb	S	X			N
Eastern redcedar	*Juniperus virginiana*	Tree	O	X	X	X	N
Japanese-clover	*Kummerowia striata*	Herb	R	X			E-Asia
Woodland blue lettuce	*Lactuca florida*	Herb	S	X			N
Sericea lespedeza	*Lespedeza cuneata*	Herb	O	X	X		E-Asia (planted)
Ox-eye daisy	*Leucanthemum vulgare*	Herb	S	X			E-Europe
Spicebush	*Lindera benzoin*	Shrub	S			X	N
Sweetgum	*Liquidambar styraciflua*	Tree	I		X	X	N
Yellow-poplar	*Liriodendron tulipifera*	Tree	O		X	X	N
Japanese honeysuckle	*Lonicera japonica*	Vine	F		X	X	E-Asia
Black medic	*Medicago lupulina*	Herb	S	X			E-Europe

Table 7-1 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
White sweet clover	*Melilotus alba*	Herb	I	X			E-Europe
Yellow sweet clover[3]	*Melilotus officinalis*	Herb	S	X			E-Europe
White mulberry	*Morus alba*	Tree	S			X	E-Asia
Red mulberry	*Morus rubra*	Tree	R			X	N
Blackgum	*Nyssa sylvatica*	Tree	O		X	X	N
Evening primrose	*Oenothera biennis*	Herb	S	X			N
Eastern hophornbeam	*Ostrya virginiana*	Tree	R			X	N
Yellow sorrell	*Oxalis dillenii*	Herb	S	X			N
Fall panic grass	*Panicum dichotomiflorum*	Grass	S	X			N
Virginia creeper	*Parthenocissus quinquefolia*	Vine	S			X	N
Passion flower	*Passiflora incarnata*	Vine	S	X			N
Pokeweed	*Phytolacca americana*	Herb	I	X			N
English plantain	*Plantago lanceolata*	Herb	O	X			E-Europe
Sycamore	*Platanus occidentalis*	Tree	S			X	N
Kentucky bluegrass	*Poa pratensis*	Grass	I	X			E-Europe (planted)
Christmas fern	*Polystichum acrostichoides*	Fern	I			X	N

Table 7-1 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Eastern cottonwood	*Populus deltoides*	Tree	R			X	N
Black cherry	*Prunus serotina*	Tree	O	X	X	X	N
White oak	*Quercus alba*	Tree	O			X	N
Scarlet oak	*Quercus coccinea*	Tree	I			X	N
Southern red oak	*Quercus falcata*	Tree	F		X	X	N
Shingle oak	*Quercus imbricaria*	Tree	S			X	N
Chinkapin oak	*Quercus muhlenbergii*	Tree	I			X	N
Northern red oak	*Quercus rubra*	Tree	I		X	X	N
Shumard oak	*Quercus shumardii*	Tree	I		X	X	N
Post oak	*Quercus stellata*	Tree	O		X	X	N
Black oak	*Quercus velutina*	Tree	S			X	N
Carolina buckthorn	*Rhamnus caroliniana*	Tree	S			X	N
Fragrant sumac	*Rhus aromatica*	Shrub	R			X	N
Winged sumac	*Rhus copallina*	Shrub	S	X	X	X	N
Smooth sumac	*Rhus glabra*	Shrub	I	X	X	X	N
Carolina rose	*Rosa carolina*	Shrub	R			X	N
Multiflora rose	*Rosa multiflora*	Shrub	R			X	E-E. Asia

Table 7-1 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Prarie rose	*Rosa setigera*	Shrub	S		X	X	N
Hairy blackberry[3]	*Rubus allegheniensis*	Herb	O		X		N
Black raspberry	*Rubus occidentalis*	Herb	S		X		N
Sheep sorrel	*Rumex acetosella*	Herb	S	X			E-Europe
Curly dock	*Rumex crispus*	Herb	S	X			E-Europe
Sassafras	*Sassafras albidum*	Tree	F		X	X	N
Green bulrush[3]	*Scirpus atrovirens*	Herb	R	X			N
Chinese foxtail grass	*Setaria faberi*	Grass	I	X			E-Asia
Yellow foxtail grass	*Setaria glauca*	Grass	O	X			E-Eurasia
Virginia rock cress	*Sibara virginica*	Herb	S	X			N
Catbrier	*Smilax bona-nox*	Vine	S		X	X	N
Sawbrier	*Smilax glauca*	Vine	I			X	N
Bristly greenbrier	*Smilax hispida*	Vine	S			X	N
Common greenbrier	*Smilax rotundifolia*	Vine	I			X	N
Horse-nettle	*Solanum carolinense*	Herb	I	X			N
Canada goldenrod	*Solidago canadensis*	Herb	C	X			N
Goldenrod[3]	*Solidago sp.*	Herb	I	X			N

Table 7-1 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Johnson grass	*Sorghum halapense*	Grass	I	X			E-Europe
Common chickweed	*Stellaria media*	Herb	S	X			E-Eurasia
Coralberry	*Symphoricarpos orbiculatus*	Shrub	I	X	X	X	N
Common dandylion	*Taraxacum officinale*	Herb	I	X			E-Europe
Poison ivy	*Toxicodendron radicans*	Vine	S	X	X	X	N
Purpletop	*Tridens flavus*	Grass	F	X			N
Red clover	*Trifolium pratense*	Herb	I	X			E-Europe
White clover	*Trifolium repens*	Herb	S	X			E-Europe
Winged elm	*Ulmus alata*	Tree	S			X	N
American elm	*Ulmus americana*	Tree	I		X	X	N
Slippery elm	*Ulmus rubra*	Tree	S			X	N
Common mullein	*Verbascum thapsus*	Herb	S	X			E-Europe
Tall ironweed	*Vernonia gigantea*	Herb	I	X			N
Cocklebur	*Xanthium strumarium*	Herb	S	X			E-Europe

1. Abundance Categories based on frequency and coverage.
   - R = Rare: 1 or 2 locales, small populations
   - S = Scarce: several locales, or scattered small populations
   - I = Infrequent: scattered locales throughout
   - O = Occasional: well distributed but not anywhere abundant
   - F = Frequent: generally encountered
   - C = Common: characteristic and dominant

2. N = Native
   E = Exotic

3. Tentative identification based on sterile material. Other grass species of note are the Eurasian yellow foxtail and the indigenous silver plume grass.

Table 7-2
Floristic Occurrence Summary
Caldwell Lace and Leather Disposal Site
Auburn, Kentucky

	Total	Percent of Site-Wide Occurrence	Percent of Community Occurrence
Cumulative Site-Wide Occurence			
Species	128	100.0	NA
Genera	95	100.0	NA
Woody	59	46.1	NA
Herbs[1]	69	53.9	NA
Grasses	12	9.4	NA
Ferns	2	1.6	NA
Exotics	29	22.7	NA
Grassland-Pasture Community			
Species	72	56.3	100.0
Genera	63	66.3	100.0
Woody	10	7.8	13.9
Herbs[1]	62	48.4	86.1
Grasses	12	9.4	16.7
Ferns	0	0.0	0.0
Exotics	26	20.3	36.1
Scrub-Shrub Community			
Species	35	27.3	100.0
Genera	30	31.6	100.0
Woody	27	21.1	77.1
Herbs[1]	8	6.3	22.9
Grasses	2	1.6	5.7
Ferns	0	0.0	0.0
Exotics	3	2.3	8.6

Table 7-2 (Continued)
Floristic Occurrence Summary
Caldwell Lace and Leather Disposal Site
Auburn, Kentucky

	Total	Percent of Site-Wide Occurrence	Percent of Community Occurrence
Woodland Border Community			
Species	68	53.1	100.0
Genera	44	46.3	100.0
Woody	58	45.3	85.3
Herbs[1]	10	7.8	14.7
Grasses	0	0.0	0.0
Ferns	2	1.6	2.9
Exotics	4	3.1	5.9

1. Herb category includes grasses and ferns.

Table 7-3
Game Species of the Caldwell Lace and Leather Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Site Occurrence			Comments
		Grassland Pasture	Scrub-Shrub	Woodland Border	
Game Mammals					
Whitetail deer	*Odocoileus virginianus*	X	X	X	Bedding sites occasional in grassland area of Tract 1. Antler rubbings, droppings and tracks found site-wide.
Raccoon	*Procyon lotor*			X	Droppings containing persimmon seeds found in sinkhole depression near northwest end of Tract 1. (Tracts also evident at Mossy Spring - Site 8B.)
Eastern gray squirrel	*Sciurus carolinensis*			X	Numerous individuals spotted throughout woodland areas. Observed one animal feeding on post oak acorns.
Eastern cottontail rabbit	*Sylvilagus floridanus*	X	X		Droppings and tracks found primarily in grassland areas.
Game Birds					
Northern bob-white	*Colinus virginianus*	X			Observed one large resident covey of approximately 20 birds on Tract 2.
American woodcock	*Scolopax minor*			X	Flushed two birds from moist wooded ravine adjacent to south side of Tract 1.
Mourning dove	*Zenaidura macroura*	X		X	A small flock of 8-10 birds found roosting in red cedars adjacent to Tract 1.

Table 7-4
Common Birds of the Caldwell Lace and Leather Disposal Site
Auburn, Kentucky
November 12, 1992

Common Name	Scientific Name	Site Occurrence		
		Grassland-Pasture	Scrub-Shrub	Woodland Border
Cooper's hawk	*Accipiter cooperii*		X	X
Red-tailed hawk[1]	*Buteo jamaicensis*			
Northern cardinal	*Cardinalis cardinalis*		X	X
American goldfinch	*Carduelis tristus*		X	
Turkey vulture[1]	*Cathartes aura*			
Northern bob-white	*Colinus virginianus*	X		
American crow	*Corvus brachyrhynchos*		X	X
Blue jay	*Cyanocitta cristata*		X	X
American kestrel	*Falco sparverius*	X	X	
Loggerhead shrike	*Lanius ludovicianus*	X		
Song sparrow	*Melospiza melodia*		X	
Northern mockingbird	*Mimus polyglottos*	X	X	X
Carolina chickadee	*Parus carolinensis*		X	X
Tufted titmouse	*Parus bicolor*		X	
House sparrow	*Passer domesticus*	X		
Hairy woodpecker	*Picoides villosus*			X
Golden-crowned kinglet	*Regulus satrapa*		X	
American woodcock	*Scolopax minor*			X
Eastern bluebird	*Sialis sialis*	X		
White-breasted nuthatch	*Sitta carolinensis*			X
European starling[1]	*Sturnus vulgaris*			
Carolina wren	*Thryothorus ludovicianus*		X	
Brown thrasher	*Toxostoma rufum*		X	X

Table 7-4 (Continued) Common Birds of the Caldwell Lace and Leather Disposal Site Auburn, Kentucky November 12, 1992				
Common Name	Scientific Name	Site Occurrence		
		Grassland-Pasture	Scrub-Shrub	Woodland Border
American robin	*Turdus migratorius*	X	X	X
Mourning dove	*Zenaidura macroura*	X		X
White-throated sparrow	*Zonotrichia albicollis*	X	X	

1. Observed flying overhead and therefore not directly associated with the site.

Table 7-5
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Three-seeded mercury	*Acalypha rhomboidea*	Herb	S	X			N
Boxelder	*Acer negundo*	Tree	S	X	X	X	N
Sugar maple	*Acer saccharum*	Tree	R			X	N
Redtop	*Agrostis stolonifera*	Grass	I	X			E-Europe
Mimosa	*Albizzia julibrissin*	Tree	VR	X			E-Asia
Field garlic	*Allium vineale*	Herb	O	X		X	E-Europe
Spiny amaranth	*Amaranthus spinosus*	Herb	S	X			?
Common ragweed	*Ambrosia artemisiifolia*	Herb	I	X	X		N
Giant ragweed	*Ambrosia trifida*	Herb	S	X			N
Scarlet pimpernel	*Anagallis arvensis*	Herb	VR	X			E-Europe
Broomsedge	*Andropogon virginicus*	Grass	C	X	X		N
Wood anemone	*Anemone quinquefolia*	Herb	R		X	X	N
Thimbleweed	*Anemone virginiana*	Herb	R			X	N
Indian-hemp	*Apocynum cannibinum*	Herb	S	X			N
Devil's walkingstick	*Aralia spinosa*	Tree	R			X	N
Green dragon	*Arisaema dracontium*	Herb	VR				N
Jack-in-the-pulpit	*Arisaema triphyllum*	Herb	S			X	N

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Common milkweed	*Asclepias syriaca*	Herb	I	S			N-in part
Paw paw	*Asimina triloba*	Tree	S			X	N
Ebony spleenwort	*Asplenium platyneuron*	Fern	S			X	N
Calico aster[3]	*Aster lateriflorus*	Herb	S	X			N
Downy aster	*Aster pilosus*	Herb	S	X			N
False foxglove	*Aureolaria virginica*	Herb	R			X	N
Spanish needles	*Bidens bipinnata*	Herb	S	X			N
Beggar's ticks	*Bidens frondosa*	Herb	S	X	X		N
Rattlesnake fern	*Botrychium virginianum*	Fern	R			X	N
Common brome grass	*Bromus commutatus*	Grass	S	X	X		E-Europe
Trumpet creeper	*Campsis radicans*	Vine	I	X	X	X	N
Nodding thistle	*Carduus nutans*	Herb	I	X			E-Europe
Head-bearing sedge	*Carex cephalophora*	Herb	S	X			N
Flat sedge	*Carex complanata*	Herb	R	X			N
Bitternut hickory	*Carya cordiformis*	Tree	S			X	N
Pignut hickory	*Carya glabra*	Tree	I			X	N
Red hickory	*Carya ovalis*	Tree	S			X	N

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Mockernut hickory	*Carya tomentosa*	Tree	O		X	X	N
Wild senna	*Cassia marilandica*	Herb	S	X			N
Wild sensitive plant	*Cassia nictitans*	Herb	S	X			N
Hackberry	*Celtis occidentalis*	Tree	I		X	X	N
Mouse-ear chickweed	*Cerastium glomeratum*	Herb	O	X	X	X	E-Europe
Eastern redbud	*Cercis canadensis*	Tree	S		X	X	N
Milk-purslane	*Chamaesyce maculata*	Herb	S	X			N
Nodding spurge	*Chamaesyce nutans*	Herb	R	X			N
Lamb's quarters	*Chenopodium album*	Herb	I	X			E-Europe
Spotted wintergreen	*Chimaphila maculata*	Herb	S			X	N
Chickory	*Cichorium intybus*	Herb	S	X			E-Europe
Enchanter's nightshade	*Circaea lutetiana*	Herb	O			X	N
Field thistle	*Cirsium discolor*	Herb	I	X			
Virgin's-bower	*Clematis virginiana*	Vine	R			X	N
Indian squawroot	*Conopholis americana*	Herb	R			X	N
Field bindweed	*Convolvulus arvensis*	Vine	I	X			E-Europe
Horseweed	*Conyza canadensis*	Herb	I	X			N

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Tall coreopsis	*Coreopsis tripteris*	Herb	I	X			N
Roughleaf dogwood	*Cornus drummondii*	Shrub	VR	X			N
Flowering dogwood	*Cornus florida*	Tree	O		X	X	N
Panicled dogwood[3]	*Cornus racemosa*	Shrub	S		X	X	N
American hazel	*Corylus americana*	Shrub	S			X	N
Rattlebox	*Crotalaria sagittalis*	Herb	VR	X			N
Prairie-tea	*Croton monanthogynus*	Herb	S	X			N
Dodder[3]	*Cuscuta gronovii*	Vine	R	X			N
Bermuda grass	*Cynodon dactylon*	Grass	S	X			E-Europe
Wild comfrey	*Cynoglossum virginianum*	Herb	VR			X	N
Umbrella sedge[3]	*Cyperus strigosus*	Herb	S	X			N
Orchard grass	*Dactylis glomerata*	Grass	F	X			E-Europe (planted)
Queen Anne's lace	*Daucus carota*	Herb	O	X			E-Europe
Tick-trefoil	*Desmodium nudiflorum*	Herb	I			X	N
Woolly panic grass	*Dichanthelium acuminatum*	Grass	S	X			N
Bosc's panic grass	*Dichanthelium boscii*	Grass	S			X	N
Panic grass	*Dichanthelium commutatum*	Grass	S		X	X	N

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[2]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[3]
Round fruited panic grass	*Dichanthelium sphaerocarpon*	Grass	R	X			N
Buttonweed	*Diodia teres*	Herb	S	X			N
Wild yam	*Dioscorea villosa*	Vine	R			X	N
Persimmon	*Diospyros virginiana*	Tree	I	X	X	X	N
Carolina tobaccoweed	*Elephantopus carolinianus*	Herb	VR			X	N
Virginia wild rye	*Elymus virginicus*	Grass	R	X			N
Fringed love grass	*Eragrostis pectinacea*	Grass	VR	X			N
Silver plume grass	*Erianthus alopecuroides*	Grass	O	X			N
White-top fleabane	*Erigeron strigosus*	Herb	S	X			N
Tall thoroughwort	*Eupatorium altissimum*	Herb	O	X			N
White snakeroot	*Eupatorium rugosum*	Herb	S			X	N
Flat-topped goldenrod	*Euthamia graminifolia*	Herb	S	X			N
Meadow fescue	*Festuca arundinacea*	Grass	F	X			E-Eurasia (planted)
Woodland fescue	*Festuca obtusa*	Grass	VR			X	N
White ash	*Fraxinus americana*	Tree	R			X	N
Bedstraw	*Galium aparine*	Herb	S	X		X	N
Wild-licorice	*Galium circaezans*	Herb	R			X	N

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Hairy bedstraw	*Galium pilosum*	Herb	S		X	X	N
Fragrant bedstraw	*Galium triflorum*	Herb	O			X	N
Carolina cranesbill	*Geranium carolinianum*	Herb	S	X			N
White avens	*Geum canadense*	Herb	O			X	N
Spring avens	*Geum vernum*	Herb	S			X	N
Honeylocust	*Gleditsia triacanthos*	Tree	S	X	X	X	N
Purple cudweed	*Gnapthalium purpureum*	Herb	S	X			N
Pale-leaved sunflower[3]	*Helianthus strumosus*	Herb	I	X			N
Shrubby St. John's-wort	*Hypericum prolificum*	Shrub	R			X	N
Dotted St. John's-wort	*Hypericum punctatum*	Herb	R	X	X		N
St. Andrew's cross	*Hypericum stragulum*	Herb	S	X			N
Touch-me-not[3]	*Impatiens capensis*	Herb	R	X			N
Wild potato vine	*Ipomea pandurata*	Vine	I	X			N
Black walnut	*Juglans nigra*	Tree	S			X	N
One-sided rush	*Juncus secundus*	Herb	VR	X			N
Path rush	*Juncus tenuis*	Herb	O	X	X	X	N
Eastern redcedar	*Juniperus virginiana*	Tree	O	X	X	X	N

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			Native/Exotic[2]
				Grassland Pasture	Scrub Shrub	Woodland Border	
Japanese-clover	*Kummerowia striata*	Herb	F	X			E-Asia
Wild lettuce	*Lactuca canadensis*	Herb	R	X			N
Woodland blue lettuce	*Lactuca floridana*	Herb	S	X			N
Prickly lettuce	*Lactuca serriola*	Herb	I	X			E-Europe
Poor man's pepper	*Lepidium virginicum*	Herb	R	X			N
Sericea lespedeza	*Lespedeza cuneata*	Herb	O	X	X		E-Asia (planted)
Hairy bush-clover	*Lespedeza hirta*	Sub-shrub	S	X			N
Ox-eye daisy	*Leucanthemum vulgare*	Herb	S	X			E-Europe
Spicebush	*Lindera benzoin*	Shrub	S			X	N
Common yellow flax	*Linum medium*	Herb	S	X			N
Lily-leaved twayblade	*Liparis lilifolia*	Herb	VR			X	N
Sweetgum	*Liquidambar styraciflua*	Tree	I		X	X	N
Yellow-poplar	*Liriodendron tulipifera*	Tree	O		X	X	N
Japanese honeysuckle	*Lonicera japonica*	Vine	F		X	X	E-Asia
Black medic	*Medicago lupulina*	Herb	S	X			E-Europe
White sweet clover	*Melilotus alba*	Herb	I	X			E-Europe

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Yellow sweet clover	*Melilotus officinalis*	Herb	S	X			E-Europe
White mulberry	*Morus alba*	Tree	S			X	E-Asia
Red mulberry	*Morus rubra*	Tree	R			X	N
Blackgum	*Nyssa sylvatica*	Tree	O		X	X	N
Evening primrose	*Oenothera biennis*	Herb	S	X			N
Eastern hophornbeam	*Ostrya virginiana*	Tree	R			X	N
Yellow sorrell	*Oxalis dillenii*	Herb	S	X			N
Fall panic grass	*Panicum dichotomiflorum*	Grass	S	X			N
Virginia creeper	*Parthenocissus quinquefolia*	Vine	S			X	N
Passion flower	*Passiflora incarnata*	Vine	S	X			N
Yellow passion-flower	*Passiflora lutea*	Vine	R			X	N
Beefsteak plant	*Perilla frutescens*	Herb	I	X			E-Asia
Lopseed	*Phryma leptostachya*	Herb	S			X	N
Pokeweed	*Phytolacca americana*	Herb	I	X			N
Clearweed	*Pilea pumila*	Herb	I			X	N
Bracted plantain	*Plantago aristata*	Herb	O	X			N
English plantain	*Plantago lanceolata*	Herb	O	X			E-Europe

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Broad-leaved plantain	*Plantago rugelii*	Herb	O	X			N
Sycamore	*Platanus occidentalis*	Tree	S			X	N
Kentucky bluegrass	*Poa pratensis*	Grass	I	X			E-Europe (planted)
May-apple	*Podophyllum peltatum*	Herb	O			X	N
Bird knotweed	*Polygonum aviculare*	Herb	O	X			N
Lady's thumbprint	*Polygonum persicaria*	Herb	S	X			E-Europe
Christmas fern	*Polystichum acrostichoides*	Fern	I			X	N
Eastern cottonwood	*Populus deltoides*	Tree	R			X	N
Common cinquefoil	*Potentilla simplex*	Herb	I	X	X		N
Peach	*Prunus persica*	Tree	R			X	E-Asia
Black cherry	*Prunus serotina*	Tree	O	X	X	X	N
Bracken fern	*Pteridium aquilinum*	Fern	VR	X			N
Mountain mint[3]	*Pycnanthemum sp.*	Herb	R	X			N
False dandelion	*Pyrrhopappus carolinianus*	Herb	S	X			N
White oak	*Quercus alba*	Tree	O			X	N
Scarlet oak	*Quercus coccinea*	Tree	I			X	N
Southern red oak	*Quercus falcata*	Tree	F		X	X	N

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Shingle oak	*Quercus imbricaria*	Tree	S			X	N
Chinkapin oak	*Quercus muhlenbergii*	Tree	I			X	N
Northern red oak	*Quercus rubra*	Tree	I		X	X	N
Shumard oak	*Quercus shumardii*	Tree	I		X	X	N
Post oak	*Quercus stellata*	Tree	O		X	X	N
Black oak	*Quercus velutina*	Tree	S			X	N
Carolina buckthorn	*Rhamnus caroliniana*	Tree	S			X	N
Fragrant sumac	*Rhus aromatica*	Shrub	R			X	N
Winged sumac	*Rhus copallina*	Shrub	S	X	X	X	N
Smooth sumac	*Rhus glabra*	Shrub	I	X	X	X	N
Carolina rose	*Rosa carolina*	Shrub	R			X	N
Multiflora rose	*Rosa multiflora*	Shrub	R			X	E-E. Asia
Prairie rose	*Rosa setigera*	Shrub	S		X	X	N
Hairy blackberry[3]	*Rubus allegheniensis*	Herb	O		X		N
Northern dewberry	*Rubus flagellaris*	Herb	S	X	X		N
Black raspberry	*Rubus occidentalis*	Herb	S		X		N
Black-eyed susan	*Rudbeckia hirta*	Herb	S	X			?

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Sheep sorrel	*Rumex acetosella*	Herb	S	X			E-Europe
Curly dock	*Rumex crispus*	Herb	S	X			E-Europe
Rose-pink	*Sabatia angularis*	Herb	VR	X			N
Black willow	*Salix nigra*	Tree	VR		X		N
Canada black snakeroot	*Sanicula canadensis*	Herb	O	X	X	X	N
Sassafras	*Sassafras albidum*	Tree	F		X	X	N
Green bulrush	*Scirpus atrovirens*	Herb	R	X			N
Chinese foxtail grass	*Setaria faberi*	Grass	I	X			E-Asia
Yellow foxtail grass	*Setaria glauca*	Grass	O	X			E-Eurasia
Virginia rock cress	*Sibara virginica*	Herb	S	X			N
False Solomon's-seal	*Smilacina racemosa*	Herb	I			X	N
Catbrier	*Smilax bona-nox*	Vine	S		X	X	N
Carrion flower	*Smilax ecirrhata*	Herb	R			X	N
Sawbrier	*Smilax glauca*	Vine	I			X	N
Bristly greenbrier	*Smilax hispida*	Vine	S			X	N
Common greenbrier	*Smilax rotundifolia*	Vine	I			X	N
Horse-nettle	*Solanum carolinense*	Herb	I	X			N

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Canada goldenrod	*Solidago canadensis*	Herb	C	X			N
Licorice goldenrod	*Solidago odora*	Herb	I	X			N
Johnson grass	*Sorghum halapense*	Grass	I	X			E-Europe
Rough dropseed	*Sporobolus asper*	Grass	VR	X			N
Common chickweed	*Stellaria media*	Herb	S	X			E-Eurasia
Pencil flower	*Stylosanthes biflora*	Herb	R	X			N
Coralberry	*Symphoricarpos orbiculatus*	Shrub	I	X	X	X	N
Common dandylion	*Taraxacum officinale*	Herb	O	X			E-Europe
Crane-fly orchid	*Tipularia discolor*	Herb	VR			X	N
Poison ivy	*Toxicodendron radicans*	Vine	S	X	X	X	N
Purpletop	*Tridens flavus*	Grass	F	X			N
Low hop-clover	*Trifolium campestre*	Herb	S	X			E-Europe
Red clover	*Trifolium pratense*	Herb	I	X			E-Europe
White clover	*Trifolium repens*	Herb	F	X			E-Europe
Sessile toadshade[3]	*Trillium sessile*	Herb	VR			X	N
Winged elm	*Ulmus alata*	Tree	S			X	N
American elm	*Ulmus americana*	Tree	I		X	X	N

Table 7-5 (Continued)
Flora of the Caldwell Lace and Leather Waste Disposal Site
Auburn, Kentucky

Common Name	Scientific Name	Life Form	Overall Abundance[1]	Site Occurrence			
				Grassland Pasture	Scrub Shrub	Woodland Border	Native/Exotic[2]
Slippery elm	*Ulmus rubra*	Tree	S			X	N
Corn-salad	*Valerianella radiata*	Herb	VR	X			N
Common mullein	*Verbascum thapsus*	Herb	S	X			E-Europe
Narrow-leaved vervain	*Verbena simplex*	Herb	S	X			N
White vervain	*Verbena urticifolia*	Herb	S	X		X	N
Yellow wingstem[3]	*Verbesina alternifolia*	Herb	S			X	N
Tall ironweed	*Vernonia gigantea*	Herb	I	X			N
Rusty blackhaw	*Viburnum rufidulum*	Shrub	VR			X	N
Hairy vetch	*Vicia villosa*	Herb	R	X			E-Europe
Cocklebur	*Xanthium strumarium*	Herb	S	X			E-Europe

1. Abundance Categories based on frequency and coverage.
   - R = Rare: 1 or 2 locales, small populations
   - S = Scarce: several locales, or scattered small populations
   - I = Infrequent: scattered locales throughout
   - O = Occasional: well distributed but not anywhere abundant
   - F = Frequent: generally encountered
   - C = Common: characteristic and dominant
2. N = Native
   - E = Exotic
   - ? = Species may be native in part, origin unknown
3. Tentative identification based on sterile material.

Table 7-6
Floristic Occurrence Summary
Caldwell Lace and Leather Disposal Site
Auburn, Kentucky

	Total	Percent of Site-Wide Occurrence	Percent of Community Occurrence
Cumulative Site-Wide Occurence			
Species	213	100.0	NA
Genera	151	100.0	NA
Woody	64	30.0	NA
Herbs[1]	149	70.0	NA
Grasses	21	9.9	NA
Ferns	4	1.9	NA
Exotics	42	19.7	NA
Grassland-Pasture Community			
Species	128	60.1	100.0
Genera	102	67.5	100.0
Woody	13	6.1	10.2
Herbs[1]	115	54.0	89.8
Grasses	18	8.5	14.1
Ferns	1	0.5	0.8
Exotics	38	17.8	29.7
Scrub-Shrub Community			
Species	45	21.1	100.0
Genera	38	25.2	100.0
Woody	28	13.1	62.2
Herbs[1]	17	8.0	37.8
Grasses	3	1.4	6.7
Ferns	0	0.0	0.0
Exotics	4	1.9	8.9

Table 7-6 (Continued)
Floristic Occurrence Summary
Caldwell Lace and Leather Disposal Site
Auburn, Kentucky

	Total	Percent of Site-Wide Occurrence	Percent of Community Occurrence
Woodland Border Community			
Species	100	46.9	100.0
Genera	69	45.7	100.0
Woody	61	28.6	61.0
Herbs[1]	39	18.3	39.0
Grasses	3	1.4	3.0
Ferns	3	1.4	3.0
Exotics	6	2.8	6.0

1. Herb category includes all non-woody forbs, grasses, sedges, rushes, and ferns.

NA = Not Applicable

Table 7-7
Birds Observed on the Caldwell Lace and Leather Site
Auburn, Kentucky, June 30 and July 1, 1993

Common Name	Overall Abundance[1]	Site Occurrence		
		Grassland Pasture	Scrub Shrub	Woodland Border
Barn swallow[2]	C	X	X	
Carolina wren	O		X	X
Eastern kingbird	O	X		
Willow flycatcher	R		X	
Turkey vulture[2]	O	X	X	X
Rufous-sided towhee	C		X	X
Blue jay	C		X	X
White-eyed vireo	O		X	
Yellow breasted chat	O		X	
Common yellowthroat	R		X	
Prairie warbler	R		X	X
Yellow-billed cuckoo	O			X
House finch	C	X	X	
Indigo bunting	C		X	X
American goldfinch	C		X	
Field sparrow	C	X	X	
Chipping sparrow	O			X
Song sparrow	C	X	X	
Northern cardinal	C		X	X

[1]Overall abundance categories based on the following:
R=Rare: 1 or 2 individuals seen or heard
O=Occasional: More than 2 but less than 5 individuals seen or heard
C=Common: More than 5 individuals seen or heard

[2]Observed flying over site and therefore association with site is unknown.

Table 7-8
Common Mammals Known or Likely to Occur on or in the Vicinity of the Caldwell Site and the Off-Site Springs[1,2]

Common Name	Scientific Name	Typical Habitat
Opossum	*Didelphis marsupialis*	Forest edge and along woodland streams and ponds
Short-tailed shrew	*Blarina brevicauda*	Moist forest, brushland, brushy fencerows, weedfields, dense pastures
Least shrew	*Cryptotis parva*	Grasslands, fields, fence rows having dense cover of ungrazed bluegrass
Eastern mole	*Scalopus aquaticus*	Sandy soils of floodplains and streambanks, meadows, pastures, gardens, lawns, and woodlands
Eastern cottontail	*Sylvilagus floridanus*	Wide-ranging, from grasslands to thickets to deep woods and swamps
Eastern chipmunk	*Tamias striatus*	Deciduous forests, brushy areas
Woodchuck	*Marmota monax*	Forest edge, fence rows, roadsides
Eastern gray squirrel	*Sciurus carolinensis*	Hardwood forests, river bottoms
Fox squirrel	*Sciurus niger*	Open country, with scattered oak, hickory and walnut trees
Southern flying squirrel	*Glaucomys volans*	Woodlots and forests of deciduous or mixed deciduous-coniferous forests
Deer mouse	*Peromyscus maniculatus*	Wide-ranging, nearly all dry-land habitats
White-footed mouse	*Peromyscus leucopus*	Wooded or brushy areas preferred; sometimes open areas
Muskrat	*Ondatra zibethicus*	Aquatic areas
House mouse	*Mus musculus*	Houses, weed fields, and brushland
Red fox	*Vulpes vulpes*	Farmlands and other open areas
Gray fox	*Urocyon cinereoargenteus*	Hardwood forests, wooded or brushy hilly terrain
Raccoon	*Procyon lotor*	Woodlands, brushland, farmland, and other habitats

Table 7-8 (Continued)
Common Mammals Known or Likely to Occur on or in the Vicinity of the Caldwell Site and the Off-Site Springs[1,2]

Common Name	Scientific Name	Typical Habitat
Long-tailed weasel	*Mustela frenata*	Forest edge, brushland, fencerows and streambanks
Mink	*Mustela vison*	Riparian areas of streams and lakes
Striped skunk	*Mephitis mephitis*	Farmland, brushland, woodland edge, open woods, weedy fields, rocky areas, cliffs and small caves
White-tailed deer	*Odocoileus virginianus*	Second growth woodland, forest edge, brushland, open forest

[1]Exclusive of the order *Chiroptera* (bats).

[2]Sources: *Mammals of Kentucky* by Roger W. Barbour and Wayne Davis, University of Kentucky; and *A Field Guide to the Mammals, North America North of Mexico*, by William H. Burt and Richard P. Grossenheider, Houghton Mifflin Company.

Table 7-9
Mammals Known or Likely to Occur on the Caldwell Lace and Leather Disposal Site

Common Name	Presumed Site Occurrence*		
	Grassland Pasture	Scrub Shrub	Woodland Border
Opossum	L	L	L
Short-tailed shrew	U	L	C
Least shrew	L	L	U
Eastern mole	L	U	L
Eastern cottontail	L	L	L
Eastern chipmunk	U	L	L
Woodchuck	C	L	L
Eastern grey squirrel	U	U	C
Fox squirrel	U	U	L
Southern flying squirrel	U	U	L
Deer mouse	L	L	L
White-footed mouse	U	L	L
House mouse	L	L	U
Red fox	L	L	L
Gray fox	L	L	L

Table 7-9 (Continued)
Mammals Known or Likely to Occur on the
Caldwell Lace and Leather Disposal Site

Common Name	Presumed Site Occurrence*		
	Grassland Pasture	Scrub Shrub	Woodland Border
Racoon	L	L	L
Long-tailed weasel	U	L	L
Striped skunk	L	L	L
White-tailed deer	C	C	C

*Presumed occurrence based on species habitat preference and occurrence of that habitat on the Caldwell Lace and Leather Site

L=Likely

U=Unlikely

C=Confirmed via sign or actual sighting of animal.

Table 7-10
Flora of Off-Site Springs and Seeps
Caldwell Lace Leather Site

Common Name	Scientific Name	Life Form	Site Occurrence							
			Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
Three-seeded mercury	*Acalypha rhomboidea*	Herb			X	X				X
Red maple	*Acer rubrum*	Tree		X						
Sugar maple	*Acer saccharum*	Tree							X	X
Small-flowered agrimony	*Agrimonia parviflora*	Herb						X		
Hairy agrimony	*Agrimonia pubescens*	Herb					X	X		
Redtop	*Agrostis stolonifera*	Grass			X	X				
Water-plantain	*Alisma plantago-aquatica*	Herb			X					
Stream alder	*Alnus serrulata*	Shrub		X						
Giant ragweed	*Ambrosia trifida*	Herb			X					X
Green dragon	*Arisaema dracontium*	Herb					X	X		
Jack-in-the-pulpit	*Arisaema triphyllum*	Herb					X	X		
River cane	*Arundinaria gigantea*	Grass								X
Butterfly weed	*Asclepias tuberosa*	Herb			X					
Ebony spleenwort	*Asplenium platyneuron*	Fern	X							X
Heart-leaved aster[1]	*Aster cordifolius*	Herb					X			X

Table 7-10 (Continued)
Flora of Off-Site Springs and Seeps
Caldwell Lace Leather Site

Common Name	Scientific Name	Life Form	Site Occurrence							
			Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
Water-hyssop	*Bacopa rotundifolia*	Herb								X
Beggar's ticks	*Bidens frondosa*	Herb			X					
False nettle	*Boehmeria cylindrica*	Herb		X						X
Sparse-lobed grape fern	*Botrychium biternatum*	Fern		X						
Trumpet creeper	*Campsis radicans*	Vine	X							
Brown sedge	*Carex brunnescens*	Herb		X						
Frank's sedge	*Carex frankii*	Herb			X					
Sallow sedge	*Carex lurida*	Herb		X						
Fox sedge	*Carex vulpinoidea*	Herb			X					
Bitternut hickory	*Carya cordiformis*	Tree	X							
Hackberry	*Celtis occidentalis*	Tree	X				X	X		X
Eastern redbud	*Cercis canadensis*	Tree	X							
Lamb's quarters	*Chenopodium album*	Herb								X
Enchanter's nightshade	*Circaea lutetiana*	Herb						X		
Virgin's bower	*Clematis virginiana*	Vine					X	X		
Poison-hemlock	*Conium maculatum*	Herb			X	X	X			

Table 7-10 (Continued)
Flora of Off-Site Springs and Seeps
Caldwell Lace Leather Site

Common Name	Scientific Name	Life Form	Site Occurrence							
			Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
Roughleaf dogwood	*Cornus drummondii*	Shrub				X				
Flowering dogwood	*Cornus florida*	Tree		X					X	
Panicled dogwood	*Cornus racemosa*	Shrub					X	X		
Honewort	*Cryptotaenia canadensis*	Herb	X							
Orchard grass	*Dactylis glomerata*	Grass			X					
Queen Anne's lace	*Daucus carota*	Herb			X	X				X
Hayscented fern	*Dennstaedtia punctilobula*	Fern								X
Woolly panic grass	*Dichanthelium acuminatum*	Grass	X	X						
Wild yam	*Dioscorea villosa*	Vine		X						
Persimmon	*Diospyros virginiana*	Tree				X		X		
Engelmann's spikerush	*Eleocharis engelmanni*	Herb	X							
Creeping spikerush	*Eleocharis erythropoda*	Herb			X					
Blunt spikerush	*Eleocharis obtusa*	Herb		X						
Virginia wild rye	*Elymus virginicus*	Grass	X				X	X	X	X
Philadelphia fleabane	*Erigeron philadelphicus*	Herb								X
Meadow fescue	*Festuca arundinacea*	Grass			X	X				

Table 7-10 (Continued)
Flora of Off-Site Springs and Seeps
Caldwell Lace Leather Site

Common Name	Scientific Name	Life Form	Site Occurrence							
			Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
White ash	*Fraxinus americana*	Tree	X				X	X		
Green ash	*Fraxinus pennsylvanica*	Tree						X		
Bedstraw	*Galium aparine*	Herb	X							X
White avens	*Geum canadense*	Herb		X				X	X	X
Spring avens	*Geum vernum*	Herb								X
Honeylocust	*Gleditsia triacanthos*	Tree						X		
Hedge-hyssop	*Gratiola visicidula*	Herb			X					
Velvet grass	*Holcus lanatus*	Grass		X						
Bigleaf waterleaf	*Hydrophyllum macrophyllum*	Herb					X			
Dwarf St. John's-wort	*Hypericum mutilum*	Herb			X					
Bottlebrush grass	*Hystrix patula*	Grass					X		X	X
Touch-me-not	*Impatiens capensis*	Herb		X			X	X		
Black walnut	*Juglans nigra*	Tree	X				X	X		X
Path rush	*Juncus tenuis*	Herb								X
Eastern redcedar	*Juniperus virginiana*	Tree		X					X	X
Prickly lettuce	*Lactuca serriola*	Herb			X					

Table 7-10 (Continued)
Flora of Off-Site Springs and Seeps
Caldwell Lace Leather Site

Common Name	Scientific Name	Life Form	Site Occurrence							
			Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
White grass	*Leersia virginica*	Grass		X			X	X	X	X
Sericea lespedeza	*Lespedeza cuneata*	Herb			X					
Ox-eye daisy	*Leucanthemum vulgare*	Herb								X
Spicebush	*Lindera benzoin*	Shrub	X				X	X		X
Yellow-poplar	*Liriodendron tulipifera*	Tree		X						
Japanese honeysuckle	*Lonicera japonica*	Vine		X		X	X	X	X	
Virgina bugle-weed	*Lycopus virginicus*	Herb			X					
Moneywort	*Lysimachia nummularia*	Herb			X					
Winged loosestrife	*Lythrum alatum*	Herb			X					
Moonseed	*Menispermum canadense*	Vine					X			
Japanese grass	*Microstegium vimineum*	Grass		X						X
Red mulberry	*Morus rubra*	Tree	X	X		X		X		X
Nimblewill	*Muhlenbergia schreberi*	Grass								X
Blackgum	*Nyssa sylvatica*	Tree		X						
Yellow sorrell	*Oxalis dillenii*	Herb								X
Cowbane	*Oxypolis rigidior*	Herb		X						

Table 7-10 (Continued)
Flora of Off-Site Springs and Seeps
Caldwell Lace Leather Site

Common Name	Scientific Name	Life Form	Site Occurrence							
			Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
Virginia creeper	*Parthenocissus quinquefolia*	Vine	X	X			X	X	X	X
Beefsteak plant	*Perilla frutescens*	Herb								X
Frogfruit	*Phyla lanceolata*	Herb			X					
Clearweed	*Pilea pumila*	Herb	X					X		X
Broad-leaved plantain	*Plantago rugelii*	Herb								X
Sycamore	*Platanus occidentalis*	Tree	X			X	X	X		X
Woodland bluegrass	*Poa sylvestris*	Grass						X	X	
River-weed[1]	*Podostemon ceratophyllum*	Herb				X				X
Bird knotweed	*Polygonum aviculare*	Herb								X
Lady's thumbprint	*Polygonum persicaria*	Herb			X					X
Christmas fern	*Polystichum acrostichoides*	Fern							X	
Cottonwood	*Populus deltoides*	Tree	X							
Common snailseed	*Potamogeton diversifolius*	Herb			X					
Black cherry	*Prunus serotina*	Tree		X		X		X	X	X
White oak	*Quercus alba*	Tree	X							X
Chinkapin oak	*Quercus muhlenbergii*	Tree	X				X			

Table 7-10 (Continued)
Flora of Off-Site Springs and Seeps
Caldwell Lace Leather Site

Common Name	Scientific Name	Life Form	Site Occurrence							
			Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
Northern red oak	*Quercus rubra*	Tree							X	
Smooth sumac	*Rhus glabra*	Shrub				X				
Multiflora rose	*Rosa multiflora*	Shrub		X		X				X
Hairy blackberry	*Rubus allegheniensis*	Herb				X				
Curly dock	*Rumex crispus*	Herb			X					
Elderberry	*Sambucus canadensis*	Shrub		X				X		
Water-pimpernel	*Samolus parviflorus*	Herb								X
Canada black snakeroot	*Sanicula canadensis*	Herb		X			X	X	X	X
Green bulrush	*Scirpus atrovirens*	Herb			X					
Lined bulrush	*Scirpus pendulus*	Herb			X					
Catbrier	*Smilax bona-nox*	Vine	X			X				
Carrion flower	*Smilax eccirhata*	Herb	X							
Sawbrier	*Smilax glauca*	Vine		X						
Horse-nettle	*Solanum carolinense*	Herb			X					
Canada goldenrod[1]	*Solidago canadensis*	Herb			X	X	X			
Bladder-nut	*Staphylea trifolia*	Shrub	X							

Table 7-10 (Continued)
Flora of Off-Site Springs and Seeps
Caldwell Lace Leather Site

Common Name	Scientific Name	Life Form	Site Occurrence							
			Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
Common chickweed	*Stellaria media*	Herb								X
Coralberry	*Symphoricarpos orbiculatus*	Shrub	X	X			X	X	X	X
Japanese hedge-parsley	*Torilis japonica*	Herb			X					
Poison ivy	*Toxicodendron radicans*	Vine	X	X		X	X	X	X	X
Cattail	*Typha latifolia*	Herb			X					
American elm	*Ulmus americana*	Tree		X			X	X	X	X
White vervain	*Verbena urticifolia*	Herb			X					
Yellow winstem[1]	*Verbesina alternifolia*	Herb					X	X		X
Water speedwell	*Veronica anagallis-aquatica*	Herb			X					
Common blue violet	*Viola sorroria*	Herb					X			X
Creamy violet[1]	*Viola striata*	Herb					X			
Fox grape	*Vitis vulpina*	Vine	X			X	X			
Cocklebur	*Xanthium strumarium*	Herb			X					

[1]Tentative identification based on sterile material.

Table 7-11
Floristic Occurrence Summary
Off-Site Springs and Seeps

	Cumulative Total	Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	Long South Fork Spring	Barnett-Karst Window	Mud River Spring
Species	125	26	30	33	18	31	31	17	48
Genera	106	24	29	31	18	29	28	17	46
Woody	40	18	16	0	11	15	18	10	14
Herbs[1]	85	8	14	33	7	16	13	7	34
Grasses	12	2	4	3	2	3	3	4	6
Ferns	4	1	1	0	0	0	0	1	2
Exotics	21	0	4	13	6	2	1	1	8

[1]Herb category includes all non-woody forbs, grasses, sedges, rushes, and ferns.

Table 7-12
Birds Observed at and in the Vicinity of the Off-site Springs near the Caldwell Lace and Leather Disposal Site
Auburn, Kentucky on June 30 and July 1, 1993

Bird	Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	Long South Fork Spring	Barnett Karst Window	Mud River Spring
Spotted sandpiper								X
Bobwhite		X						
Barn swallow		X	X	X	X	X		
Rough-winged swallow			X	X				
Purple martin							X	
Blue-gray gnatcatcher					X	X		
Carolina chickadee		X			X	X		
Carolina wren			X	X				X
Tufted titmouse					X	X		
Mourning dove			X	X	X	X		X
Eastern bluebird		X			X	X		
Robin	X	X			X	X		X
Mockingbird							X	X
Brown thrasher							X	
Eastern meadowlark		X	X	X			X	X

Table 7-12 (Continued)
Birds Observed at and in the Vicinity of the Off-site Springs near the Caldwell Lace and Leather Disposal Site
Auburn, Kentucky on June 30 and July 1, 1993

Bird	Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
Ruby-throated hummingbird					X	X		
Eastern kingbird					X	X		
Wood thrush	X							
Loggerhead shrike		X					X	
Starling							X	
Red-winged blackbird		X	X	X				
Downy woodpecker		X						
Killdeer		X						
Common crow		X						
Turkey vulture		X	X	X				
Blue jay	X							
Yellow-billed cuckoo								X
Summer tanager			X	X				X
Cowbird							X	
House finch							X	
Indigo bunting	X	X			X	X		

Table 7-12 (Continued)
Birds Observed at and in the Vicinity of the Off-site Springs near the Caldwell Lace and Leather Disposal Site
Auburn, Kentucky on June 30 and July 1, 1993

Bird	Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	8C Runoff	Barnett Karst Window	Mud River Spring
Blue grosbeak							X	
Field sparrow		X			X	X		
Grasshopper sparrow		X						
Northern cardinal	X							

Table 7-13
Mammals[1] Known or Likely to Occur on or in the Vicinity of the Off-Site Springs[2]
Caldwell Lace Leather

Mammal	Presumed Occurrence							
	Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	Long South Fork Spring	Barnett Window	Mud River Spring
Opossum	L	L	L	L	L	L	L	L
Short-tailed shrew	C	L	L	L	L	L	L	L
Least shrew	U	U	L	L	U	U	U	U
Eastern mole	L	U	L	L	U	U	U	U
Eastern cottontail	L	L	L	L	L	L	L	L
Eastern chipmunk	L	L	U	U	L	L	L	L
Woodchuck	L	L	L	L	L	L	C	L
Eastern gray squirrel	C	C	L	L	L	L	L	L
Fox squirrel	L	L	U	U	L	L	L	L
Southern flying squirrel	L	L	U	U	L	L	L	L
Deer mouse	L	L	L	L	L	L	L	L
White-footed mouse	L	L	L	L	L	L	L	L
Muskrat	U	U	U	U	U	U	U	L
House mouse	L	L	L	L	L	L	L	L
Red fox	L	L	L	L	L	L	L	L
Gray fox	L	L	L	L	L	L	L	L

Table 7-13 (Continued)
Mammals[1] Known or Likely to Occur on or in the Vicinity of the Off-Site Springs[2]
Caldwell Lace Leather

Mammal	Presumed Occurrence							
	Lagoon Spring	McPherson Spring	Duncan Tile Spring	Green Boiling Spring	Mossy Spring	Long South Fork Spring	Barnett Window	Mud River Spring
Racoon	L	L	L	L	L	L	L	L
Long-tailed weasel	L	L	L	L	L	L	L	L
Mink	U	U	U	U	L	U	U	L
Striped skunk	L	L	L	L	L	L	L	L
White-tailed deer	C	L	L	L	L	L	L	L

[1]Exclusive of the Order Chiroptera (bats).
[2]Presumed occurrence based on species' habitat preference and occurrence of that habitat at or in the vicinity of the spring site.
L=Likely
U=Unlikely
C=Confirmed via sign or actual sighting of animal.

Table 7-14
Caldwell Lace Leather
Ambient Water Chemistry Measurements
(for eight locations)
July 1993

Sampling Location	pH	Temp °C	O_2 mg/L	Conductivity μohm	Salinity $^o/_{oo}$	Alkalinity mg/L $CaCO_3$	Hardness mg/L $CaCO_3$
LAGOON SPRING	No water present at time of sampling						
LAGOON SPRING POND	7.0	26.4	4.95	50	0.0	17	16
GREEN BOILING SPRING	No water present at time of sampling						
DUNCAN TILE SPRING	7.3	25.5	19.8	386	0.2	*	*
MCPHERSON SPRING	5.5	18.2	2.50	66	0.0	*	*
MUD RIVER SPRING	7.4	14.1	7.82	466	0.2	178	204
LONG SOUTH FORK/RUNOFF	7.2	14.7	9.20	454	0.2	*	*
MOSSY SPRING	7.1	13.5	8.96	444	0.2	176	211

* = No sample collected

Table 7-15
Caldwell Lace Leather
MACROBENTHOS QUALITATIVE SAMPLE LIST
(five sample locations having standing or flowing water)
July 13-14, 1993

TAXON	LAGOON SPRING POND	DUNCAN TILE SPRING	RUNOFF SPRING	MOSSY SPRING	MUD RIVER SPRING	MCPHEARSON SPRING
Porifera						
Hydrozoa						
Platyhelmenthes						
Tubellaria		R				
Hirundinia						
Oligochaeta						
Isopoda			R	D	C	
Amphipoda				R	D	
Decapoda		C	C	R	C	C
Gastropoda	A	D	A	A	D	
Bivalvia						
Anisoptera	A	C				
Zygoptera	D	D				
Hemiptera	A	C		R		
Coleoptera	D	D	R	C	C	R
Lepidoptera						
Sialidae						
Corydalidae						
Tipulidae		R				
Empididae						
Simuliidae						
Tabanidae		R				
Culicidae						
Chironomidae	C	C	A	C	C	
Plecoptera				R		
Ephemeraoptera	R	R		R	C	
Tricoptera	R				D	
other	frogs				y	frogs

Relative Abundance: R = rare (< 3) C = Common (3 -9)
A = Abundant (>10) D = Dominant (> 50)

Table 7-16
Caldwell Lace Leather
Pollution Sensitive Aquatic Insects
(collected at springs)
July 1993

Sample Location	EPT Taxa			Comments
	Ephemeroptera	Plecoptera	Trichoptera	
Lagoon Spring				
Lagoon Spring Pond	Family: Baetidae (1) *Callibaetis sp.* Family: Caenidae (1) *Caenis sp.*		(1) Unidentified species	Inhabitants of slow moving water.
Green Boiling Spring				
Duncan Tile Spring	Family: Baetidae (1) Callbaetis sp.			Inhabitants of slow moving water.
McPherson Spring				
Mud River Spring	Family: Baetidae (4) *Baetis sp.*		Family: Brachycentridae (>50) *Micrasema sp.*	Inhabitants of cold water (<15°C)
Mossy Spring	Family: Baetidae (1) *Baetis sp.*	Family: Nemaouridae (1) *Amphinemura sp.*		Inhabitants of cold water (<15°C)
Runoff/Long South Fork Spring				

Table 7-17
Chironomids and other Dipteran Taxa Collected at Springs and Seeps
Caldwell Lace Leather Site

Site	Family	Genus	Number
Duncan Tile Spring	Tipulidae Chironomidae	*Pseudolimnophila* *Clintanypus*	1 3
Lagoon Spring Pond	Cauboridae	*Chauborus* *Procladius* *Chironomous*	1 1 2
Long South Fork/Runoff	Chironomidae	*Stictochironomous*	7
Mossy Spring	Chironomidae	*Stictochironomous* *Polypedilum* *Paratanytarus*	1 2 1
Mud River Spring	Chironomidae	*Conchapelopia* *Polypedilum*	1 2

FIELD DATA SHEET

Name of Water Body Duncan Tile Station #
Date 7/13/93 Investigator(s) mandeley/meyer
Comments

Rapid Bioassessment Protocol I

Biosurvey Field Data Sheet

RELATIVE ABUNDANCE OF AQUATIC BIOTA

Periphyton	0	1	2	(3)	4	Slimes	(0)	1	2	3	4
Filamentous Algae	0	1	2	(3)	4	Macroinvertebrates	0	1	2	3	(4)
Macrophytes	0	1	2	3	(4)	Fish	0	1	(2)	3	4

0 = Absent/Not Observed 1 = Rare 2 = Common 3 = Abundant 4 = Dominant

MACROBENTHOS QUALITATIVE SAMPLE LIST (Indicate Relative Abundance R = Rare, C = Common, A = Abundant, D = Dominant)

Porifera	Anisoptera C	Chironomidae C
Hydrozoa	Zygoptera D	Plecoptera
Platyhelminthes	Hemiptera C	Ephemeroptera R
Turbellaria R	Coleoptera D	Trichoptera
Hirudinea	Lepidoptera	Other
Oligochaeta /	Sialidae	
Isopoda	Corydalidae	
Amphipoda	Tipulidae R	
Decapoda C	Empididae	
Gastropoda D	Simuliidae	
Bivalvia	Tabanidae R	
	Culicidae	

Rare < 3 Common 3-9 Abundant > 10 Dominant > 50 (Estimate)

Observations

Permanent water in ditch between two fields. Spring fed.

PHYSICAL CHARACTERIZATION/WATER QUALITY
FIELD DATA SHEET

Duncan Tk 7/13/93

11:00 CDT

PHYSICAL CHARACTERIZATION

RIPARIAN ZONE/INSTREAM FEATURES

Predominant Surrounding Land Use:

Forest Field/Pasture (Agricultural) Residential Commercial Industrial Other _____

Local Watershed Erosion: (None) Moderate Heavy

Local Watershed NPS Pollution: No evidence (Some Potential Sources) Obvious Sources

Estimated Stream Width 3-4 ft m Estimated Stream Depth: Riffle _____ m Run _____ m Pool 6" m

High Water Mark 10" m Velocity _____ Dam Present: Yes __ (No)__ Channelized: Yes __ (No)__

Canopy Cover: (Open) Partly Open Partly Shaded Shaded

SEDIMENT/SUBSTRATE:

Sediment Odors: Normal Sewage Petroleum Chemical Anaerobic (None) Other _____

Sediment Oils: (Absent) Slight Moderate Profuse

Sediment Deposits: Sludge Sawdust Paper Fiber Sand Relict Shells Other _____

Are the undersides of stones which are not deeply embedded black? Yes No NO STONES

Inorganic Substrate Components		
Substrate Type	Diameter	Percent Composition in Sampling Area
Bedrock		
Boulder	>256-mm (10 in.)	
Cobble	64-256-mm (2.5-10 in.)	
Gravel	2-64-mm (0.1-2.5 in.)	
Sand	0.06-2.00-mm (gritty)	
Silt	.004-.06-mm	} 100%
Clay	<.004-mm (slick)	

Organic Substrate Components		
Substrate Type	Characteristic	Percent Composition in Sampling Area
Detritus	Sticks, Wood, Coarse Plant Materials (CPOM)	
Muck-Mud	Black, Very Fine Organic (FPOM)	
Marl	Grey, Shell Fragments	

WATER QUALITY

Temperature 25.5 C Dissolved Oxygen 19.8 pH 7.29 Conductivity .386 Other Sal 0.2

Instrument(s) Used _____

Stream Type: Coldwater (Warmwater)

Water Odors: Normal Sewage Petroleum Chemical None Other _____

Water Surface Oils: Slick Sheen Globs Flecks None

Turbidity: Clear Slightly Turbid Turbid Opaque Water Color _____

WEATHER CONDITIONS bright, sunny, mid day

PHOTOGRAPH NUMBER

OBSERVATIONS AND/OR SKETCH

HABITAT ASSESSMENT FIELD DATA SHEET

Name of Water Body Duncan Tile Station # _____

Date 7/13 Investigator Mandsley, Meyer

Comments Backflow from drainage from BIC pipe

10:50 CDT
7/13/93

HABITAT PARAMETER	CATEGORIES: EXCELLENT	GOOD	FAIR	POOR
1. BOTTOM SUBSTRATE/ AVAILABLE COVER	>50% rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16-20	30-50% rubble, gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble, gravel or other stable habitat. Habitat availability < desirable. (8) 6-10	<10% rubble, gravel or other stable habitat. Lack of habitat is obvious. 0-5
2. EMBEDDED-NESS	Gravel, cobble, and boulder are <25% surrounded by fine sediment. 16-20	Gravel, cobble, and boulder are 25-50% surrounded by fine sediment. 11-15	Gravel, cobble, and boulder are 50-75% surrounded by fine sediment. 6-10	Gravel, cobble, and boulder are >75% surrounded by fine sediment. (0) 0-5
3. <= 5 CFS	Cold; > 2 cfs Warm; >5 cfs 10-20	1-2 cfs 2-6 cfs 11-15	0.5-1 cfs 1-2 cfs 6-10	0.5 cfs 1 cfs 0-5
OR >5 CFS	Slow (<0.3 m/s), deep (>0.5m); slow, shallow (<0.5m); fast (>0.3m/s) deep; fast, shallow habitats all present 16-20	3 of 4 habitats present. (Missing riffles or runs get lower score than missing pools). 11-15	2 of 4 habitats present. (Missing riffles/runs get lower score.) 6-10	Dominated by one velocity/depth category (usually pool). (0) 0-5
4. CHANNEL ALTERATION	Little / no enlargement of islands or point bars, and/or no channelization (13) 12-15	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present. 8-11	Moderate deposition of new gravel, coarse sand on old and new bars; pools partially filled w/silt; and/or embankments on both banks. 4-7	Heavy deposits of fine material, bar development increase Most pools filled w/ silt; and/or extensive channelization. 0-3
5. BOTTOM SCOURING AND DEPOSITION	<5% of bottom affected. (14) 12-15	5-30% affected. Scour at constrictions and steep grades. Some deposition in pools. 8-11	30-50% affected. Deposit and scour at obstructions, bends, and constrictions. Some filling of pools 4-7	>50% bottom changing nearly year long. Pools absent due to deposition. Only large rocks exposed. 0-3
6. RUN/BEND, POOL/RIFFLE RATIOs	5-7. Variety of habitat. Deep riffles and pools. 12-15	7-15. Adequate depth in pools and riffles Bends provide habitat 8-11	15-25. Occassional riffle or bend. Bottom provide some habitat 4-7	>25. Essentially a straight stream. Flat water or shallow Poor habitat. (2) 0-3
7. BANK STABILITY	Stable. No erosion or bank failure. Side slopes <30%. 9-10	Moderately stable Infrequent erosion mostly healed over. Side slopes to 40%. (8) 6-8	Moderately unstable. Moderate erosion and side slopes to 60%. High erosion during high flow. 3-6	Unstable. Many eroded areas. Side slopes >60%. "Raw" areas frequent on straight and bends. 0-2
8. BANK VEGETATIVE STABILITY (10)	>80% of streambank covered by vegetation or boulders and cobbles. 9-10	50-79% covered by vegetation, gravel or larger material. 6-8	25-49% covered by vegetation, gravel or larger material. 3-5	<25% covered by vegetation, gravel or larger material. 0-2
9. STREAMSIDE COVER	Dominant vegetation is shrub 9-10	Dominant vegetation is of tree form. 6-8	Dominant vegetation is grass or forbes. (5) 3-5	>50% no vegetation Dominant material is soil, rock, bridge materials, culverts, or mine tailings. 0-2
COLUMN TOTALS	37	8	17	2
SCORE	60			

NO rubble observed

MACPHERSON SPRINGS
7/13/93

Rapid Bioassessment Protocol I

Biosurvey Field Data Sheet

RELATIVE ABUNDANCE OF AQUATIC BIOTA

Periphyton	(0)	1	2	3	4	Silmes	(0)	1	2	3	4
Filamentous Algae	(0)	1	2	3	4	Macroinvertebrates	0	(1)	2	3	4
Macrophytes	(0)	1	2	3	4	Fish	(0)	1	2	3	4

0 = Absent/Not Observed 1 = Rare 2 = Common 3 = Abundant 4 = Dominant

MACROBENTHOS QUALITATIVE SAMPLE LIST (Indicate Relative Abundance R = Rare, C = Common, A = Abundant, D = Dominant)

Porifera	Anisoptera	Chironomidae
Hydrozoa	Zygoptera	Plecoptera
Platyhelminthes	Hemiptera	Ephemeroptera
Turbellaria	Coleoptera R Dytiscidae	Trichoptera
Hirudinea	Lepidoptera	Other frogs C
Oligochaeta	Sialidae	
Isopoda	Corydalidae	
Amphipoda	Tipulidae	
Decapoda C	Empididae	
Gastropoda	Simuliidae	
Bivalvia	Tabanidae	
	Culicidae	

Rare < 3 Common 3–9 Abundant > 10 Dominant > 50 (Estimate)

Observations

Intermittent flow Now standing water only

Figure 6.1-1. Biosurvey Field Data Sheet for use with Rapid Bioassessment Protocol I.

1/12/17

PHYSICAL CHARACTERIZAT[illegible]R QUALITY
FIELD DATA SH

MacPheanson (BKG)

PHYSICAL CHARACTERIZATION

RIPARIAN ZONE/INSTREAM FEATURES

Predominant Surrounding Land Use:

Forest Field/Pasture (Agricultural) Residential Commercial Industrial Other _____

Local Watershed Erosion: (None) Moderate Heavy

Local Watershed NPS Pollution: (No evidence) Some Potential Sources Obvious Sources

Estimated Stream Width 1 m Estimated Stream Depth: Riffle _____ m Run _____ m Pool _____ m

High Water Mark 8" m Velocity 0 Dam Present: Yes ___ (No) ___ Channelized: Yes ___ (No) ___

Canopy Cover: Open Partly Open Partly Shaded (Shaded)

SEDIMENT/SUBSTRATE:

Sediment Odors: Normal Sewage Petroleum Chemical Anaerobic (None) Other _____

Sediment Oils: (Absent) Slight Moderate Profuse

Sediment Deposits: Sludge Sawdust Paper Fiber Sand Relict Shells Other SILT

Are the undersides of stones which are not deeply embedded black? Yes No NA

Inorganic Substrate Components		
Substrate Type	Diameter	Percent Composition in Sampling Area
Bedrock		
Boulder	>256-mm (10 in.)	
Cobble	64-256-mm (2.5-10 in.)	
Gravel	2-64-mm (0.1-2.5 in.)	
Sand	0.06-2.00-mm (gritty)	
Silt	.004-.06-mm	≥ 100%
Clay	<.004-mm (slick)	

Organic Substrate Components		
Substrate Type	Characteristic	Percent Composition in Sampling Area
Detritus	Sticks, Wood, Coarse Plant Materials (CPOM)	30%
Muck-Mud	Black, Very Fine Organic (FPOM)	
Marl	Grey, Shell Fragments	

9:35 AM CDT

WATER QUALITY

Temperature 18.2 C Dissolved Oxygen 2.50 pH 5.51 Conductivity .066 Other SAL 0.0

Instrument(s) Used _____

Stream Type: Coldwater (Warmwater)

Water Odors: Normal Sewage Petroleum Chemical (None) Other _____

Water Surface Oils: Slick Sheen Globs Flecks (None)

Turbidity: (Clear) Slightly Turbid Turbid Opaque Water Color _____

WEATHER CONDITIONS Hot, muggy, sunny

PHOTOGRAPH NUMBER

OBSERVATIONS AND/OR SKETCH Origin of spring does not have water visible

HABITAT ASSESSMENT FIELD DATA SHEET

Name of Water Body MacPhearson Sp Station # BKG

Date 7/13/93 Investigator MAudsley Meyer

Comments Origin of Spring shows NO flow

HABITAT PARAMETER	CATEGORIES			
	EXCELLENT	GOOD	FAIR	POOR
1. BOTTOM SUBSTRATE/ AVAILABLE COVER	>50% rubble,gravel, submerged logs, undercut banks,or other stable habitat 16-20	30-50% rubble,gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble,gravel or other stable habitat. Habitat availability < desirable. 6-10	<10% rubble,gravel or other stable habitat. Lack of habitat is obvious. (4) 0-5
2. EMBEDDED-NESS	Gravel,cobble, and boulder are <25% surrounded by fine sediment. 16-20	Gravel,cobble, and boulder are 25-50% surrounded by fine sediment. 11-15	Gravel,cobble, and boulder are 50-75% surrounded by fine sediment. 6-10	Gravel,cobble, and boulder are >75% surrounded by fine sediment. (0) 0-5
3. <= 5 CFS	Cold: > 2 cfs Warm: >5 cfs 10-20	1-2 cfs 2-6 cfs 11-15	0.5-1 cfs 1-2 cfs 6-10	0.5 cfs 1 cfs 0-5
OR >5 CFS	Slow (<0.3 m/s),deep (>0.5m);slow,shallow (<0.5m);fast(>0.3m/s) deep; fast,shallow habitats all present 16-20	3 of 4 habitats present. (Missing riffles or runs get lower score than missing pools). 11-15	2 of 4 habitats present. (Missing riffles/runs get lower score.) 6-10	Dominated by one velocity/depth category (usually pool). (0) 0-5
4. CHANNEL ALTERATION	Little / no enlargement of islands or point bars, and/or no channelization (13) 12-15	Some new increase in bar formation,mostly from coarse gravel; and/or some channelization present. 8-11	Moderate deposition of new gravel,coarse sand on old and new bars;pools partially filled w/silt;and/or embankments on both banks. 4-7	Heavy deposits of fine material, bar development increase Most pools filled w/ silt;and/or extensive channelization. 0-3
5. BOTTOM SCOURING AND DEPOSITION	<5% of bottom affected. (14) 12-15	5-30% affected.Scour at constrictions and steep grades. Some deposition in pools. 8-11	30-50% affected. Deposit and scour at obstructions, bends, and constrictions. Some filling of pools 4-7	>50% bottom changing nearly year long. Pools absent due to deposition. Only large rocks exposed. 0-3
6. RUN/BEND, POOL/RIFFLE RATIOs	5-7. Variety of habitat.Deep riffles and pools. 12-15	7-15. Adequate depth in pools and riffles Bends provide habitat 8-11	15-25. Occassional riffle or bend.Bottom provide some habitat 4-7	>25. Essentially a straight stream. Flat water or shallow Poor habitat. (1) 0-3
7. BANK STABILITY	Stable. No erosion or bank failure.Side slopes <30%. 9-10	Moderately stable Infrequent erosion mostly healed over. Side slopes to 40%. (8) 6-8	Moderately unstable. Moderate erosion and side slopes to 60%. High erosion during high flow. 3-5	Unstable. Many eroded areas. Side slopes >60%. "Raw" areas frequent on straight and bends. 0-2
8. BANK VEGETATIVE STABILITY	>80% of streambank covered by vegetation or boulders and cobbles. (10) 9-10	50-79% covered by vegetation, gravel or larger material. 6-8	25-49% covered by vegetation, gravel or larger material. 3-5	<25% covered by vegetation, gravel or larger material. 0-2
9. STREAMSIDE COVER	Dominant vegetation is shrub 9-10	Dominant vegetation is of tree form. (7) 6-8	Dominant vegetation is grass or forbes. 3-5	>50% no vegetation Dominant material is soil,rock, bridge materials,culverts,or mine tailings. 0-2
COLUMN TOTALS	37	15		
SCORE	57			

7/13/93

FIELD DATA SHEET

Name of Water Body Mossey Spring Station #
Date 7/14/93 Investigator(s)
Comments

Rapid Bioassessment Protocol I

Biosurvey Field Data Sheet

RELATIVE ABUNDANCE OF AQUATIC BIOTA

Periphyton	(0)	1	2	3	4	Slimes	(0)	1	2	3	4
Filamentous Algae	(0)	1	2	3	4	Macroinvertebrates	0	1	2	3	(4)
Macrophytes	(0)	1	2	3	4	Fish	(0)	1	2	3	4

0 = Absent/Not Observed 1 = Rare 2 = Common 3 = Abundant 4 = Dominant

MACROBENTHOS QUALITATIVE SAMPLE LIST (Indicate Relative Abundance R = Rare, C = Common, A = Abundant, D = Dominant)

Porifera	Anisoptera	Chironomidae C
Hydrozoa	Zygoptera	Plecoptera R
Platyhelminthes	Hemiptera R	Ephemeroptera R
Turbellaria	Coleoptera C Haliplidae	Trichoptera
Hirudinea	Lepidoptera	Other Gerridae (water striders) (4
Oligochaeta	Sialidae	
Isopods D	Corydalidae	
Amphipods R	Tipulidae	
Decapods R	Empididae	
Gastropods A (3 species)	Simuliidae	
Bivalvia	Tabanidae	
	Culicidae	

Rare < 3 Common 3-9 Abundant > 10 Dominant > 50 (Estimate)

Observations

Permanent spring-fed stream. Hard rocker covered with moss. Very little organic debris. Bottoming pools and between rocks is clean gravel. Isopoda super abundant.

PHYSICAL CHARACTERIZATION/WATER QUALITY
FIELD DATA SHEET

Mossy Springs

2:10 CDT
7/13/93

PHYSICAL CHARACTERIZATION

RIPARIAN ZONE/INSTREAM FEATURES

Predominant Surrounding Land Use:

Forest (Field/Pasture) Agricultural Residential Commercial Industrial Other _____

Local Watershed Erosion: (None) Moderate Heavy

Local Watershed NPS Pollution: No evidence (Some Potential Sources) Obvious Sources

Estimated Stream Width 3-5 ft m Estimated Stream Depth: Riffle _____ m Run 2" m Pool 4-6" m

High Water Mark 10-12" m Velocity _____ Dam Present: Yes _____ (No) Channelized: Yes _____ (No)

Canopy Cover: Open Partly Open Partly Shaded (Shaded)

SEDIMENT/SUBSTRATE:

Sediment Odors: Normal Sewage Petroleum Chemical Anaerobic (None) Other _____

Sediment Oils: (Absent) Slight Moderate Profuse

Sediment Deposits: Sludge Sawdust Paper Fiber (Sand) Relict Shells Other _____

Are the undersides of stones which are not deeply embedded black? Yes (No)

Inorganic Substrate Components

Substrate Type	Diameter	Percent Composition in Sampling Area
Bedrock		
Boulder	>256-mm (10 in.)	- 60%
Cobble	64-256-mm (2.5-10 in.)	- 20%
Gravel	2-64-mm (0.1-2.5 in.)	10%
Sand	0.06-2.00-mm (gritty)	
Silt	.004-.06-mm	10%
Clay	(.004-mm (slick)	

Organic Substrate Components

Substrate Type	Characteristic	Percent Composition in Sampling Area
Detritus	Sticks, Wood, Coarse Plant Materials (CPOM)	10%
Muck-Mud	Black, Very Fine Organic (FPOM)	
Marl	Grey, Shell Fragments	

WATER QUALITY

Temperature 13.5 C Dissolved Oxygen 8.96 pH 7.08 Conductivity .444 Other .2%

Instrument(s) Used YSI

Stream Type: (Coldwater) Warmwater

Water Odors: (Normal) Sewage Petroleum Chemical None Other _____

Water Surface Oils: Slick Sheen Globs Flecks (None)

Turbidity: (Clear) Slightly Turbid Turbid Opaque Water Color _____

WEATHER CONDITIONS Sunny, bright, clear

PHOTOGRAPH NUMBER

OBSERVATIONS AND/OR SKETCH

HABITAT ASSESSMENT FIELD DATA SHEET

Name of Water Body Mossy Spring Station # 7/13/93

Date 7/13 Investigator

Comments

HABITAT PARAMETER	CATEGORIES: EXCELLENT	GOOD	FAIR	POOR
1. BOTTOM SUBSTRATE/ AVAILABLE COVER	>50% rubble,gravel, submerged logs, undercut banks,or other stable habitat (18) 16-20	30-50% rubble,gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble,gravel or other stable habitat. Habitat availability < desirable. 6-10	<10% rubble,gravel or other stable habitat. Lack of habitat is obvious. 0-5
2. EMBEDDED-NESS	Gravel,cobble, and boulder are <25% surrounded by fine sediment. (18) 16-20	Gravel,cobble, and boulder are 25-50% surrounded by fine sediment. 11-15	Gravel,cobble, and boulder are 50-75% surrounded by fine sediment. 6-10	Gravel,cobble, and boulder are >75% surrounded by fine sediment. 0-5
3. <= 5 CFS	Cold: > 2 cfs Warm: >5 cfs 10-20	1-2 cfs 2-5 cfs 11-15	0.5-1 cfs 1-2 cfs 6-10	0.5 cfs 1 cfs 0-5
OR >5 CFS	Slow (<0.3 m/s),deep (>0.5m);slow,shallow (<0.5m);fast(>0.3m/s) deep; fast,shallow habitats all present 16-20	3 of 4 habitats present. (Missing riffles or runs get lower score than missing pools). (15) 11-15	2 of 4 habitats present. (Missing riffles/runs get lower score.) 6-10	Dominated by one velocity/depth category (usually pool). 0-5
4. CHANNEL ALTERATION	Little / no enlargement of islands or point bars, and/or no channelization (14) 12-15	Some new increase in bar formation,mostly from coarse gravel; and/or some channelization present. 8-11	Moderate deposition of new gravel,coarse sand on old and new bars;pools partially filled w/silt;and/or embankments on both banks. 4-7	Heavy deposits of fine material, bar development increase. Most pools filled w/ silt;and/or extensive channelization. 0-3
5. BOTTOM SCOURING AND DEPOSITION	<5% of bottom affected. (14) 12-15	5-30% affected.Scour at constrictions and steep grades. Some deposition in pools. 8-11	30-50% affected. Deposit and scour at obstructions, bends, and constrictions. Some filling of pools 4-7	>50% bottom changing nearly year long. Pools absent due to deposition. Only large rocks exposed. 0-3
6. RUN/BEND, POOL/RIFFLE RATIOss	5-7. Variety of habitat.Deep riffles and pools. 12-15	7-15. Adequate depth in pools and riffles Bends provide habitat (10) 8-11	15-25. Occassional riffle or bend.Bottom provide some habitat 4-7	>25. Essentially a straight stream. Flat water or shallow Poor habitat.. 0-3
7. BANK STABILITY	Stable. No erosion or bank failure.Side slopes <30%. 9-10	Moderately stable Infrequent erosion mostly healed over. Side slopes to 40%. (7) 6-8	Moderately unstable. Moderate erosion and side slopes to 60%. High erosion during high flow. 3-5	Unstable. Many eroded areas. Side slopes >60%. "Raw" areas frequent on straight and bends. 0-2
8. BANK VEGETATIVE STABILITY	>80% of streambank covered by vegetation or boulders and cobbles. (9) 9-10	50-79% covered by vegetation, gravel or larger material. 6-8	25-49% covered by vegetation, gravel or larger material. 3-5	<25% covered by vegetation, gravel or larger material. 0-2
9. STREAMSIDE COVER	Dominant vegetation is shrub 9-10	Dominant vegetation is of tree form. (12) 6-8	Dominant vegetation is grass or forbes. 3-5	>50% no vegetation Dominant material is soil,rock, bridge materials,culverts,or mine tailings. 0-2
COLUMN TOTALS	73	40		
SCORE	113			

1125

FIELD DATA SHEET

Name of Water Body Mud River Station # 7/14/93
Date _____ Investigator(s) _____
Comments _____

Rapid Bioassessment Protocol I

Biosurvey Field Data Sheet

RELATIVE ABUNDANCE OF AQUATIC BIOTA

Periphyton	0	1	(2)	3	4	Slimes	(0)	1	2	3	4
Filamentous Algae	0	1	(2)	3	4	Macroinvertebrates	0	1	2	3	(4)
Macrophytes	(0)	1	2	3	4	Fish	0	(1)	2	3	4

0 = Absent/Not Observed 1 = Rare 2 = Common 3 = Abundant 4 = Dominant

MACROBENTHOS QUALITATIVE SAMPLE LIST (Indicate Relative Abundance R = Rare, C = Common, A = Abundant, D = Dominant)

Porifera	Anisoptera	Chironomidae C
Hydrozoa	Zygoptera	Plecoptera
Platyhelminthes	Hemiptera	Ephemeroptera C
Turbellaria	Coleoptera C	Trichoptera D
Hirudinea	Lepidoptera	Other
Oligochaeta	Sialidae	
Isopoda C	Corydalidae	
Amphipoda D	Tipulidae	
Decapoda C	Empididae	
Gastropoda D	Simuliidae	
Bivalvia	Tabanidae	
	Culicidae	

Rare < 3 Common 3-9 Abundant > 10 Dominant > 50 (Estimate)

Observations

Permanent flow from several springs
Emerging rocks moss covered. Scuds (Amipoda) and snails dominant animals

1125

HABITAT ASSESSMENT FIELD DATA SHEET

Name of Water Body Mud River Station #

Date Investigator

Comments

HABITAT PARAMETER	CATEGORIES: EXCELLENT	GOOD	FAIR	POOR
1. BOTTOM SUBSTRATE/ AVAILABLE COVER	>50% rubble,gravel, submerged logs, undercut banks,or other stable habitat (20) 16-20	30-50% rubble,gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble,gravel or other stable habitat. Habitat availability < desirable. 6-10	<10% rubble,gravel or other stable habitat. Lack of habitat is obvious. 0-5
2. EMBEDDED-NESS	Gravel,cobble, and boulder are <25% surrounded by fine sediment. (19) 16-20	Gravel,cobble, and boulder are 25-50% surrounded by fine sediment. 11-15	Gravel,cobble, and boulder are 50-75% surrounded by fine sediment. 6-10	Gravel,cobble, and boulder are >75% surrounded by fine sediment. 0-5
3. <= 5 CFS	Cold; > 2 cfs Warm; >5 cfs 10-20	1-2 cfs 2-5 cfs 11-15	0.5-1 cfs 1-2 cfs 6-10	0.5 cfs 1 cfs 0-5
OR >5 CFS	Slow (<0.3 m/s),deep (>0.5m);slow,shallow (<0.5m);fast(>0.3m/s) deep; fast,shallow habitats all present 16-20	3 of 4 habitats present. (Missing riffles or runs get lower score than missing pools). (15) 11-15	2 of 4 habitats present. (Missing riffles/runs get lower score.) 6-10	Dominated by one velocity/depth category (usually pool). 0-5
4. CHANNEL ALTERATION	Little / no enlargement of islands or point bars, and/or no channelization (15) 12-15	Some new increase in bar formation,mostly from coarse gravel; and/or some channelization present. 8-11	Moderate deposition of new gravel,coarse sand on old and new bars;pools partially filled w/silt;and/or embankments on both banks. 4-7	Heavy deposits of fine material; bar development increase Most pools filled w/ silt;and/or extensive channelization. 0-3
5. BOTTOM SCOURING AND DEPOSITION	<5% of bottom affected. (15) 12-15	5-30% affected.Scour at constrictions and steep grades. Some deposition in pools. 8-11	30-50% affected. Deposit and scour at obstructions, bends, and constrictions. Some filling of pools 4-7	>50% bottom changing nearly year long. Pools absent due to deposition. Only large rocks exposed. 0-3
6. RUN/BEND, POOL/RIFFLE RATIOxx	5-7. Variety of habitat.Deep riffles and pools. 12-15	7-15. Adequate depth in pools and riffles Bends provide habitat (10) 8-11	15-25. Occassional riffle or bend.Bottom provide some habitat 4-7	>25. Essentially a straight stream. Flat water or shallow Poor habitat. 0-3
7. BANK STABILITY	Stable. No erosion or bank failure.Side slopes <30%. 9-10	Moderately stable Infrequent erosion mostly healed over. Side slopes to 40%. (7) 6-8	Moderately unstable. Moderate erosion and side slopes to 60%. High erosion during high flow. 3-5	Unstable. Many eroded areas. Side slopes >60%. "Raw" areas frequent on straight and bends. 0-2
8. BANK VEGETATIVE STABILITY	>80% of streambank covered by vegetation or boulders and cobbles. 9-10	50-79% covered by vegetation, gravel or larger material. (7) 6-8	25-49% covered by vegetation, gravel or larger material. 3-5	<25% covered by vegetation, gravel or larger material. 0-2
9. STREAMSIDE COVER	Dominant vegetation is shrub 9-10	Dominant vegetation is of tree form. (6) 6-8	Dominant vegetation is grass or forbes. 3-5	>50% no vegetation Dominant material is soil,rock, bridge materials,culverts,or mine tailings. 0-2
COLUMN TOTALS	64	45		
SCORE	110			

PHYSICAL CHARACTERIZATION/WATER QUALITY
FIELD DATA SHEET

Mud Rock 11:25

7/14/93

PHYSICAL CHARACTERIZATION

RIPARIAN ZONE/INSTREAM FEATURES

Predominant Surrounding Land Use:

Forest (Field/Pasture) Agricultural Residential Commercial Industrial Other _____

Local Watershed Erosion: None (Moderate) Heavy

Local Watershed NPS Pollution: No evidence (Some Potential Sources) Obvious Sources

Estimated Stream Width 10ft m Estimated Stream Depth: Riffle 4-6 m Run 4-6 m Pool 8-10 m

High Water Mark 2ft m Velocity ____ Dam Present: Yes __ (No) Channelized: Yes __ (No)

Canopy Cover: Open Partly Open (Partly Shaded) Shaded

SEDIMENT/SUBSTRATE:

Sediment Odors: Normal Sewage Petroleum Chemical Anaerobic (None) Other _____

Sediment Oils: (Absent) Slight Moderate Profuse

Sediment Deposits: Sludge Sawdust Paper Fiber (Sand) Relict Shells Other _____

Are the undersides of stones which are not deeply embedded black? Yes (No)

Inorganic Substrate Components		
Substrate Type	Diameter	Percent Composition in Sampling Area
Bedrock		30-40%
Boulder	>256-mm (10 in.)	10%
Cobble	64-256-mm (2.5-10 in.)	≥ 20%
Gravel	2-64-mm (0.1-2.5 in.)	20%
Sand	0.06-2.00-mm (gritty)	10%
Silt	.004-.06-mm	
Clay	<.004-mm (slick)	

Organic Substrate Components		
Substrate Type	Characteristic	Percent Composition in Sampling Area
Detritus	Sticks, Wood, Coarse Plant Materials (CPOM)	
Muck-Mud	Black, Very Fine Organic (FPOM)	
Marl	Grey, Shell Fragments	

Mid Channel 14.1 7.81 7.22 .1464 .290

WATER QUALITY 14.6 8.01 7.43 .438 .2

#1 14.1 7.82 7.41 .466 .290

Temperature 14.1 C Dissolved Oxygen 7.82 pH 7.41 Conductivity .466 Other .290

Instrument(s) Used

Stream Type (Coldwater) ~~Warmwater~~

Water Odors: Normal Sewage Petroleum Chemical (None) Other _____

Water Surface Oils: Slick Sheen Globs Flecks (None)

Turbidity: (Clear) Slightly Turbid Turbid Opaque Water Color _____

WEATHER CONDITIONS Partly cloudy; just finished brief shower.

PHOTOGRAPH NUMBER

OBSERVATIONS AND/OR SKETCH

HABITAT ASSESSMENT FIELD DATA SHEET

Name of Water Body LAGOON SPRING Station #_____

Date _____ Investigator _____

Comments NO H_2O but channel present

HABITAT PARAMETER	CATEGORIES			
	EXCELLENT	GOOD	FAIR	POOR
1. BOTTOM SUBSTRATE/ AVAILABLE COVER	>50% rubble, gravel, submerged logs, undercut banks, or other stable habitat (19) 16-20	30-50% rubble, gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble, gravel or other stable habitat. Habitat availability < desirable. 6-10	<10% rubble, gravel or other stable habitat. Lack of habitat is obvious. 0-5
2. EMBEDDED-NESS	Gravel, cobble, and boulder are <25% surrounded by fine sediment. (19) 16-20	Gravel, cobble, and boulder are 25-50% surrounded by fine sediment. 11-15	Gravel, cobble, and boulder are 50-75% surrounded by fine sediment. 6-10	Gravel, cobble, and boulder are >75% surrounded by fine sediment. 0-5
3. <= 5 CFS	Cold: > 2 cfs Warm: >5 cfs 10-20	1-2 cfs 2-5 cfs 11-15	0.5-1 cfs 1-2 cfs 6-10	0.5 cfs 1 cfs 0-5
OR				
>5 CFS	Slow (<0.3 m/s), deep (>0.5m); slow, shallow (<0.5m); fast (>0.3m/s) deep; fast, shallow habitats all present 16-20	3 of 4 habitats present. (Missing riffles or runs get lower score than missing pools). 11-15	2 of 4 habitats present. (Missing riffles/runs get lower score.) 6-10	Dominated by one velocity/depth category (usually pool). (1) 0-5
4. CHANNEL ALTERATION	Little / no enlargement of islands or point bars, and/or no channelization (12) 12-15	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present. 6-11	Moderate deposition of new gravel, coarse sand on old and new bars; pools partially filled w/silt; and/or embankments on both banks. 4-7	Heavy deposits of fine material, bar development increase Most pools filled w/ silt; and/or extensive channelization. 0-3
5. BOTTOM SCOURING AND DEPOSITION	<5% of bottom affected. (14) 12-15	5-30% affected. Scour at constrictions and steep grades. Some deposition in pools. 8-11	30-50% affected. Deposit and scour at obstructions, bends, and constrictions. Some filling of pools 4-7	>50% bottom changing nearly year long. Pools absent due to deposition. Only large rocks exposed. 0-3
6. RUN/BEND, POOL/RIFFLE RATIOs	5-7. Variety of habitat. Deep riffles and pools. 12-15	7-15. Adequate depth in pools and riffles Bends provide habitat 8-11	15-25. Occassional riffle or bend. Bottom provide some habitat 4-7	>25. Essentially a straight stream. Flat water or shallow Poor habitat. NA 0-3
7. BANK STABILITY	Stable. No erosion or bank failure. Side slopes <30%. 9-10	Moderately stable Infrequent erosion mostly healed over. Side slopes to 40%. (6) 6-8	Moderately unstable. Moderate erosion and side slopes to 60%. High erosion during high flow. 3-5	Unstable. Many eroded areas. Side slopes >60%. "Raw" areas frequent on straight and bends. 0-2
8. BANK VEGETATIVE STABILITY	>80% of streambank covered by vegetation or boulders and cobbles. (9) 9-10	50-79% covered by vegetation, gravel or larger material. 6-8	25-49% covered by vegetation, gravel or larger material. 3-5	<25% covered by vegetation, gravel or larger material. 0-2
9. STREAMSIDE COVER	Dominant vegetation is shrub (9) 9-10	Dominant vegetation is of tree form. 6-8	Dominant vegetation is grass or forbes. 3-5	>50% no vegetation Dominant material is soil, rock, bridge materials, culverts, or mine tailings. 0-2
COLUMN TOTALS	52	6	____	1
SCORE	59			

PHYSICAL CHARACTERIZATION/WATER QUAL...
FIELD DATA SHEET

9:05 CVI

PHYSICAL CHARACTERIZATION

RIPARIAN ZONE/INSTREAM FEATURES

Predominant Surrounding Land Use:

Forest Field/Pasture (Agricultural) Residential Commercial Industrial Other _____

Local Watershed Erosion: (None) Moderate Heavy

Local Watershed NPS Pollution: No evidence (Some Potential Sources) Obvious Sources

Estimated Stream Width ~2FT m Estimated Stream Depth: Riffle ? m Run ? m Pool ? m

High Water Mark 12" m Velocity ? Dam Present: Yes (No) Channelized: Yes (No)

Canopy Cover: Open Partly Open Partly Shaded (Shaded)

SEDIMENT/SUBSTRATE:

Sediment Odors: Normal Sewage Petroleum Chemical Anaerobic (None) Other _____

Sediment Oils: (Absent) Slight Moderate Profuse

Sediment Deposits: Sludge Sawdust Paper Fiber Sand Relict Shells Other _____

Are the undersides of stones which are not deeply embedded black? Yes (No)

Inorganic Substrate Components			Organic Substrate Components		
Substrate Type	Diameter	Percent Composition in Sampling Area	Substrate Type	Characteristic	Percent Composition in Sampling Area
Bedrock			Detritus	Sticks, Wood, Coarse Plant Materials (CPOM)	
Boulder	>256-mm (10 in.)	20%			
Cobble	64-256-mm (2.5-10 in.)	50%			
Gravel	2-64-mm (0.1-2.5 in.)	10%	Muck-Mud	Black, Very Fine Organic (FPOM)	
Sand	0.06-2.00-mm (gritty)				
Silt	.004-.06-mm	20%	Marl	Grey, Shell Fragments	
Clay	<.004-mm (slick)				

WATER QUALITY

Temperature _____ C Dissolved Oxygen _____ pH _____ Conductivity _____ Other _____

Instrument(s) Used _____

Stream Type: Coldwater Warmwater

Water Odors: Normal Sewage Petroleum Chemical None Other _____

Water Surface Oils: Slick Sheen Globs Flecks None

Turbidity: Clear Slightly Turbid Turbid Opaque Water Color _____

NO H2O QUALITY - (NO H2O)

WEATHER CONDITIONS Clear, Hot

PHOTOGRAPH NUMBER

OBSERVATIONS AND/OR SKETCH NO WATER Present

FIELD DATA SHEET

Name of Water Body Lacroix Spring Pond Station # 0925
Date 7/14/03 Investigator(s) _____
Comments _____

Rapid Bioassessment Protocol I

Biosurvey Field Data Sheet

RELATIVE ABUNDANCE OF AQUATIC BIOTA

Periphyton	0	1	2	(3)	4	Slimes	(0)	1	2	3	4
Filamentous Algae	0	1	(2)	3	4	Macroinvertebrates	0	1	2	3	(4)
Macrophytes	0	1	2	3	(4)	Fish	(0)	1	2	3	4

0 = Absent/Not Observed 1 = Rare 2 = Common 3 = Abundant 4 = Dominant

MACROBENTHOS QUALITATIVE SAMPLE LIST (Indicate Relative Abundance R = Rare, C = Common, A = Abundant, D = Dominant)

Porifera	Anisoptera A	Chironomidae C
Hydrozoa	Zygoptera D	Plecoptera I
Platyhelminthes	Hemiptera A	Ephemeroptera R
Turbellaria	Coleoptera D	Trichoptera R
Hirudinea	Lepidoptera	Other
Oligochaeta	Sialidae	tadpoles (at the Green Fro
Isopoda	Corydalidae	
Amphipoda	Tipulidae	
Decapoda	Empididae	
Gastropoda A	Simuliidae	
Bivalvia	Tabanidae	
	Culicidae	

Rare < 3 Common 3 - 9 Abundant > 10 Dominant > 50 (Estimate)

Observations

Pond. No visible inlet or outlet

PHYSICAL CHARACTERIZATION/WATER QUALITY
FIELD DATA SHEET

LAGOON Pond Spring

7/14/93 0925

PHYSICAL CHARACTERIZATION

RIPARIAN ZONE/INSTREAM FEATURES

Predominant Surrounding Land Use:

Forest Field/Pasture Agricultural Residential Commercial Industrial Other _____

Local Watershed Erosion: None Moderate Heavy

Local Watershed NPS Pollution: No evidence Some Potential Sources Obvious Sources

Estimated Stream Width _____ m Estimated Stream Depth: Riffle _____ m Run _____ m Pool _____ m

High Water Mark _____ m Velocity _____ Dam Present: Yes ___ No ___ Channelized: Yes ___ No ___

Canopy Cover: Open Partly Open Partly Shaded Shaded

SEDIMENT/SUBSTRATE:

Sediment Odors: Normal Sewage Petroleum Chemical Anaerobic None Other _____

Sediment Oils: Absent Slight Moderate Profuse

Sediment Deposits: Sludge Sawdust Paper Fiber Sand Relict Shells Other _____

Are the undersides of stones which are not deeply embedded black? Yes No

Inorganic Substrate Components		
Substrate Type	Diameter	Percent Composition in Sampling Area
Bedrock		
Boulder	>256-mm (10 in.)	
Cobble	64-256-mm (2.5-10 in.)	
Gravel	2-64-mm (0.1-2.5 in.)	
Sand	0.06-2.00-mm (gritty)	
Silt	.004-.06-mm	
Clay	<.004-mm (slick)	

Organic Substrate Components		
Substrate Type	Characteristic	Percent Composition in Sampling Area
Detritus	Sticks, Wood, Coarse Plant Materials (CPOM)	
Muck-Mud	Black, Very Fine Organic (FPOM)	
Marl	Grey, Shell Fragments	

WATER QUALITY

Temperature 26.4 C Dissolved Oxygen 4.95 pH 7.02 Conductivity .050 Other _____

Instrument(s) Used _____

Stream Type: Coldwater Warmwater

Water Odors: Normal Sewage Petroleum Chemical None Other _____

Water Surface Oils: Slick Sheen Globs Flecks None

Turbidity: Clear Slightly Turbid Turbid Opaque Water Color _____

WEATHER CONDITIONS

PHOTOGRAPH NUMBER

OBSERVATIONS AND/OR SKETCH

HABITAT ASSESSMENT FIELD DATA SHEET

Name of Water Body Lagoon Spring Pond Station # _____

Date 7/14/93 Investigator Meyer / Maudsley

Comments Not applicable - No channel, No flow
This water body is a pond. filled by
surface run-off.

HABITAT PARAMETER	CATEGORIES: EXCELLENT	GOOD	FAIR	POOR
1. BOTTOM SUBSTRATE/ AVAILABLE COVER	>50% rubble, gravel, submerged logs, undercut banks, or other stable habitat 16-20	30-50% rubble, gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble, gravel or other stable habitat. Habitat availability < desirable. 6-10	<10% rubble, gravel or other stable habitat. Lack of habitat is obvious. 0-5
2. EMBEDDED-NESS	Gravel, cobble, and boulder are <25% surrounded by fine sediment. 16-20	Gravel, cobble, and boulder are 25-50% surrounded by fine sediment. 11-15	Gravel, cobble, and boulder are 50-75% surrounded by fine sediment. 6-10	Gravel, cobble, and boulder are >75% surrounded by fine sediment. 0-5
3. <= 5 CFS	Cold: > 2 cfs Warm: >5 cfs 10-20	1-2 cfs 2-5 cfs 11-15	0.5-1 cfs 1-2 cfs 6-10	0.5 cfs 1 cfs 0-5
OR >5 CFS	Slow (<0.3 m/s), deep (>0.5m); slow, shallow (<0.5m); fast (>0.3m/s) deep; fast, shallow habitats all present 16-20	3 of 4 habitats present. (Missing riffles or runs get lower score than missing pools). 11-15	2 of 4 habitats present. (Missing riffles/runs get lower score.) 6-10	Dominated by one velocity/depth category (usually pool). 0-5
4. CHANNEL ALTERATION	Little / no enlargement of islands or point bars, and/or no channelization 12-15	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present. 8-11	Moderate deposition of new gravel, coarse sand on old and new bars; pools partially filled w/silt; and/or embankments on both banks. 4-7	Heavy deposits of fine material, bar development increase Most pools filled w/ silt; and/or extensive channelization. 0-3
5. BOTTOM SCOURING AND DEPOSITION	<5% of bottom affected. 12-15	5-30% affected. Scour at constrictions and steep grades. Some deposition in pools. 8-11	30-50% affected. Deposit and scour at obstructions, bends, and constrictions. Some filling of pools 4-7	>50% bottom changing nearly year long. Pools absent due to deposition. Only large rocks exposed. 0-3
6. RUN/BEND, POOL/RIFFLE RATIOss	5-7. Variety of habitat. Deep riffles and pools. 12-15	7-15. Adequate depth in pools and riffles Bends provide habitat 8-11	15-25. Occassional riffle or bend. Bottom provide some habitat 4-7	>25. Essentially a straight stream. Fla water or shallow Poor habitat. 0-3
7. BANK STABILITY	Stable. No erosion or bank failure. Side slopes <30%. 10 9-10	Moderately stable Infrequent erosion mostly healed over. Side slopes to 40%. 6-8	Moderately unstable. Moderate erosion and side slopes to 60%. High erosion during high flow. 3-5	Unstable. Many erode areas. Side slopes >60%. "Raw" areas frequent on straight and bends. 0-2
8. BANK VEGETATIVE STABILITY	>80% of streambank covered by vegetation or boulders and cobbles. 10 9-10	50-79% covered by vegetation, gravel or larger material. 6-8	25-49% covered by vegetation, gravel or larger material. 3-5	<25% covered by vegetation, gravel o larger material. 0-2
9. STREAMSIDE COVER	Dominant vegetation is shrub 9-10	Dominant vegetation is of tree form. 6 6-8	Dominant vegetation is grass or forbes. 3-5	>50% no vegetation Dominant material is soil, rock, bridge materials, culverts, c mine tailings. 0-2
COLUMN TOTALS	____	____	____	____
SCORE	____			

PHYSICAL CHARACTERISATION/WATER QUALITY
FIELD DATA SHEET

Green Bowling Spring

12:10 pm CDT

PHYSICAL CHARACTERISATION

RIPARIAN ZONE/INSTREAM FEATURES

Predominant Surrounding Land Use: corn field

Forest . Field/Pasture (Agricultural) Residential Commercial Industrial Other _____

Local Watershed Erosion: (None) Moderate Heavy

Local Watershed NPS Pollution: No evidence (None Potential Sources) Obvious Sources

Estimated Stream Width 1' m Estimated Stream Depth: Riffle _____ m Run _____ m Pool _____ m

High Water Mark _____ m Velocity _____ Dam Present: Yes ___ No ___ Channelized: Yes ___ No ___

Canopy Cover: Open Partly Open Partly Shaded (Shaded)

SEDIMENT/SUBSTRATE:

Sediment Odors: (Normal) Sewage Petroleum Chemical Anaerobic None Other _____

Sediment Oils: (Absent) Slight Moderate Profuse

Sediment Deposits: Sludge Sawdust Paper Fiber Sand Relict Shells Other _____

Are the undersides of stones which are not deeply embedded black? Yes (No) No Stones

Inorganic Substrate Components		
Substrate Type	Diameter	Percent Composition in Sampling Area
Bedrock		
Boulder	>256-mm (10 in.)	
Cobble	64-256-mm (2.5-10 in.)	
Gravel	2-64-mm (0.1-2.5 in.)	
Sand	0.06-2.00-mm (gritty)	
Silt	.004-.06-mm	
Clay	<.004-mm (slick)	

Organic Substrate Components		
Substrate Type	Characteristic	Percent Composition in Sampling Area
Detritus	Sticks, Wood, Coarse Plant Materials (CPOM)	
Muck-Mud	Black, Very Fine Organic (FPOM)	
Marl	Grey, Shell Fragments	

WATER QUALITY (No water)

Temperature _____ C Dissolved Oxygen _____ pH _____ Conductivity _____ Other _____

Instrument(s) Used _____

Stream Type: Coldwater Warmwater

Water Odors: Normal Sewage Petroleum Chemical None Other _____

Water Surface Oils: Slick Sheen Globs Flecks None

Turbidity: Clear Slightly Turbid Turbid Opaque Water Color _____

WEATHER CONDITIONS Partly cloudy

PHOTOGRAPH NUMBER

OBSERVATIONS AND/OR SKETCH No water on wt

HABITAT ASSESSMENT FIELD DATA SHEET

Name of Water Body Green Boiling Springs Station # _____

Date 7/13/99 Investigator Meyer / Mandsley

Comments Assessment not applicable to this water body. It's a spring with essentially no channel, riffles runs etc. No water on this date.

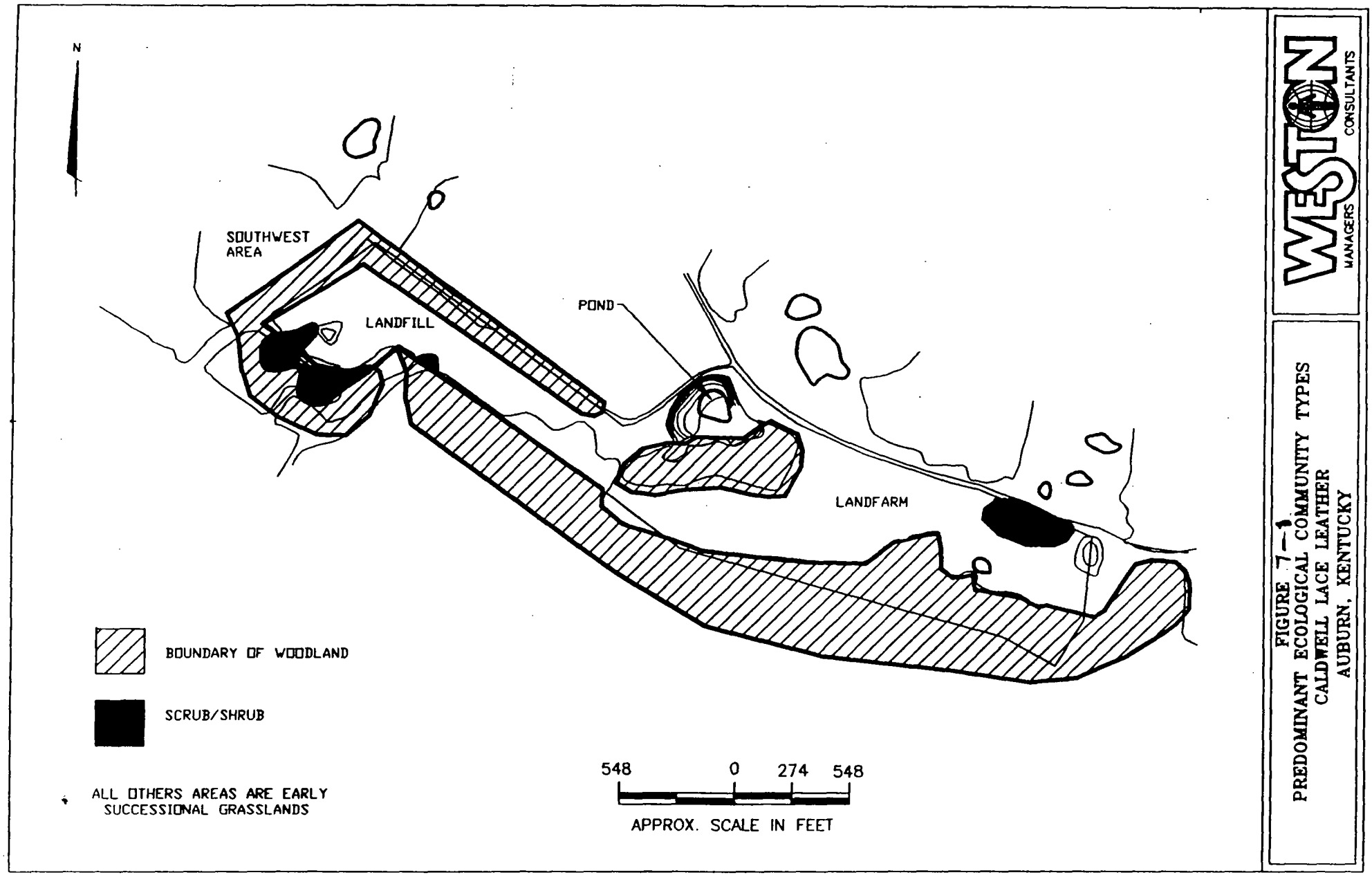
HABITAT PARAMETER	CATEGORIES: EXCELLENT	GOOD	FAIR	POOR
1. BOTTOM SUBSTRATE/ AVAILABLE COVER	>50% rubble, gravel, submerged logs, undercut banks, or other stable habitat 16-20	30-50% rubble, gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble, gravel or other stable habitat. Habitat availability < desirable. 6-10	<10% rubble, gravel or other stable habitat. Lack of habitat is obvious. 0-5
2. EMBEDDED-NESS	Gravel, cobble, and boulder are <25% surrounded by fine sediment. 16-20	Gravel, cobble, and boulder are 25-50% surrounded by fine sediment. 11-15	Gravel, cobble, and boulder are 50-75% surrounded by fine sediment. 6-10	Gravel, cobble, and boulder are >75% surrounded by fine sediment. 0-5
3. <= 5 CFS	Cold; > 2 cfs Warm; >5 cfs 10-20	1-2 cfs 2-5 cfs 11-15	0.5-1 cfs 1-2 cfs 6-10	0.5 cfs 1 cfs 0-5
OR >5 CFS	Slow (<0.3 m/s), deep (>0.5m); slow, shallow (<0.5m); fast (>0.3m/s) deep; fast, shallow habitats all present 16-20	3 of 4 habitats present. (Missing riffles or runs get lower score than missing pools). 11-15	2 of 4 habitats present. (Missing riffles/runs get lower score.) 6-10	Dominated by one velocity/depth category (usually pool). 0-5
4. CHANNEL ALTERATION	Little / no enlargement of islands or point bars, and/or no channelization 12-15	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present. 8-11	Moderate deposition of new gravel, coarse sand on old and new bars; pools partially filled w/silt; and/or embankments on both banks. 4-7	Heavy deposits of fine material, bar development increase Most pools filled w/ silt; and/or extensive channelization. 0-3
5. BOTTOM SCOURING AND DEPOSITION	<5% of bottom affected. 12-15	5-30% affected. Scour at constrictions and steep grades. Some deposition in pools. 8-11	30-50% affected. Deposit and scour at obstructions, bends, and constrictions. Some filling of pools 4-7	>50% bottom changing nearly year long. Pools absent due to deposition. Only large rocks exposed. 0-3
6. RUN/BEND, POOL/RIFFLE RATIOS	5-7. Variety of habitat. Deep riffles and pools. 12-15	7-15. Adequate depth in pools and riffles Bends provide habitat 8-11	15-25. Occassional riffle or bend. Bottom provide some habitat 4-7	>25. Essentially a straight stream. Flat water or shallow Poor habitat. 0-3
7. BANK STABILITY	Stable. No erosion or bank failure. Side slopes <30%. 10 9-10	Moderately stable Infrequent erosion mostly healed over. Side slopes to 40%. 6-8	Moderately unstable. Moderate erosion and side slopes to 60%. High erosion during high flow. 3-5	Unstable. Many eroded areas. Side slopes >60%. "Raw" areas frequent on straight and bends. 0-2
8. BANK VEGETATIVE STABILITY	>80% of streambank covered by vegetation or boulders and cobbles. 10 9-10	50-79% covered by vegetation, gravel or larger material. 6-8	25-49% covered by vegetation, gravel or larger material. 3-5	<25% covered by vegetation, gravel or larger material. 0-2
9. STREAMSIDE COVER	Dominant vegetation is shrub 9 9-10	Dominant vegetation is of tree form. Mixture 6-8	Dominant vegetation is grass or forbes. 3-5	>50% no vegetation Dominant material is soil, rock, bridge materials, culverts, or mine tailings. 0-2
COLUMN TOTALS	____	____	____	____
SCORE	____			

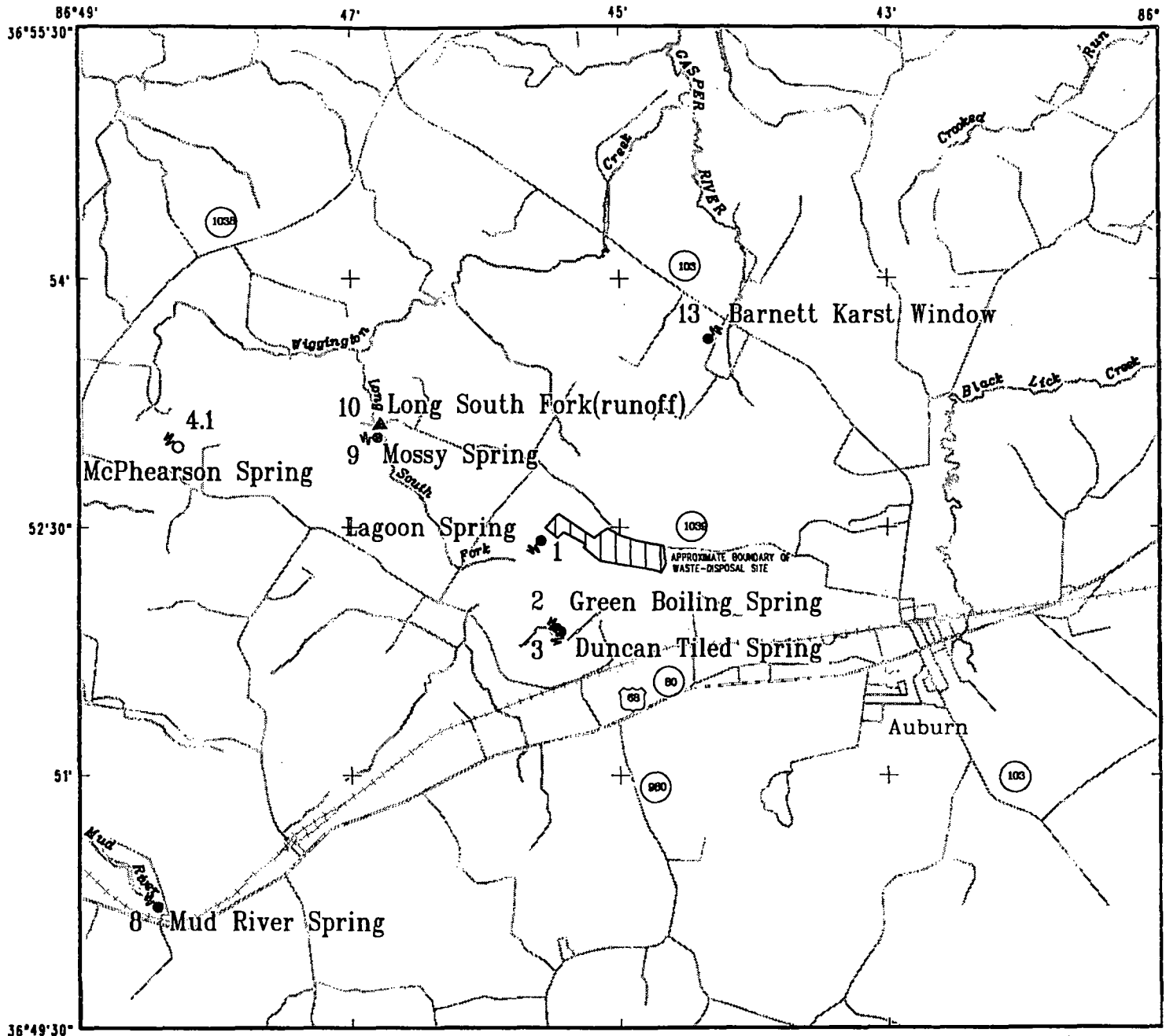
Figure XXVIII.1. SHORT - TERM CHRONIC TOXICITY TEST – AMPHIPOD SURVIVAL TEST

Industry/Study: Caldwell Lace Leather Date Start: 7/16/93 Species: Hyalella azteca Aeration? (y/n): _____
Location: Auburn, KY Date Stop: 7/26/93 Analyst: JR Maudsley / M. Weirich

Sample ID #	Rep. #	Survival						Dissolved Oxygen						Initial Water Chemistry					
		0 (#)	2* (✓)	4 (✓)	6 (✓)	8 (✓)	10 (#)	0	2	4	6	8	10	pH	Alkalinity (mg/L)	Hardness (mg/L)	Conductivity (mg/L)	Salinity (‰)	Chlorine (mg/L)
Control Sediment	1	5	✓	✓	✓		2	8.7	7.9	7.9	5.9	7.8	7.9	7.2					
	2	5		✓	✓		3												
	3	5		✓	✓		3												
	4	5		✓	✓		2												
	5																		
	6																		
Lagoon Spring Pond Sed.	1	5	✓	✓	✓		2	4.9	6.8	7.0	4.9	6.9	6.3	6.5					
	2	5		✓	✓		3												
	3	5		✓	✓		2												
	4	5		✓	✓		3												
	5																		
	6																		
Mud River Sed.	1	5	✓	✓	✓		5	6.2	7.2	7.5	5.3	7.2	7.1	7.5					
	2	5		✓	✓		3												
	3	5		✓	✓		5												
	4	5		✓	✓		4												
	5																		
	6																		
Mossy Spring Sed.	1	5	✓	✓	✓		5	6.5	7.6	7.6	6.0	7.4	7.2	7.2					
	2	5		✓	✓		5												
	3	5		✓	✓		5												
	4	5		✓	✓		4												
	5																		
	6																		

* 7/17/93 Added a 1cc square of "conditioned" paper toweling to each test vessel.


N
SOUTHWEST AREA
LANDFILL
POND
LANDFARM
BOUNDARY OF WOODLAND
SCRUB/SHRUB
ALL OTHERS AREAS ARE EARLY SUCCESSIONAL GRASSLANDS
548 0 274 548
APPROX. SCALE IN FEET
WESTON MANAGERS CONSULTANTS
FIGURE 7-1
PREDOMINANT ECOLOGICAL COMMUNITY TYPES
CALDWELL LACE LEATHER
AUBURN, KENTUCKY

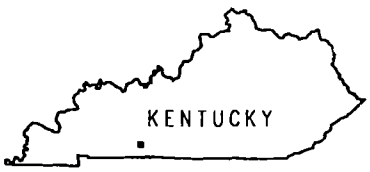


Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator Projection, Zone 16
Contours from U.S. Geological Survey
Auburn 1951, Dennis 1952, Homer 1951, and
South Union 1951.

Modified from Mull, D.S., 1992, Use of dye tracing to define the direction of ground-water flow from a superfund waste-disposal site in karst terrane, near Auburn, Kentucky: U.S. Geological Survey Water-Resources Investigations Report 92-4195

1 0 1 MILES

1 0 1 KILOMETERS



Location of Study Area

EXPLANATION

DYE-RECOVERY SITES AND IDENTIFIER

6 SPRING

10 STREAM

4.1 SELECTED SPRING AND IDENTIFIER

FIGURE 7-2 SELECTED MONITORING SITES

8

8.0 SUMMARY AND CONCLUSIONS

8.1 SUMMARY

8.1.1 BACKGROUND INFORMATION

The Caldwell Lace Leather (CLL) Site is located along State Highway 1036 (Cemetery Road) approximately 2.5 miles northwest of the City of Auburn, Kentucky. The Site is divided into two areas, one a landfill and the other a landfarm. In 1972, the Caldwell Lace Leather Company began disposing of leather wastes (including chrome and vegetable tanning wash sludge, fleshings, screenings, and leather and gasket scraps) in the landfill. In 1979, the Company was sold to Browning Arms, Inc. Disposal practices continued in the same manner. Later in 1983, Mr. Harry L. Williamson and Mr. J. Richard Howlett purchased the Company and the landfill areas. North Park, Inc., a subsidiary of Auburn Leather Company owned by Mr. Howlett, purchased the entire company and the disposal site in 1985. Between 1986 and 1989, a part of the disposal site known as the landfarming area was sold to Danny and Nellie P. Basham who currently uses the land for livestock grazing. North Park, Inc. has ceased corporate activities; however, Mr. Howlett still owns the portion of the Site known as the landfill area.

Waste disposal in the landfill consisted of three separate stages. Between 1972 and 1982, chrome and vegetable tanning wash sludge, fleshings, screenings, and leather and gasket scraps were landfilled in unlined trenches or placed in unlined lagoons. This disposal area was closed in 1983 and covered with several feet of soil and vegetation.

Between 1982 and 1985, the second disposal practice, landfarming, was started on approximately 29 acres east of the landfilling area. This area received sludge from the chrome and vegetable tanning plant.

A third disposal area, started in 1983, involved approximately 5 acres adjacent to the old landfilling area. This area was permitted by Kentucky to receive only screenings, fleshings, leather scraps, and gasket scraps. As with earlier landfilling practices, wastes were disposed of in trenches.

Under the direction of the State, a landfill closure plan was initiated in 1985 for the 5-acre landfilling area. The closure consisted of a three-phased approach involving the application of lime and fertilizer, regrading, revegetation and ground/surface water monitoring. All phases were completed in 1989. The landfarming area received waste until 1985 and was never officially closed.

During the operation of the landfill and landfarm, the KNREPC documented solid waste permit violations. The violations related to operations of all the disposal areas along with the containment of waste, types of waste being disposed, and general construction requirements as dictated by each permit.

Due to the nature of the wastes, the method of disposal and the karst nature of the Auburn area, the State and EPA believed the potential existed for groundwater contamination.

The Site was included on the National Priorities List (NPL) "Superfund sites" on August 30, 1990. This list makes available Federal Superfund money to clean up sites as necessary.

The potentially responsible parties (PRPs) for the CLL Site declined to perform the RI/FS; therefore, EPA has spent Federal Superfund money to perform the investigation. EPA, its consultants (U.S. Geological Survey and Roy F. Weston, Inc.) and the State began the investigation in May 1990.

8.1.2 REMEDIAL INVESTIGATION SUMMARY

During the investigation, various studies, field sampling and laboratory analyses were conducted to evaluate the potential exposure routes to humans and the environment. These activities are detailed in the Administrative Record and briefly summarized as follows:

Private Wells

A survey was conducted to determine the number, use and quality of private wells within a two-mile radius around the Site. Five of those wells were sampled. Two of the wells showed lead at concentrations close to the EPA regulatory standard; however, these wells were resampled two months later and lead contamination was not detected. The lead detected in these wells is not likely Site-related for two reasons; first, these wells were not determined to be connected to the Site during the dye-trace studies, and second, lead is often found in residential wells with older plumbing.

Ecological Studies

EPA performed three ecological surveys. These surveys included walking the Site and surrounding area, searching for endangered species and documenting the habitats. The surveys also included studying sensitive species to determine whether the Site had adversely impacted them. EPA has determined that the species studied showed no noticeable impairments.

Soil

Eighty-two soil samples were collected and analyzed for hazardous compounds to determine if normal contact with surface soil would cause human or environmental concerns. These samples were collected at depths of 12 to 18 inches. Although compounds were detected in the surface soil, normal contact with the soil would not pose an unacceptable risk.

Ninety-seven soil samples were collected at depths greater than eighteen inches. These samples were collected to determine the nature of the waste in the trenches and whether contaminants were migrating through the trenches and eventually into ground water. Contaminants were detected in the waste but were not found to have migrated beyond the trenches.

Springs/Sediment

Dye-trace studies were conducted to determine the direction of ground-water flow from the CLL Site. Eight nearby springs were identified as being connected to the Site and representative of ground-water and surface-water quality.

Nineteen sediment samples and 49 spring samples were collected from the Site and eight surrounding springs. Five contaminants were identified -- aluminum, chromium, lead, manganese, and bis(2-ethylhelxyl)phthalate. Of these contaminants, only manganese could potentially pose unacceptable human health effects. Because the average manganese concentration in springs did not exceed the average background spring concentration or concentrations in two of the private wells, EPA believes manganese concentrations do not warrant a cleanup action at the Site.

Leachate

One leachate sample was collected from the landfill area. The sample was evaluated as part of the surface water pathway. A variety of contaminants were detected in the sample, including -- chromium, lead, mercury, cyanide and organic acids and alcohols associated with tanning processes.

Contaminants of Concern

As a results of the sampling activities, 31 contaminants were identified as contaminants of concern. Aluminum, barium, chromium, lead, manganese, and nickel were some of the most frequently detected contaminants. The 31 contaminants were further evaluated as part of the risk assessment discussed below.

8.1.3 FATE AND TRANSPORT

Based on the physical and hydrogeological features present at the CLL Site, the potential exists for migration of some of the more mobile contaminants already detected in site groundwater and surface water. Due to the site hydrogeology, chemicals entering the groundwater system may be flushed from the groundwater system and discharged off-site. The depth of the groundwater table (30 to 40 ft.) in the area may help to slow the process of contaminant leaching, and the extensive system of sinkholes and fractures helps dilute and disperse any contaminant which does reach the groundwater medium. Important chemical factors in the water such as the pH, redox potential, ionic strength of the water, and the concentration of ionic complexes in the water all contribute to the fate of individual chemicals within the physical terrain.

The pH of the soil, adsorption rates, organic content in the soil, redox potentials, and the presence of sinkholes at the site play significant roles in determining fate and transport. Adsorption renders some chemicals relatively immobile, making transport unlikely. However, the presence of sinkholes and/or fractures in the karst terrain may provide avenues for contaminant migration into the groundwater medium as runoff waters feed into them.

Based upon the survey of the physicochemical, geological, and hydrogeological features at the Caldwell Lace Leather Site, we would expect to find the majority of contamination to reside in the soil medium. Most of the organics detected in Site soil are relatively immobile and have not migrated to groundwater or surface water. In addition, modeling indicated that chromium will not significantly leach from Site soil, a conclusion supported by the fact that groundwater chromium concentrators are well below MCLs. However, the potential does exist for some contaminants to migrate into groundwater through sinkholes, runoff and leaching. Thus, while contamination may occur in all media at this Site, their persistence in each medium is directly related to the present physical and chemical properties as addressed in Section 6.

8.1.4 RISK ASSESSMENT

Hypothetical carcinogenic risks were evaluated for:

- Current landfarm residents
- Current landfill trespassers
- Future landfill residents
- Future landfill farm worker

Potential Risks Associated with Current Resident and Trespasser

The current resident at the CLL Site was assumed to be potentially exposed to contaminants in the groundwater, landfarm surface soil, surface water, and sediment pathways. The trespasser was assumed to be potentially exposed to contaminants in the landfill surface soil, water, and sediment.

Potential Carcinogenic Risk

Total cancer risk for the current resident (children and adult) through exposure to 95% upperbound concentrations of compounds in all on-Site pathways is 2E-5. Since there is not a pathway existing in the current resident scenario which shows a cancer risk exceeding 1E-4, there are not compounds of carcinogenic concern. The major contributors to the total risk pathway were groundwater ingestion (3E-6), surface soil ingestion (2E-5), and dermal contact with surface soil (2E-6).

The total cancer risk for the trespasser is 6E-7 through surface soil, sediment, and surface water pathways. The total risk of each pathway did not exceed 1E-4, therefore, there are not compounds of carcinogenic concern.

Potential Noncarcinogenic Risks

The total hazard index for the current residents age 1 to 6 years old, age 7 to 16 years old, and the adult were 12, 4, and 2, respectively. The majority of the risk by contaminants was due to manganese through groundwater ingestion. For 1 to 6 year-olds, manganese contributed 10 of the HI of 11. For the youth (7-16 years old) the hazard index for manganese was 3 out of the HI of 4. The adult hazard index exceeded the HI of 1.0; all other pathways did not exceed the unity value.

The total hazard index for the trespasser was 0.03, which does not exceed the level of concern.

Potential Risk Associated with Hypothetical Resident and Work Exposures

The future landfill resident at the Caldwell Site was assumed to be potentially exposed to contaminants in the groundwater, surface soil, surface water, and sediment pathways. The future landfill worker at CLL was assumed to be exposed to contaminants in the surface and subsurface soils.

Potential Carcinogenic Risk

The total cancer risk for the future resident (children and adult) through all pathways is 3E-5. Since there is no pathway existing which shows a risk exceeding 1E-4, there are no specific contaminants of carcinogenic risk concern. The major contributors to the total risk by pathway were groundwater ingestion, surface soil ingestion, and dermal contact with surface soil.

The future worker total cancer risk is 7E-6. The exposure in landfill surface and subsurface soil (at potential risk levels of 3E-6 and 4E-6, respectively) to arsenic and beryllium generates the majority of the risk for these pathways.

Potential Noncarcinogenic Risk

The total hazard index for the future scenario 1-6 year-old child was 12 through the groundwater ingestion pathway, and the ingestion of surface soil. Ingestion of groundwater contributed 11 of the total while the surface soil pathway hazard index was 0.8. Of the total hazard index, manganese contributed nearly all of the risk in the groundwater pathway.

The total hazard index for the 7-16 year old is 14. The groundwater use pathway contributed nearly all of the total noncancer risk for this age group, with manganese contributing nearly all the risk.

The total hazard index for the future adult resident was 2. The groundwater pathway contributed a hazard index of 2 due to manganese.

The total hazard index for the future worker is 0.09. None of the pathways generated a noncancer risk exceeding 1.0.

Lead Toxicity

In the absence of lead health criteria, an approach was considered as recommended by EPA Region IV Risk Assessment Guidance. The approach was to predict mean lead blood levels in children using the Lead Uptake/Biokinetic Model (Version 0.5) now being evaluated by EPA. EPA has set a level of concern when greater than 50% of the child population age 1 to 6 years exceed the 10 μg/dL.

Using the parameters in the model, the results indicated that 99.04% of the 1-6 year old child hypothetically exposed at the CLL Site would have blood levels less than 10 μg/dL. The 50%

(average) modeled concentration for the child 1-6 years was found to be 3.24 μg/dL at the CLL Site in a hypothetical exposure scenario. In conclusion, the actual blood lead level of the child resident (if exposed at the CLL Site) would likely be much lower than was predicted, assuming that the parameters used in the model do not change. Since the predicted average blood level of lead was less than 10 μg/dL under very conservative assumptions, it is reasonable to assume lead would not pose a health problem.

Comparison of Lead Groundwater Concentration to ARARs

The exposure point concentrations that were calculated in the Exposure Assessment (Section 3 of the Risk Assessment Report), were compared to ARARs. The average lead groundwater concentration (not considering samples in which lead was not detected) of 13.6 mg/L used in the biokinetic model was less that the current action level of 15 μg/L published by the Office of Drinking Water, EPA. The 15 μg/L level was based on protection of children from adverse effects when their blood levels reached 10 μg/dL.

8.2 CONCLUSIONS

8.2.1 RISK CHARACTERIZATION OF MANGANESE

Manganese is primarily responsible for the elevated groundwater hazard indices in the risk characterization. Manganese is not eliminated from the contaminants of concern list because its maximum detection (4,200 μg/L) exceeded twice the average background concentration (1,085 μg/L). However, the exposure point concentration for manganese in groundwater is 400 μg/L which is less than the average background concentration. In three out of the five spring monitoring events, the background concentration exceeded concentrations in any Site-related spring. In the Site-related springs, only three out of 21 samples were greater than 170 μg/L; however background spring concentrations in four out of five samples, yielded results greater than 570 μg/L.

8.2.2 RECOMMENDED ACTIONS

EPA recommends that no Federal cleanup action be taken at the CLL Site at this time. However, EPA recommends that the Commonwealth of Kentucky or the current landfill owner continue spring monitoring because this is a primary pathway by which the landfill portion of the Site could potentially impact human health or the environment in the future. The current landfill owner has expressed his intentions to improve the landfill area for wildlife. Several management practices can be incorporated into ongoing land management activities that will enhance the property for a wildlife habitat. Regardless of the proposed wildlife habitat, EPA

recommends that future land use restrictions be placed on the landfill property to prevent land use activities that would expose the subsurface waste to human contact or the environment. Since EPA is not proposing to take a cleanup action, these land use restrictions would be voluntarily implemented by the landowner, or put in place by Kentucky or local government. The land-use restrictions would further reduce any potential future risk connected with the CLL Site.

EPA will continue to review information from Kentucky or any other entity to ensure acceptable health and environmental standards are maintained.

APPENDIX A

INTERPRETATION OF DYE-TESTS AND RELATED STUDIES (QUINLAN)

Final Report

INTERPRETATION OF DYE-TESTS AND RELATED STUDIES CALDWELL LACE LEATHER CO. WASTE DISPOSAL SITES LOGAN CO., KENTUCKY

November 1982

James F. Quinlan, Ph.D.
Certified Professional Geologist (Indiana) #498
Box 8
Mammoth Cave, Ky. 42259

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PLATES (In Pocket)

1. Traced Groundwater Flow-Routes, Dye-Input and Dye-Monitoring Sites, Springs, and Wells Measured.

2. Potentiometric Surface and Traced Groundwater Flow-Routes.

3. Topographic Elongations Influenced by Joints (Fractures) in Bedrock: a Clue to the Location of Subsurface Flow-Routes.

CONCLUSIONS

A series of dye-tests run between May 1981 and April 1982 have conclusively shown that surface water (and, therefore, most leachate and ground water) from the Caldwell Lace Leather Co. waste disposal and landspreading sites, 2.5 miles west of Auburn, flows in two nearly opposite directions and to two different rivers. A total of 13 dye-tests were run and 57 sites were monitored for dye-recovery. Eleven of these tests, however, were not run from the Caldwell property itself. The 13 tests served to show not only where leachate and groundwater from the property does go but also where groundwater adjacent to and near the property does not go. Most of the Caldwell property drains to the southwest, via caves, to a successive series of four springs linked by sinking streams and caves.

The complexity of the routing of the subsurface drainage and its intimate relationship with the surface drainage is illustrated by summarizing the fate of dye-laden water that was injected into a sinkhole on the landspreading site at dye-input site E, shown on Plates 1 and 2 (in pocket). Water and dye flows southwest to the first spring encountered, at dye-monitoring site #3. Then it flows along the surface for a few feet, sinks into the ground, flows to a stream segment in an unroofed cave (#18) and then flows to a second spring (#17) which flows along the surface, sinks, flows to a second

unroofed cave (#35), and then to a third spring (#30) that flows along the surface for about 1.6 miles, sinks, and re-appears at a fourth spring (#14), about four miles from the landspreading site. This fourth spring is the head of Mud River which flows five miles to Lake Hancock, the back-up water supply for Russellville. Some surface water (and, therefore, leachate and ground water) from this landspreading site flows about 1.4 miles north, via caves, to two springs (#42 and #45) that sink underground and flow 0.8 mile to the spring at the head of Gasper River (#24). These flow routes and others are discussed in greater detail in the body of this report.

A dye-test at M has also shown that surface water (and, therefore, leachate and ground water) from the western part of the old Caldwell waste disposal site flows approximately 1800 ft. southwest to Lagoon Spring (#4). When the discharge of this spring is high (an estimated 5 to 10% of each year) its water travels along the surface to Wiggington Creek, a tributary of the Gasper River. For an estimated 60% of the year, however, Lagoon Spring's discharge seeps underground before any water reaches a flowing tributary of Wiggington Creek. And for an estimated 30 to 35% of the year Lagoon Spring does not flow; it sits as a small pool of water or it may dry up. At all times, however, this spring is interpreted to be a high-level overflow route for ground water that normally flows northwest to Wiggington Creek, or southwest to one or more of the springs that flow to the Mud River Spring.

And it is possible that the water beneath Lagoon Spring flows both to the Gasper River and to the Mud River! I don't know but this could be tested with a dye-trace.

No domestic water supply wells are known to drain from either of the Caldwell waste disposal sites.

Neither the landspreading site nor the old disposal site is hydrologically suitable for the disposal of tannery waste or any other potentially toxic waste. Put more succinctly, both sites are unsafe and liable to have a predictable failure at an unpredictable time because they are on a sinkhole-pocked limestone terrain. The landspreading site and possibly also the old disposal site drain to the back-up public water supply for Russellville, Lake Hancock. Both sites should be abandoned and an alternative disposal site should be sought and evaluated as soon as possible -- as I first recommended in June 1981. Nevertheless, most available chemical data suggest that the sites are functioning safely and efficiently at this time. I strongly endorse the continued, but temporary usage of the landspreading site while an alternative site is actively being sought and while monitoring of water quality is done as recommended herein.

There is no possibility that leachate from the old Caldwell disposal site or from the landspreading site has flowed or will flow to either the B. and J. Reeves well (#86), north and northwest of the old disposal site, or to the R. and J. Stamps property, east of the landspreading site.

Eight springs should be sampled regularly for essential monitoring of water quality. As shown on the maps and in the box in the southwest corner of Plates 1 and 2, water from the disposal sites flows to six of these springs (circled in red). The other two springs (circled in green) are background controls to be used to show whether the six springs are chemically the same as or different from the numerous springs that do not include diluted leachate. A sample of the liquid waste that is spread on the land should also be analyzed, but less frequently, as discussed below.

The 4-site sampling plan used since August, 1982 -- Duncan Tiled Spring (#15 on Plates 1 and 2), Mud River Spring (#14), Well House Spring (#45) and the one background control, Spring Acres Swimming Pool Spring (#13) -- is insufficient for adequate monitoring of the leachate. It is only half of the 8-site sampling plan that I strongly advocated in my letters of March 16, 1982 to Caldwell's attorney, G. William Leach, and April 1, 1982 to the President of Caldwell. It is only half of the sampling plan that we agreed to use. In order to satisfactorily monitor the ground water all eight of the sites must be tested. Accordingly, the other four sites -- Lee Spring (#3), Lagoon Spring (#4), Long South Fork (#8C) and a second control site, Mossy Spring (#8B) -- should be monitored monthly for at least six months. And, for comparability of analyses, the other four sites should also be monitored for the same six months. Thereafter all eight sites should be monitored at least quarterly for one year and

then annually for at least two years after cessation of usage of the disposal sites. The waste liquid to be landspread should be sampled bi-monthly for 6 months, then also quarterly for a year and annually thereafter.

Although sites #30 and 37 are also circled in red on Plates 1 and 2, these are alternative sites, to be used only if access to #15 were to be lost or if it were to temporarily cease flowing. All three of these sites flow to #14 but they have much less dilution of leachate than present at #14.

I realize that the State has given tentative approval to the interim 4-site sampling plan. Now, however, the State's approval of whatever sampling plan is adopted can be based on a more complete understanding of the geology and hydrology of the site.

The eight springs and the leachate should be analyzed for the following parameters: Total Chromium, Chloride, Nitrate, 5-day Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), and Specific Conductance. The rationale for the selection of these parameters is given in a separate section of this report. Analysis for other parameters may be required by the State but those cited above are the most sensitive indicators of whether leachate is or is not flowing to the six springs and whether leachate is or is not, therefore, a threat to groundwater quality. Unless it can be shown that there are significant amounts of Cadmium, Lead, and Barium in the waste being landspread and, assuming a dilution of these elements by a factor of at least 100 in the

spring water (a reasonable and conservative estimate), unless the probable resultant concentration of these three elements in spring water is greater than the limits of detection of the laboratory methods used for analysis, there is no sense in wasting time and money looking for what is not relevant and what cannot be detected! Also, there is no sense in purchasing analyses for any chemical or physical parameter unless someone in a position of responsibility is prepared to interpret their significance. Unless the parameter can be shown to relevant to the problem at hand and one can state which numerical values of the parameter are significant, to require a company to determine the value of the parameter is equivalent to forcing it to pay an unjustifiably levied fine!

The drilling of observation wells up-gradient and down-gradient from the disposal sites would be a waste of time and money! Specifically, since the sites are located along a groundwater divide, it is physically impossible to drill wells up-gradient from them. There is no guarantee that any of several wells that could be drilled down-gradient from the disposal sites would intercept water flowing from them. The most efficient and representative sampling plan will use the springs that I have shown to have a known relationship to the sites.

A comparison of the analysis for pesticides in the liquid in a lagoon at the old disposal site with analyses of the Auburn public water supply, drinking water at Mammoth Cave National Park, and several springs and creeks shows that the

lagoon waste has less than 0.1 to 0.4 as much pesticide as these other waters (Table 2). Comparison of analyses for Chromium in two springs known to drain from the disposal sites with a "control" spring shows there is no significant difference between the three sites (Table 3).

The Conductivity (Specific Conductance) of the randomly selected sample of liquid waste in a lagoon at the old disposal site is 18,500 micromhos/cm. The conductivity of a spring shown to drain from this site (Lagoon Spring, #4) is 359 micromhos/cm which is significantly less than that of four other springs to which diluted waste from the landspreading site would flow (mean of 470 micromohs) and 13 other springs to which leachate from either disposal site could not flow (mean of 445 micromohs), as shown in Table 1. The low conductivity of Lagoon Spring is merely a consequence of the relatively small drainage basin size and relatively short residence time of water in the Lagoon Spring groundwater basin.

This report concludes with suggestions for five simple, cost-effective studies that can not only increase Caldwell's knowledge of the fate of waste disposed of on its property but also save the company far much more money than they will cost.

INTRODUCTION

This study was initiated because the State of Kentucky requested that the Caldwell Lace Leather Co. secure an evaluation of groundwater flow-directions in the vicinity of its

proposed landspreading site, 2.5 miles west of Auburn. This site and the adjacent waste disposal site are in the northwest corner of the U.S. Geological Survey 7.5-minute Auburn quadrangle, the northeast corner of the Dennis quadrangle, and the southwest corner of the Homer quadrangle. The basic questions to be answered were:

1. Where do the two waste disposal sites drain to? And by what routes?
2. How should the dye-test results and the site geology be interpreted in relation to the suitability of the sites for disposal of tannery waste?

Part of the site was to be used for landspreading as described by Sommers, Nelson, and Spies (1980), Torrey (1979), and Knezek and Miller (1976), and as regulated by the Kentucky Division of Waste Management (1982a and b).

Dr. James F. Quinlan was selected by the company because of his extensive 20-year experience in dye-tracing and groundwater movement in limestone areas of Kentucky, 18 other states, and 18 countries. He was ably helped by Joseph A. Ray, a most reliable, experienced field assistant.

Current production of the Caldwell tannery uses an average of 12,000 lbs. of cattle hide per day. A description of the tannery processes and waste treatment processes used has been published by the Environmental Protection Agency (Thackston, 1973). There have been no substantial changes in the operation of the plant since then (J. Richard Howlett, Oral Communication). Accordingly, no attempt will be made herein to summarize these processes and the waste generated by them. Two facts, however, should be mentioned:

1. The tannery uses principally the Hair Pulp, Alum Tan, Retan-Wet Finish processes, with small amounts of chrome and vegetable tanning. The Alum Tan process does not fit into the Environmental Protection Agency's (EPA's) classification of tanning processes into 7 sub-categories (EPA, 1979, p. 38751). The EPA, however, informally classifies the tannery under the Hair Pulp, Chrome Tan, Retan-Wet Finish sub-category (J. Richard Howlett, Oral Communication).

2. The EPA has excluded Chromium-bearing tannery wastes from Hazardous Waste Status if the waste has such status solely because of its Chromium content (EPA, 1980, p. 72035). This is because almost all the Chromium in tannery waste is in the trivalent state. It is hexavalent Chromium that is toxic and hexavalent Chromium is virtually absent from Caldwell waste. (Analyses for total Chromium in tannery waste can be presumed to be for trivalent Chromium; the actual concentration of trivalent Chromium is obtained by subtracting the minisucle amount of hexavalent Chromium from the value for the total Chromium.)

GEOLOGY AND SOILS

The geology of the disposal site area has been mapped by the U.S. Geological Survey (Gildersleeve, 1966; Rainey, 1965a and b; and Klemic, 1963). The soils have been mapped by the Soil Conservation Service (Dye, Barton, and Froedge (1975).

The sites are on an east-west-trending ridge that is partially capped by 0 to 60 feet of Big Clifty Sandstone that is locally shaley. This sandstone is underlain by the Girkin Limestone, about 150 feet thick. These two formation are the ones most relevant to groundwater movement in the immediate vicinity of the sites. At the bottom of the upper two-thirds of the Girkin is 5 to 25 feet of sandstone and shale, the Bethel Member; beneath the Girkin is more than 200 feet of Ste. Genevieve Limestone. Local relief is about 170 feet but only up to 70 feet of the higher areas is capped by sandstone.

The beds dip north-northwest at about 40 feet per mile. The nearest known fault is more than 5 miles north of the sites but the sandstone is fractured and slumped as a result of lowering of it in response to solution of limestone at the sandstone-limestone contact.

Although Figure 1 shows 11 sinkholes mapped by the Soil Conservation Service (Dye, Barton, and Froedge, 1975, sheet no. 21), there are numerous unmapped sinkholes on the Caldwell property. The existance of these unmapped sinkholes, particularly on and near the landspreading site, strongly implies that this site may readily leak runoff (and therefore, leachate) directly to the underlying limestone bedrock. The presence of these numerous unmapped sinkholes is clear proof of the inappropriateness of the property for the disposal of any potentially toxic waste.

Soil thickness, as determined by drilling, ranges from 0 to 43 feet (Stokely, 1972).

There are gross discrepancies between the published geologic map and the soils map. These discrepancies are clearly seen in Figure 1 when one realizes that Talbott soils (identified by the symbols TaB, TaC, and TaD) are derived from the weathering of limestone -- yet are shown overlying the sandstone above the limestone -- and the Linker soils (identified by the symbol LnC) are derived from the weathering of sandstone, siltstone, shale. Figure 1, compiled from the superimposition of data from the published geologic maps and soil map, shows allegedly "limestone-derived soils" developed on

sandstone and allegedly "sandstone-derived soils" developed on limestone.[1] The correspondence between the soil map and geologic maps does not have to be perfect but this total lack of correlation between soil-type and bedrock geology is impossible! My field observations show that the geologic maps are more correct than the soil map. In actuality, most of the old disposal site is on soil-covered limestone; most of the landspreading site is on soil-covered sandstone that has repeatedly been breached by the development of sinkholes.

According to the Soil Conservation Service (Dye, Barton, and Froedge, 1975) the Linker soils (where the lagoons are) have severe limitations for use as lagoons (because of their rapid permeability) and severe limitation for septic tank absorption fields and sanitary landfills (because of locally shallow depth to bedrock). The Talbott soils (underlying most of the landspreading site) have severe limitations for septic tank absorption fields because of their moderately slow permeability. But, since I have shown herein that the soils map is wrong to an undetermined degree, it is not possible to be confident about which soils are where on the Caldwell property and, from the soils map, what the soil properties are at a given location.

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[1]The soils map (Sheet 2 of 4) showing the relation between soils and topography that was submitted to the State (Caldwell Lace Leather Co., 1980), is incorrectly compiled and erroneous. The stated scale of the map is 1 inch = 400 ft. The actual scale of the topographic map is 1 inch = 500 feet and the actual scale of the superimposed soils map is 1 inch = 290 ft! The effect of this compilation error is to inadvertently misrepresent the type of soils on which waste has been disposed of in lagoons and on which waste was to be spread on a field.

SUMMARY AND INTERPRETATION OF DYE-TRACING RESULTS

Water with dye was injected into two sinkholes (A and E on Plate 1) on the landspreading site. Water from dye-input site E flows 800 feet to Lee Spring (dye-monitoring site #3) where it flows a few feet along the surface before sinking into the ground. It then flows 2300 feet to a cave stream (Duncan Natural Well, #17) to which the water from dye-input site A also drains. The water from sites A and E then flows 1000 ft. southwest to Duncan Tiled Spring (#15) -- and after heavy rains, also to an adjacent sinkhole #37) that also discharges water on the Duncan property. It then flows 2000 feet along the surface, sinks, and flows underground 1000 feet to a cave stream sometimes used for lawn-watering (Coy Wright Natural Well, #35), and thence 400 feet to a third spring (#30), also on the Coy Wright property. From this spring the dyed water (and any leachate that might be present) flows as a surface stream 2000 feet to the northwest, then 6000 feet southwest (parallel to and just north of Highway 68), to where it sinks at L and flows underground about 8000 feet to the large spring at the head of Mud River (#14). This large spring includes flow from the Spring Acres Swimming Pool Spring (#13). (Water from the landspreading site does not flow to #13). Mud River then flows about 5 miles to Lake Hancock, a back-up water supply for Russellville.

Water and dye were injected into a sinkhole at F located 800 feet north of Highway 1039, the north edge of the landspreading site, on the Steve Wilson property. The flow was

to the north and then northeast to two springs 7000 feet away (#42 and #45, 800 and 1000 feet north of the Barnett residence). Wellhouse Spring, #45, is a flowing stream at the bottom of a small sinkhole. After moderate rains, water from the spring at 800 feet (#42) sends water flowing 3000 feet along the surface to where it sinks on the north side of Highway 103. The flow from both of these springs (and the sinking point of the stream that flows from one of them) goes 4000 feet north to Crawford Spring (#24), at the head of the Gasper River. Water in Crawford Spring has been mixed with water that has flowed three miles from where Black Lick Creek sinks at J, half a mile north of the railroad tracks in Auburn.

The groundwater divide between water that flows northeast and water that flows southwest is in a zone about 1000 feet wide which partially underlies the landspreading site. Although it might be that all groundwater (and leachate) from the site flows to the southwest it is probable that, at the eastern third of the site, some groundwater also flows to the north and northeast. Surface runoff from the usable part of the eastern third of the landspreading site definitely flows to the north and northeast.

Two wells used for domestic water supplies were monitored for dye during the tests, one on the Duncan property (#16) and one on the Barnett property (#43). Neither well showed the slightest trace of dye. Therefore, neither is likely to be contaminated by anything draining from the landspreading site. Other domestic wells were not monitored.

Two springs no longer used as drinking water sources, Coy Wright Natural Well (#35) and Wellhouse Spring (#45) were also monitored. Dye injected at or adjacent to the land-spreading site was traced to these two springs. Although other wells southwest and northeast of this site could possibly be contaminated, such contamination would depend upon whether these wells happen to intercept cave passages that convey water from the ridge area. Dye tests might determine whether contamination could occur. However, wells northwest and southeast of the landspreading site are exceedingly unlikely to be contaminated by drainage from it.

Lagoon Spring (#4) does <u>not</u> drain the landspreading site but it does drain a significant part of the old Caldwell disposal property that used lagoons. A dye-test was run from a sinkhole (M) 1800 feet northeast, on the Delty Hall property, to Lagoon Spring. (This sinkhole is about 150 feet northwest of the fence line that separates the wooded Hall property from a plowed field.) Lagoon Spring is ephemeral; it ceases to flow during the drier parts of the year. Sometimes Lagoon Spring has a definite, but not overpowering, odor that is suggestive of sewage. No complete analyses of Lagoon Spring water have been made but it should be checked and regularly monitored, as recommended herein. Analysis of Chromium in Lagoon Spring water showed a concentration of 0.001 ppm -- no more than at a control spring, #8B -- suggesting that the trivalent Chromium is efficiently absorbed by clays (Environmental Protection Agency, 1980, p. 72030).

Water from Lagoon Spring may flow in the southwest-trending and then northwest-trending channel that I have called the Long South Fork of Wiggington Creek. (This creek is a tributary of the Gasper River.) Usually, however, the flow of Lagoon Spring seeps into the ground in a 300 to 1000 ft. reach that crosses a plowed field adjacent to the spring. The water that seeps into the ground in this variable reach then flows to the northwest (toward monitoring site #8C, on Long South Fork of Wiggington Creek) or to the southwest (toward monitoring site #14, Mud River Spring) or it may flow in both of these directions. There is not enough data to indicate which of these two flow directions is taken -- or if both of them are -- but, in my opinion, the most probable flow-direction is to the northwest, to Long South Fork. The monthly testing of water quality which I have recommended herein for sites #13, 14, 8B, and 8C will monitor flow in each possible direction. A dye-test might determine where the water from Lagoon Spring flows and it could eliminate the cost of analyzing water from one or two of the eight monitoring sites.

The results of other dye tests are clearly shown in Plates 1 and 2.

Whereas flow through gravel, sand, and clay is slow, intergranular, and predictable through mathematical analysis (Prickett, Naymik, and Lonnquist, 1981), most flow in limestone is rapid, through conduits (caves), and unpredictable by mathematical analysis. Some of the flow-routes in limestone

are unquestionably in caves developed along cracks and fractures (known as joints) in bedrock. The existence of these joints in the vicinity of the disposal sites can be logically inferred from the distribution and elongation of both the sinkholes and the vally segments shown on Plate 1 and, more clearly, on Plate 3. The topographic expression of a joint lies between the two arrow tips and parallel to their direction. Such joints can greatly influence the direction of groundwater movement. The effect of some major joints on the topography and groundwater movement is obscured by several of the flowlines drawn over them on Plate 1.

SUMMARY AND INTERPRETATION OF WATER-LEVEL MEASUREMENTS

The water-level data, contoured on Plate 2, shows that the water table beneath the site is an elongate, sausage-shaped mound that is concave northward. This data maximizes the correctness of the interpretation of the dye-trace results. Water beneath the old waste disposal site flows to the southwest. Water beneath the landspreading site flows both north and southwest. West of the old disposal site, however, water flow is to the west, but, I repeat for stress, no water from the site is likely to flow west to the B. and J. Reeves property. Similarly, I repeat, no water from either the old disposal site or the landspreading site is likely to flow east to the R. and J. Stamps property.

RELEVANCE OF INTERPRETATION OF DYE TRACES AND WATER LEVEL MEASUREMENTS TO LAWSUITS BROUGHT AGAINST CALDWELL LACE LEATHER CO.

The dye-test from the Delty Hall property (M) to Lagoon Spring (#4) conclusively shows that water flow is to the southwest, not north or northwest to the Reeves well (#86). If a dye-test were to be run from Sinkhole C, on the Stamps property and 250 ft. southwest of the old disposal site, water flow would also be to Lagoon Spring. I would welcome the opportunity to prove with a dye-test that flow from either M or C (or both of these input sites) is not to the Reeves well. I strongly suspect that the contamination of this well is related to flow from Mr. Reeves' septic tank absorption field near his home, uphill from the well. Some of the contamination of this well could also be a result of a rat or other rodent having fallen into it.

In September 1980 the Warner Laboratories (Nashville) ran two analyses of B. and J. Reeves "well and faucet water and one sample of liquid material that flows across a field on the Reeves property." This laboratory also identified "large amounts of rodent hair and possibly some amounts of animal tissue in the two well water samples." I am unaware of Caldwell tanning rodent hides in addition to cattle hides. The water analyses for Chromium do not suggest contamination by Caldwell -- unless it can be shown that the samples were properly collected, preserved, protected, and analysed with "standard solutions" as a quality control on analytical accuracy. Also, do we know whether the samples were collected from a chrome-plated faucet?

The following are three reasons why there is no way leachate from either the old disposal site or the landspreading site could contaminate groundwater or surface ponds on the R. and J. Stamps property:

1. Flow directions of groundwater beneath the Caldwell property are demonstrably to the north and southwest.

2. The probability that leachate or runoff from the Caldwell property would flow uphill along the ground surface to the Stamps property is exceedingly small.

3. Dye from the Kinkade Swallet (O), where a surface stream sinks into the ground, flows northeast to Atchley Spring (S) and thence to Wire Hole Spring (#26). Therefore any groundwater that might migrate eastward from the Caldwell property would be "picked-off" and diverted northward or southward before it traveled any farther eastward.

METHODS USED FOR DYE-TRACING

Thirteen dye-tests were run, each using one of the following three dyes as a tracer: Fluorescein (2 tests), optical brightener (3 tests), and Direct Yellow #96 (8 tests). Fluorescein is a bright green dye that is used for coloring shampoo, foods, and the liquid in bubble-levels and for tracing groundwater. It is recovered on detectors consisting of activated coconut charcoal in a 2.5-inch-square packet made of aluminum screen wire. The charcoal accumulates and stores the dye and, upon elution, releases it in a concentration greater than in the groundwater that passed through the detector. The charcoal is washed with a jet of water, dumped into a small jar, and eluted with a solution of ammonium hydroxide, 1-propanol, and distilled water. The dye, if present, is

visible in this solution at a concentration as small as 1 part per billion.

Optical brighteners are organic compounds, chiefly stilbene derivatives, that strongly absorb light in the invisible, ultra-violet region of the spectrum and emit it in the form of long-wave, visible blue light. Stated colloquially, optical brighteners in laundry detergents are what "makes your whites whiter than white". Two different optical brighteners were used: Calcofluor White ST Solution and CBS-X. Brightener is recovered on a 1 X 2 X 4-inch detector consisting of surgical cotton. After being left in a spring or stream for several days, a cotton detector is washed with a high-speed jet of water and examined for characteristic blue-white fluorescence under a long-wave ultra-violet lamp. A similar dye-detection procedure is used with Direct Yellow #96. This dye is also a stilbene derivative but its fluorescence is canary yellow rather than blue-white.

The following injection sequence was used for each of four dye-tests run from sinkholes that did not have flowing streams emptying into them during dry weather. A "primer" of 950 gallons of water was emptied into the sink. Dye injection started as a second 950-gallon load of water was emptied. This was followed by a "chaser" consisting of 1900 gallons. The total water-input for each of these tests (at sites A, E, F and M on Plate 1) was 3800 gallons.

Dye-detection methods are discussed in more detail by Quinlan (1981). He has had experience in running and

interpreting more than 500 dye-tests in Kentucky, chiefly in the Mammoth Cave area.

A summary of what dyes were used in each test, how much of each dye was used in each test, and the results of each test is given in Appendix A. Appendix B is a summary of what was done and the results for each day dye-detectors were set and recovered.

Beforeany dye-traces were run detectors were set, collected, and tested -- in order to establish the background levels, if any, of each of the dyes in springs and streams. As shown in Appendix B (page 61), background concentrations of optical brightener were found only at four locations -- thus suggesting that the water which sinks in Black Creek flows northwest to the Gasper River, as confirmed by Dye-Test #1 (Appendix A, page 37) and shown on Plates 1 and 2. This background of optical brightener is from laundry detergent used in homes in Auburn and ultimately discharged from the municipal sewage treatment plant there.

METHODS USED TO MAP POTENTIOMETRIC SURFACE

For this discussion a potentiometric surface will be considered to be the same as a water table. Water levels were measured with the aid of a Soiltest Model DR-762A electric tape. A probe was lowered down 28 wells and, when an electrical circuit was closed by interception of the water level therein, the water depth was recorded. Measurements were made during 11 days of low-flow conditions during April

1981. Measurements were recorded to the nearest inch. Well elevations were interpolated between the 10-foot contour interval of the topographic quadrangles. I believe the elevations are correct to within ± 2 feet. These data were combined with U.S. Geological Survey open-file data on 21 wells and with stream elevations (as shown on the topographic maps) and used to determine the configuration of the potentiometric surface.

The curvilinear flow routes of the dye-traces shown in Plate 2 were drawn by linking dye-input points and dye-recovery points by lines perpendicular to the potentiometric contours. The flow-routes link the cave rivers, springs, and streams between the dye-input points and the dye-recovery points.

The data sheets for the water-levels measured for Caldwell are included as Appendix C.

WATER QUALITY STUDIES

I will not try to summarize or interpret the numerous chemical analyses that have been run on leachate, well waters, and other samples prior to my association with Caldwell. In my opinion, some of these analyses were unnecessary. I shall, instead, discuss chiefly the analyses that have been made under my direction.

At the start of this study, when we were searching for various springs and streams to which leachate might flow, it was decided to check the Conductivity (Specific Conductance) of the water at the various sites visited. Such a check might show whether leachate-bearing waters are chemically similar to or different from other waters. (The Conductivity of a

water increases almost linearly with increases in Total Dissolved Solids. Conductivity is an inexpensive 2-minute determination made in the field with a special meter.) The results, shown in Table 1, show that although the conductivity of liquid in a randomly selected lagoon is 18,500 micromhos, the conductivity of all the other waters is much less. The conductivities of the other waters are approximately the same and not suggestive of contamination by leachate. Also, this is baseline data that can be used for comparison with conductivity data that might be acquired during water quality monitoring of the landspreading operation.

A colleague who regularly uses a gas chromatograph graciously offered to test some water samples for pesticides. This offer was accepted so that it could be learned if lagoon leachate included significant amounts of pesticides. The results, shown in Table 2, conclusively show that there are no significant concentrations of pesticides in the leachate tested.

As a quick, rough check on whether the odor at Lagoon Spring (#4) might be related to leachate from lagoons on the nearby old disposal site is was decided to analyze for Chromium there, at a spring to which part of the landspreading site drains, (Duncan Tiled Spring, #15) and also at a control spring (Mossy Spring, #8B). The results are shown in Table 3.

As has already been discussed in the Conclusions section of this report, and as will be discussed in the section entitled Rationale for Recommended Monitoring Plan, the 4-site

TABLE 1 - Conductivity (SpC), Temperature, and Estimated Discharge of Dye-Monitoring Sites, May 9, 1981

Site #		SpC Micro-mhos	Temp. °F	Discharge cfs
	Major Springs			
1	Waterworks Blue Hole	480	55.5	1.0
14	Mud River Spring	435	55.2	3.0
13	Spring Acres Swimming Pool Spring	425	55.1	2.0
24	Crawford Spring	545	56.3	3.0
12	Blue Spring	436	53.7	0.25
8B	Mossy Spring	459	53.5	0.35
	Minor Springs			
2	Atchley Spring	462	55.3	.05
3	Lee Spring	440	54.9	.02
4	Lagoon Spring	359	56.8	Pool
5	Bitch Spring	500	54.2	0.04
6	Road Spring	370	59.4	0.05
7	Watersnake Spring	470	58.3	0.06
15	Duncan Tiled Spring	460	55.1	0.12
18	Hulse Spring	334	54.0	.02
19	Stamps Spring	490	54.5	.005
20	Hall Spring	550	55.8	.15
26	Wire Hole Spring	360	60.2	.005
	Major Creeks			
9	Mud River @ School	452	60.0	5.0
21	Black Lick Creek	595	56.8	2.0
25	Gasper River	490	60.4	4.0
	Streams			
8C	Long South Fork (5/15)	426	55.4	0.1
10	Briggs Creek	420	63.5	.005
22	Wigginton Creek	405	57.7	1.0
23	Gasper Creek	501	55.5	0.1
27	Crooked Run	425	59.8	0.25
28	Black Lick Creek	455	67.0	0.5
	Other			
16	Duncan Pumping Well	530	56.0	-
-	Lagoon @ old disposal site	18,500	-	-

TABLE 2 - Pesticides in Waters Sampled on 5/13/81

SITE #	SITE NAME	PESTICIDE -- parts per trillion				
		Lindane	Heptachlors	Aldrins	Dieldrins	DDT's
1	Water Works Blue Hole	37.70	40.99	70.97	<0.5	98.44
11	Mud River @ Bridge	4.72	4.31	8.47	<0.5	2.80
12	Blue Spring	4.72	29.02	2.39	<0.5	5.27
21	Black Lick Creek	5.42	5.04	10.72	<0.5	4.44
-	Lagoon Leachate	1.72	3.25	2.46	<0.5	1.11
-	Tap Water @ Mammoth Cave	7.71	6.40	12.61	5.56	0.2
-	Green River @ Mammoth Cave	29.94	21.57	66.00	<0.5	12.72

INTERPRETATION: The above concentrations are far below those generally considered to be a hazard to human health or to animal life (McKee and Wolf, 1963). The highest concentration of pesticides is in the public water supply for Auburn. The lowest concentration is in the lagoon leachate from the old disposal site. Therefore, lagoon leachate is not a likely source of pesticides that may be found in local springs and surface streams.

TABLE 3 - Chromium content of selected springs sampled on 4/24/82

Site #	Site Name	Chromium (ppm)
4	Lagoon Spring	0.001
15	Duncan Tiled Spring	<0.001
8B	Mossy Spring	0.001

INTERPRETATION: On the basis of one set of samples (an insufficient number) it can be seen that there is no more Chromium in Lagoon Spring than in the control, Mossy Spring, but this could be because the trivalent Chromium present in the waste is strongly absorbed by clays (EPA, 1979, p. 72030). The lack of significant amounts of Chromium at Lagoon Spring does not mean its water is free of leachate. However, its relatively low conductivity, shown in Table 1, suggests that there is no great amount of Chloride present as an indicator of leachate contamination here.

monitoring plan that the State tentatively approved is not the one that I recommended and to which we had agreed. Nevertheless, an interpretation of these data, summarized in Table 4, should be given. The concentrations of Cadmium, Chromium, Lead, Barium, and Total Dissolved Solids and the values for Specific Conductance are essentially the same in the waters that drain from the disposal sites as they are in the control spring (#13). The concentration of Nitrate (as N) is greatest at the control spring because the amount of fertilizer used and cattle raised in its drainage basin is probably much greater than in the other three groundwater basins. The significantly higher concentrations of Chloride at two springs (#15 and 45) suggests that their waters include leachate. According to Thackston (1973, p. 14) the tannery waste ranges from 3600 to 4700 ppm Chloride. Therefore Chloride, which does not significantly react with clays, may be a good "natural tracer" for leachate -- if similar concentrations of Chloride do not occur in numerous springs that do not drain waste disposal sites. It would be worthwhile to do a survey of Chloride at other springs.

EVALUATION OF SUITABILITY OF LANDSPREADING SITE FOR WASTE DISPOSAL

The suitability of the landspreading site needed to be evaluated according to numerous physical and economic criteria. Those with which I have been concerned are the hydrology and geology of the site and the potential concentrations of leachate in groundwater.

TABLE 4 - Results of Monitoring 4 of 8 Sites Necessary for Essential Monitoring of Water Quality During August (A), September (S), and October (O), 1982.

PARAMETER		SITE NUMBER			
		15	14	13	45
Cadmium (mg/l)	A	0.0026	0.0022	0.0022	0.0024
	S	0.0014	0.0014	0.0014	0.0014
	O	0.0019	0.0018	0.0016	0.0016
Chromium (mg/l)	A	<0.001	<0.001	<0.001	<0.001
	S	<0.001	<0.001	<0.001	<0.012
	O	<0.005	<0.005	<0.005	<0.005
Lead (mg/l)	A	0.014	0.016	0.013	0.011
	S	0.019	0.017	0.018	0.022
	O	0.014	0.016	0.013	0.015
Barium (mg/l)	A	0.041	0.057	0.045	0.053
	S	<0.001	<0.001	<0.001	<0.001
	O	<0.07	<0.07	<0.07	<0.07
Specific Conductance (micromohs per cm @ 25°C)	A	440	425	420	435
	S	430	445	430	435
	O	490	430	440	490
Total Dissolved Solids (mg/l)	A	323	281	255	288
	S	296	264	273	295
	O	274	278	240	278
Nitrate (N) (mg/l)	A	1.22	2.62	3.96	1.8
	S	1.68	3.19	4.15	2.32
	O	2.1	3.3	3.6	3.8
Chloride (mg/l)	A	24.0	8.2	7.0	19.0
	S	12.8	4.8	4.1	4.96
	O	17.2	5.1	5.1	12.4

KEY TO SITE NUMBERS: 15 - Duncan Tiled Spring, 14 - Mud River Spring, 13 - Spring Acres Swimming Pool Spring, 45 - Wellhouse Spring. Sites #15, 14, and 45 are springs to which water from the landspreading site flows. Site #13 is a control, for regional background.

In brief, the site is hydrologically unsuitable for waste disposal. It is not possible to predict adequate dilution and neutralization of the leachate beneath the site and in its immediate vicinity. Leachate can seep through the soil, friable sand, and fractured sandstone. It may, therefore, quickly reach groundwater in the underlying limestone. These statements are true even though the soil is locally as much as 43 ft. thick. The various groundwater flow-directions have already been discussed. The crucial unknown is the probable amount of dilution and neutralization of the leachate.

The travel-time of leachate through the soil and sand on the landspreading site, after reaching a fracture or open fissure in the sandstone, can be as rapid as from 50 to 200 ft. per minute. In contrast, the flow-rate through sand and through unfractured, unfissured sandstone is perhaps as slow as 1 ft. per week. The fast rate cited is approximate, but known. The slow rate is conjectural, but unknown. The assumption must be made that the fast travel-time rate is more representative of the site. Therefore, one cannot confidently predict the leachate will have been safely neutralized by reactions with clays before it reaches the underlying limestone and enters a zone where water movement is more rapid than it is in the sandstone.

It can be argued that leachate will be sufficiently diluted by mixing with groundwater to meet all applicable water quality standards. I believe this may be true. But there is a risk that wells both southwest and northeast of the site

could be contaminated. Also, a future well drilled in this southwest-northeast-trending zone could be contaminated if it intercepted a cave passage.

For all of these reasons I recommend consideration of an alternate waste disposal site. In the meantime, however, the landspreading site can be prudently used with caution and regular monitoring.

I would be glad to assist Caldwell and its consulting engineers in evaluating alternative waste disposal sites.

RECOMMENDED MONITORING PLAN

As shown more clearly on Plate 1 than on Plate 2, the following eight springs should be sampled monthly for at least 6 months, then quarterly for a year, and annually. They should not be sampled before at least 5 days after any rain of more than 1/4 inch:

	Name of Sampling Site	Location
3.	Lee Spring	200 ft. south of south edge of site
15.	Duncan Tiled Spring (This spring may cease to flow during dry seasons.)	600 ft. west of Duncan barn (now 200-300 ft. west of original spring)
	or (as second choice)	
	The access hole to water that flows to Duncan Tiled Spring	500 ft. northwest of Duncan barn
	or (as third choice)	
37.	Green Boiling Hole	700 ft. northwest of Duncan barn
	or (as fourth choice)	
30.	Coy Wright Blue Hole	400 ft. south-southwest of Coy Wright residence

14.	Mud River Spring	800 ft. north-northwest of Muddy River Church, about 5 miles west of Auburn along Highway No. 68, at head of Mud River.
13.	Spring Acres Swimming Pool Spring	300 ft. south of swimming pool
45.	Well House Spring	800 ft. north of Barnett house
4.	Lagoon Spring	600 ft. southwest of west corner of old Caldwell disposal site and 400 ft. north of old barn
8B.	Mossy Spring Fork of Wiggington Creek	7200 ft. west-northwest of west corner of old Caldwell disposal site, on south (upstream) side of where tributary of Wiggington Creek is crossed by Highway No. 1039. As one faces upstream, this is the right-hand fork. It should be sampled about 50 ft. upstream from the confluence. (Actual spring is approximately 1000 ft. upstream from the confluence but sampling 50 ft. above will be satisfactory.)
8C.	Long South Fork of Wiggington Creek	Adjacent to Mossy Spring Fork but, as one faces upstream, this is the left-hand fork. It should be sampled about 50 ft. upstream from the confluence. This stream is spring-fed.

These eight springs are the minimum number that should be sampled monthly for at least 6 months and then quarterly for one year. The liquid waste to be spread upon the site should be sampled bi-monthly for 6 months, then quarterly for a year and annually. Analyses should then be annual for at least two years after cessation of usage of the site for the disposal of waste. (Knezek and Miller, 1976, recommended monthly samples for the first 2 years of operation.) All nine of these samples should always be analyzed for each of the following six pollutants or indicators of pollution:

Total Chromium
Chloride
Nitrate (as N)
5-day Biological Oxygen Demand (BOD_5)
Chemical Oxygen Demand (COD)
Specific Conductance

It is possible that the Division of Waste Management may require additional parameters to be analyzed. The need for many of these parameters can be defended.

Analyses in Caldwell's files made available to me show that the pH of the leachate ranges from 7.0 to 7.9. Accordingly, and because of the buffering capacity of bicarbonate waters in limestone, it is almost inconceivable that a leachate-rich spring water could have a pH less than 6.6 or more than 8.3; there is little sense in measuring the pH of the springs to be monitored. The pH of leachate, however, should be measured when it is analyzed.

I would be glad to assist Caldwell with recommendations on standard methods to collect and preserve samples. Unless water samples are properly collected and preserved the results are invalid and the money spent on their analysis is totally wasted.

RATIONALE FOR RECOMMENDED MONITORING PLAN

As shown on Plate 1, Springs #3, 15, 14, and 45 each drain different parts of the landspreading site. Spring #13 is the necessary control.

Spring #4 is the only spring known to drain the old disposal site. Springs #8C and 15 may drain the old disposal site but, until or unless it is known whether they do or do

not drain it, they must be monitored. (Depending on what the results of a possible dye-test from Lagoon Spring are, it might be possible to eliminate monitoring one of these springs.) Springs #13 and 8B are necessary controls for this site. Control springs are necessary so that one can confidently recognize whether water quality parameters of springs to which leachate flows are less, greater, or the same as the parameters of springs and surface waters that have no hydrologic relation to a waste disposal site. Two control springs is an adequate and prudent number.

The parameters selected for analysis are those most likely to occur in detectable concentrations and also be indicative of contamination by leachate. According to Thackston (1973, p. 14) composite waste from the Caldwell tannery is characterized by Chlorides as high as 4700 ppm, BOD_5 as high as 1050 mg/l, and COD as high as 3050 mg/l.

SUGGESTIONS FOR FUTURE WORK

The most important hydrologic problem facing Caldwell is the finding of a suitable alternative waste disposal site that is within an economically practical distance of the tannery. There are, in addition, 5 small studies that can repay their cost manyfold. They are:

1. A dye-test from the Lagoon Spring (#4) in order to determine where its waters go -- in order to justifiably cut down on the number of sites monitored.
2. A dye-test at Sinkhole C (on the Reeves property) and Sinkhole M to prove that Caldwell's waste disposal practices are not the source of the contamination in the Reeves well (#86).

3. A dye-test from the septic tank system at the Reeves residence -- in order to show it is the probable source of contaminants at the Reeves well.

4. Investigation of the chemistry of Lagoon Spring waters -- to learn what may be causing its odor and whether its waters are contaminated by leachate.

5. Investigation of the Chloride content of various springs -- to determine if Chloride analysis is a reliable, inexpensive guide to identifying springs that drain from waste disposal sites.

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APPENDIX A

Copy of Records of Dye-Tests #1 through #13

RECORD OF DYE TEST File # C-1

Input Point (Name of test) Black Lick Sinking Point Date 5/9/81 Time 11A

Tracer Direct Yellow 96 Amount 4 lbs Investigator JQ+V

Precipitation Before or During Test 1" of Rain on 5/10

Site #

	Detectors placed at	Date, Number of days since dye input, and results											
		Date	5/9	5/12	5/15								
		Number of Days	0	3	6								
24	Crawford Sp. (Rise of Gnsper R.)		-	++	-								
26	Wire Hole Sp.		Set	Pulled -									
27	Crooked Run @ White Rd		-	/	-								
28	Black Creek @ Ky (73)		-	/	-								

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks:

Interpretation: Black Lick Creek sinks on Hall property and Rises @ Crawford Sp. During low flow conditions it does not go to Wire Hole Sp. but, during floods, I suspect it probably does

RECORD OF DYE TEST File # C-

Input Point (Name of test) sinkhole nearest to paved road @ Caldwell land-spreading site, @ "A" Date 5/12/81 Time 11:

Tracer Fluorescein Amount 6 lbs Investigator VR + V

Precipitation Before or During Test 4-5" Rain on 5/18-19

site #	Detectors placed at	Date		5/7	9	12	15	19	21	22	27		
		Number of Days		-5	-3	0	3	7	9	10	15		
(2) 1	Auburn Waterworks Blue Hole				SET	/	-	-	/	-			
2	Pig Sp.					/	-	/	-	/			
3	Lee Sp					/	-	/	-	/			
4	Lagoon Sp.					/	-	/	-	/			
5	Bitch Sp					/	-	/	-	/			
6	Road Sp					/	-	/	-	/			
7	Watersnake Sp					/	-	/	-	/			
8A	Wigginton Cr. @ Cemetary Rd.				SET	/	-* Pulled						
8B	~~Mossy Sp.~~ Sp. (upstream from 8A)						SET	/	-	/			
9	Mud R. @ old school				SET	/	-	/	-	/			
10	Briggs Cr. @ Ky (1588)				SET	/	-	/	-	/			
11	Mud R. @ Stevenson Mill Rd.					SET	-	/	-	/			

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

(2) Extra set of bugs installed

Remarks: Injection sequence for all sinkhole tests:
Primer = 950 gal; Dye injected at start of 2nd 950 gal;
Chaser = 1900 gal. Total input = 3800 gallons
* Re-set @ E. Fork. See p. 3

Interpretation:

RECORD OF DYE TEST File # C-2 -1

Input Point (Name of test) _____ Date ____ Time ____

Tracer _____ Amount _____ Investigator ____

Precipitation Before or During Test _____

site #	Detectors placed at	Date, Number of days since dye input, and results											
		Date		5/7	9	12	15	19	21	22	27		
		Number of Days		-5	-3	0	3	7	9	10	15		
12	Blue Sp.					SET	—	/	—	/			
(2) 13	Spring Acres Sp.				SET	/	—	/	—	—			
14	Spring @ Rise of Mud R.				SET	/	—	/	—	/	—		
15	Duncan Tiled Sp				SET	/	—	/	++ (no bugs left)	Set A-pm	+		
16	Duncan Pumping Well					SET	— (Pulled)						
17	Duncan Natural Well				SET	/	—	/	+ (no bugs set)	Set A-pm	—		
18	Hulse Sp				↓	/	—	/	/	—			
19	Stamps Sp.					/	—	/	—	/			
20	Hall Sp.					/	—	/	—	/			
21	Black Lick Cr. above Hall Sp.					/	—	/	—	/			
22	Wigginton Cr. @ Ky (103)					/	—	—	—	/			
23	Gasper Cr. @ Ayers Rd				SET	/	—	/	—	/			

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- (2) Extra set of bugs installed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: _____

Interpretation: _____

RECORD OF DYE TEST

File # C-2 70

Input Point (Name of test) _____ Date _____ Time _____

Tracer _____ Amount _____ Investigator _____

Precipitation Before or During Test _____

Site #	Detectors placed at	Date, Number of days since dye input, and results											
		Date		5/7	9	12	15	19	21	22	27		
		Number of Days		-5	-3	0	3	7	9	10	15		
(2) 24	Crawford Sp. (Rice of Gasper R.)				SET	/	—	—	—	/			
25	Gasper R. @ Bucksville Rd				SET	/	—	/	/	/			
~~26~~	~~Wire Hole Sp~~												
27	Crooked Run @ White Rd				SET	/	Pulled						
28	Black Lick Cr. @ Ky (73)				SET	/	Pulled						
	"Joe's Bug", downstream from 20+21			SET	Pulled								
8C	E Fork of Wigginton Cr @ mossy Sp						SET	/	—	/			
37	Green Boiling Hole							Green flow dos. by Dumler					

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- (2) EXTRA set of bugs installed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: _____

Interpretation: _____

RECORD OF DYE TEST File # C-3 41

Input Point (Name of test) sinkhole 400 ft W SW of old house, Nena East edge of Caldwell land spreading site, Date 5/12/81 Time 1 pm
(Cataclysm within ST) @ E

Tracer Optical Brightener A Amount 2.5 gal Investigator VQ + JR

Precipitation Before or During Test 4-5" of Rain on 5/18-19

Site #	Detectors placed at	Date	5/5	7	9	12	15	19	21	22	27	30
		Number of Days	-9	-7	-3	0	3	7	9	10	15	18
(2) 1	Auburn Waterworks Blue Hole		SET	/	–	/	–	–	/	–	–	–
2	Pig Sp.			SET	–	/	–	/	–	/	–	–
3	Lee Sp			↓	–	/	+++	/	+++	+	+++	+++
4	Lagoon Sp.				Pool –	/	–	/	–	/	–	–
5	Bitch Sp				–	/	–	/	–	/	–	–
6	Road Sp				–	/	–	/	–	/	–	–
7	Watersnake Sp			SET	–	/	–	/	–	/	–	–
8A	Wigginton Cr. @ Cemetary Rd.		SET	/	–	/	Moved to 8B	/	–	/	–	–
8B	~~East~~ Mossy Sp. (upstream from 8A)						SET	/	–	/	–	–
9	Mud R. @ old school		SET	/	–	/	–	/	–	/	–	–
10	Briggs Cr. @ Ky. (1588)		SET	/	–	/	–	/	–	/	–	–
11	Mud R. @ Stevenson Mill Rd.					SET	–	/	–	/	–	–

Legend:
- – Negative Result
- + Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

(2) Extra set of bugs installed 5/12

Remarks: Lee Sp flooded by discharge ~ 15 minutes after start of test. Rained out on 5/19

Interpretation:

RECORD OF DYE TEST

File # C-3 42

Input Point (Name of test) _____ Date 5/4 Time _____

Tracer DB Amount _____ Investigator _____

Precipitation Before or During Test _____

Site #	Detectors placed at	Date	5/5	7	9	12	15	19	21	22	27	30
		Number of Days	-9	-7	-3	0	3	7	9	10	15	23
12	Blue Sp.					SET	-	/	-	/	-	-
(2) 13	Spring Acres Sp.		SET	/	-	/	-	/	-	-	=	-
14	Spring @ Rise of Mud R.		SET	/	-	/	-	/	-	/	-	-
15	Duncan Tiled Sp			SET	-	/	++	/	++	+	+++	+++
16	Duncan Pumping Well					SET	- Pulled					
17	Duncan Natural Well				SET	/	++	/	+	+B	+	++
18	Hulse Sp			SET	-	/	-	/	/	-	/	-
19	Stamps Sp.		SET	/	-	/	-	/	-	/	-	-
20	Hall Sp.		↓	/	-	/	DRY - *	/	-	/	/	/
21	Black Lick Cr. Above Hall Sp.			/	-	/	B+	/	B	/	/	/
22	Wigginton Cr. @ Ky (103)			/	-	/	-	-	-	/	-	-
23	Gasper Cr. @ Ayers Rd		SET	/	-	/	-	/	-	/	Pulled	

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- (2) Extra set of bugs installed 5/9
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: * Disturbed; dry

Interpretation: _____

RECORD OF DYE TEST

File # C-3 43

Input Point (Name of test) _____ Date 5/12 Time _____

Tracer OB Amount _____ Investigator _____

Precipitation Before or During Test _____

Site #	Detectors placed at	Date	5/5	7	9	12	15	19	21	22	27	30		
		Number of Days	-9	-7	-3	0	3	7	9	10	15	18		
(2) 24	Crawford Sp. (Rise of Gasper R.)		SET	/	High Bkgd	High Bkgd	B+	–	B	/	B	B–		
25	Gasper R. @ Bucksville Rd		SET	/	Slight Bkgd	/	B	/	/	/	–	/		
26	Wire Hole Sp				SET	PULLED								
27	Crooked Run @ White Rd		SET	/	–	/	PULLED							
28	Black Lick Cr. @ Ky (73)		SET	/	–	/	PULLED							
	Joe's Bug @ Black Lick Cr below Hall Sp			SET	High Bkgd PULLED									
	Crawford Blue Hole (Estavelle functions only after RAIN		SET	/	TR Bkgd PULLED									
36	E Fork of Wigginton Cr @ Mossy Sp						SET	/	–	/	–	–		
37	Green Boiling Hole									Set	+	–		

Legend:
- – Negative Result
- + Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- (2) EXTRA set of bugs installed 5/12
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: _____

Interpretation: _____

RECORD OF DYE TEST

File # Calaveras #4 44

Input Point (Name of test) Duncan Ponor Date 5/22/81 Time 2pm

Tracer Direct Yellow #96 Amount 1/2 gm Investigator JAR

Precipitation Before or During Test

Detectors placed at	Date, Number of days since dye input, and results													
	Date	5/22	24	27	30									
	Number of Days	0	2	5	8									
30. Coy Blue Hole		sat	++	+	+tr									
31. SE Fork, Above Coy Sp		|	/	-	-									
32. Coy Sp		|	/	-	-									
33. NE Fork, above confluence		|	/	-	-									
34. NW Fork, above confluence		|	/	-	-									
35. Coy Natural Well		|	++	+	+									
36. Just above Oakes Ponor		|	/	++	-									
14. Sp. at Rise of Mud R		↓	+	+?	+									

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: Positive Results @ 14 are a Result of Test #5, Also using DY

Interpretation:

RECORD OF DYE TEST

File # Cadwell #5 45

Input Point (Name of test) Onkes Manor

Date 5/22/81 Time 3pm

Tracer Direct Yellow #96 Amount 3 gal Investigator JAR

Precipitation Before or During Test

Detectors placed at	Date, Number of days since dye input, and results													
	Date	5/21	24	27	30									
	Number of Days	-1	2	5	8									
9. Mud R. @ old school		Set	/	++	-									
11. Mud R @ Stevenson Mill Rd		|	/	++	-									
12. Blue Sp		|	/	-	-									
13. Spring Across Sp		|	/	-	-									
14. Spring @ Rt of Mud R.		|	++	+?	-									
29. Mo #3 Lich Gr @ Hwy 79		↓	/	-	/									

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks:

Interpretation:

INPUT SITE "F"

RECORD OF DYE TEST

File # Caldwell #6

Input Point (Name of test) "F", Steve Wilson property, Date 5/27/81 Time 11:30 Am

Tracer Direct Yellow #96 (N Ky 1039) Amount 5 gal (10 lbs) Investigator JQ+JAR

Precipitation Before or During Test

	Detectors placed at	Date, Number of days since dye input, and results												
		Date	5/27	5/30										
		Number of Days	0	3										
1	Auburn Waterworks BH		-	-										
2	Pig. S		-	-										
4	Lagoon Sp		-	-										
5	Birch Sp		-	-										
6	Road Sp		-	-										
39	Thomas Sp		Set	-										
7	Watercress Sp		-	-										
8B	Mossy Sp		-	-										
8C	E Fork of Wigginton @ 8B		-	-										
40	Belcher Dugwell		Set	*/										
41	Belcher Fork		Set	-										
14	Sp. @ head of Mud R.		-	-										

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: * Shotgun fired

Interpretation:

RECORD OF DYE TEST File # Colwell #6

Input Point (Name of test) "F" Stear Wilson Property Date 5/27 Time ____

Tracer DY Amount ____ Investigator ____

Precipitation Before or During Test ____

	Detectors placed at	Date, Number of days since dye input, and results												
		Date	5/27	5/30										
		Number of Days	0	3										
36	Just above Oatney Cr. Ponor		-	-										
16	Duncan Pumping Well		-	-										
15	Duncan Filled Sp		-	-										
37	Green Boiling Hole		-	-										
17	Duncan Natural Well		-	-										
35	Coy Wright Natural Well		-	-										
30	Coy Wright Blue Hole		-	-										
33	NE Fork, above Confluence		-	-										
34	NW Fork, above confluence		-	-										
19	Stamps Sp..		-	-										
22	Wigginton GQ Ky (103)		-	-										
38	Sycamore Fork of Wigg. Cr.		-	-										

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: ____

Interpretation: ____

RECORD OF DYE TEST

File # Caldwell #6

Input Point (Name of test) F (Steve Wilson Property) Date 5/27 Time ____

Tracer DY Amount ____ Investigator ____

Precipitation Before or During Test ____

	Detectors placed at	Date, Number of days since dye input, and results													
		Date	5/27	5/30											
		Number of Days	0	3											
2/4	Crawford Sp @ R. in of trans. A			++											
1/2	Barnett Sp		Set	++											
1/5	Well House Sp			Set											
1/3	Barnett Pumping Well		Set	-											
1/4	Charlotte Sp		Set	DAY Hot Run											

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: ____

Interpretation: ____

Input Site M

RECORD OF DYE TEST Dedee

File # Caldwell #7

Input Point (Name of test) "M", Mrs. ~~Daddy~~ Hall

Date 5/27/81, Time 2PM

Tracer Fluorescein

Amount 7 lbs

Investigator JQ+VAR

Precipitation Before or During Test

	Detectors placed at	Date, Number of days since dye input, and results												
	Date	5/27	5/30	6/2	6/7	6/8								
	Number of Days	0	3	6	7	12								
1	Auburn Waterworks B/U	Set	-	/	-	/								
11	Lagoon Sp	|	////	/	////	++								
5	Bluth Sp	|	-	/	/	/								
6	Round Sp	|	-	/	/	-								
39	Thomas Sp	|	-	/	/	-								
7	Waterwheel Sp	|	-	/	-	-								
3.3	Mossy Sp	|	-	-	/	-								
56	E. Fork of Wiggington @ 88	|	-	-	/	faint +								
40	Baldon Dug Well	|	*	/	-	/								
41	Baldon Fork	|	-	/	/	-								
111	Sp @ head of Mud R.	↓	-	/	-	-								
20	Just above Oakey Ponor	NM Set	/	/	V. faint +	/								

(from old test)

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: * Shotgun fired

Interpretation:

RECORD OF DYE TEST File # Caldwell #1

Input Point (Name of test) M (Mrs. Delty Hall) Date 5/27 Time ____

Tracer Fluor Amount ____ Investigator ____

Precipitation Before or During Test ____

	Detectors placed at	Date, Number of days since dye input, and results												
		Date	5/27	5/30	6/2	6/3	6/8							
		Number of Days	0	3	6	7	12							
16	Duncan Pumping Well		Set	–	/	–	/							
15	Duncan Tiled Sp		+	+	/	+	+							
37	Green Boiling Hole		Set	+	/	+	+							
17	Duncan Natural Well		–	? –	/	–	–							
35	Coy Wright Natural Well		Set	– ?	/	–	–							
30	Coy Wright Blue Hole			+	–	/	V. + St. int							
33	NE Fork, above Confluence			+	/	No 7 + 7 Spec	/							
34	NW Fork, above confluence			–	/	/	/							
22	Wigginton Cr @ Ky 103			–	/	–	–							
8	Sycamore Fork of Wigg. Cr			–	/	/	–							
21	Crawford Sp @ Rise of Grassy R			–	/	–	–							
12	Barnett Sp		↓	–	/	–	/							

Legend:
- – Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: Positive Results at #15, 30, 33 & 37 are the "tail" of dye from Test #2, but they could also be from this Test. Positives are very faint. Negative results @ #17 & 35 might be related to low

Interpretation: velocity of flow of water

RECORD OF DYE TEST

File # Caldwell #7

Input Point (Name of test) M (Mrs Duffy Hall) Date 5/27 Time ____

Tracer Flour Amount ____ Investigator ____

Precipitation Before or During Test ____

	Detectors placed at	Date, Number of days since dye input, and results												
	Date	5/27	5/30	6/2	6/3	6/8								
	Number of Days	0	3	6	7	12								
45	Well House Spo		Sat	/	-	/	Water too high; could not recover							
43	Bennett Pumping Well	Sat	-	/	-	/								
44	Charlotte Spo	Sat	-	/	-	/								

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: ____

Interpretation: ____

Input 5,4 N

RECORD OF DYE TEST File # Caldwell #8

Input Point (Name of test) Hughs Ponor Date 6/3/81 Time ____

Tracer DY 96 Amount 1 Gal Investigator VAR

Precipitation Before or During Test ____

	Detectors placed at	Date, Number of days since dye input, and results												
		Date	6/3	6/8										
		Number of Days	0	5										
48	Craig Blue Hole		Sat	-										
49	Craig Fishhole Sp		↓	-										
50	Craig Swamp		↓	-										
30	Coy Wright Blue Hole		/	-										
35	Coy Wright Natural Well		-	-										
22	Coy Wright Spring		-	+++										

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: ____

Interpretation: ____

Input 8, to 0

RECORD OF DYE TEST

File # Caldwell #9

Input Point (Name of test) Kinkaid Power Date 6/3/81 Time ____

Tracer Optical Brightener (CBS-X) Amount 3 lbs Investigator ____

Precipitation Before or During Test ____

	Detectors placed at	Date, Number of days since dye input, and results												
	Date	5/30	6/3	6/8										
	Number of Days	-4	0	5										
2	Atchley Sp (= Aj Sp)	-	/	+++										
1	Auburn Water Works	-	/	-										
10	Hall Sp		Sat	-										
21	Black Lick Cr above Hall Sp		B	—	could not Recover; water too high									
14	Crawford Sp	A	B	B+										
9	Barnett Sp	-	-	-										
4	Charlotte Sp	-	-	-										

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: ____

Interpretation: ____

Input Site "P" 54

RECORD OF DYE TEST File # Caldwell #10

Input Point (Name of test) Chilas Ponor Date 6/3/81 Time ____

Tracer Dy-96 Amount 2 lbs Investigator ____

Precipitation Before or During Test ____

	Detectors placed at	Date, Number of days since dye input, and results												
		Date	6/3	6/8										
		Number of Days	0	5										
46	Collins Sp		set	+++										
47	Rossiter River K. Window		|	−										
51	Cockpit Entrance		↓	+										
13	Spring Above Sp		set	+										
14	Rice of Mud Rim		−	+										

Legend:
- − Negative Result
- + Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: ____

Interpretation: ____

. RECORD OF DYE TEST Site "Q" File # Caldwell #1

Input Point (Name of test) Pulley Ponor Date 6/3/81 Time ____

Tracer OB (CBS-X) Amount 3 lbs Investigator ____

Precipitation Before or During Test ____

	Detectors placed at	Date, Number of days since dye input, and results													
		Date	6/3	6/8											
		Number of Days	0	5											
17	Roaring River K. Wind	Set	++												
16	Collins Sp		-												
51	Cockrill Sp		++												
13	Sp along Acres Sp		++												
14	Rise of Mud Run		++												

Legend:
- - Negative Result
- + Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: ____

Interpretation: ____

RECORD OF DYE TEST Site "L" File # Caldwell #2

Input Point (Name of test) Oakes Power Date 6/3/81 Time ____

Tracer DY Amount 1.5 gal = 3 lbs Investigator ____

Precipitation Before or During Test ____

Detectors placed at	Date, Number of days since dye input, and results												
	Date	6/3	6/8										
	Number of Days	0	5										
T2 Gibbs Cave		set	-										

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: Bug I was set in "stilling well" pool. Even though results were negative there could be a flood-water connection.

Interpretation: ____

RECORD OF DYE TEST Site "S" File # Caldwell 13

Input Point (Name of test) Atchley Sp (Old Pig Sp) Date 4/12/82 Time ____

Tracer DY Amount 3 3/4 gal = 8 lbs Investigator VAR

Precipitation Before or During Test ____

	Detectors placed at	Date, Number of days since dye input, and results												
		Date	4/12	4/15										
		Number of Days	0	3										
12	Bennett Sp	Set	-											
45	Millhouse Sp	|	-											
54	Crawford Sp	|	+											
53	Blackjack Cr. @ Ponor	|	-											
2	Hall Sp	|	-											
1	Auburn Water Works BH	|	-											
	Roberson B.H (Blowhole N of Hwy 68)	|	-											
	Pr. Sp (Window S of Hwy 68)	|	-											
	Flood Pond Sink-point (window)	|	-											
3	Wire Hole Sp	↓	++											

Legend:
- \- Negative Result
- \+ Positive
- ++ Very Positive
- +++ Spectacularly, Gloriously Positive
- / Bugs not changed
- B Background
- B+ Fluorescence Significantly above Background
- NR Not Recovered (because of high water or other reason)
- L Bug Lost or Stolen
- G New or Extra Gumdrop Installed

Remarks: 1

Interpretation: Water probably moves right up the joint to Wire Hole

APPENDIX B

Copy of Records of Dye Detectors Set, Recovered, and Tested -- and the Results of Tests

BUG SHEET -- Miscellaneous Sites

TEST Caldwell #1, 2, +3 RUN BY JQ DATE 5/5/81

J A # R	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	R G D
(2)					1. Auburn Waterworks Blue Hole			X	X	
					2. Pig Spring					
					3. Lee Spring					
					4. Lagoon Spring					
					5. Bitch Spring					
					6. Road Spring					
					7. Watersnake Spring					
					8A. Wigginton Cr. @ Cemetary Rd			X	X	X
					8B. ~~Last~~ Mossy Spring					
					9. Mud R. @ old school			X	X	X
					10. Briggs Cr. @ Ky (158B)			X	X	X
					11. Mud R. @ Stevenson Mill Rd.					
					12. Blue Spring					
(3)					13. Spring Acres Spring			X	X	X
					14. Spring at Rise of Mud R.			X	X	X
					15. Duncan Tiled Sp.					
					16. Duncan Pumping Well					
					17. Duncan Natural Well					
					18. Hulse Spring					
					19. Stamps Spring			X	X	
					20. Hall Spring			X	X	
					21. Black Lick Cr. above Hall Sp			X	X	
					22. Wigginton Cr. @ Ky. (103)			X	X	X
					23. Gasper Cr. @ Ayers Rd.			X	X	X
(2)					24. Crawford Sp. (Rise of Gasper R.)			X	X	X
					25. Gasper R. @ Bucksville Rd.			X	X	X
					26. Wire Hole Spring					
					27. Crooked Run @ White Rd			X	X	X
					28. Black Lick Cr. @ Ky. (73)			X	X	X
					Crawford Blue Hole (Estavelle)			X	X	X

BUG SHEET -- Miscellaneous Sites

TEST Caldwell #1, 2, +3 RUN BY JR DATE 5/7/81

J A R #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
(2)					1. Auburn Waterworks Blue Hole					
					2. Pig Spring			X	X	X
					3. Lee Spring			X	X	X
					4. Lagoon Spring					
					5. Bitch Spring			X	X	X
					6. Road Spring			X	X	X
					7. Watersnake Spring			X	X	X
					8A. Wigginton Cr. @ Cemetary Rd					
					8B. ~~Last~~ Mossy Spring					
					9. Mud R. @ old school					
					10. Briggs Cr. @ Ky (1588)					
					11. Mud R. @ Stevenson Mill Rd.					
					12. Blue Spring					
					13. Spring Acres Spring					
					14. Spring at Rise of Mud R.					
					15. Duncan Tiled Sp.			X	X	X
					16. Duncan Pumping Well					
					17. Duncan Natural Well					
					18. Hulse Spring			X	X	X
					19. Stamps Spring					
					20. Hall Spring					
					21. Black Lick Cr. above Hall Sp.					
					22. Wigginton Cr. @ Ky. (103)					
					23. Gasper Cr. @ Ayers Rd.					
(2)					24. Crawford Sp. (Rise of Gasper R.)					
					25. Gasper R. @ Bucksville Rd.					
					26. Wire Hole Spring					
					27. Crooked Run @ White Rd					
					28. Black Lick Cr. @ Ky. (73)					
					Joe's Bug, below #28 on Blk. Lick			X	X	X

BUG SHEET -- Miscellaneous Sites

TEST Caldwell #1, 2, +3 RUN BY JQ + JR DATE 5/9/81

JAR #	AY73 Fluor. Charcoal	Rhod. WT	OB Cotton	DY96	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	K.D. Gum Drop
	—		—	—	1. Auburn Waterworks Blue Hole			X	X	
	—		—	—	2. Pig Spring			X	X	
	—		—	—	3. Lee Spring			X	X	
	—		—	—	4. Lagoon Spring			X	X	
	—		—	—	5. Bitch Spring			X	X	
	—		—	—	6. Road Spring			X	X	
	—		—	—	7. Watersnake Spring			X	X	
	—		—	—	8A. Wigginton Cr. @ Cemetary Rd			X	X	
					8B. ~~Lagoon~~ Mossy Spring					
	—		—	—	9. Mud R. @ old school			X	X	
	—		—	—	10. Briggs Cr. @ Ky (1588)			X	X	
					11. Mud R. @ Stevenson Mill Rd.					
					12. Blue Spring					
	—		—	—	13. Spring Acres Spring			X	X	X
	—		—	—	14. Spring at Rise of Mud R.			X	X	
	—		—	—	15. Duncan Tiled Sp.			X	X	
					16. Duncan Pumping Well					
					17. Duncan Natural Well			X	X	X
	—		—	—	18. Hulse Spring			X	X	
	—		—	—	19. Stamps Spring			X	X	
	—		—	—	20. Hall Spring			X	X	
	—		++ Bkgd		21. Black Lick Cr. above Hall Sp.			X	X	
	—		—	—	22. Wigginton Cr. @ Ky. (103)			X	X	
	—		—	—	23. Gasper Cr. @ Ayers Rd.			X	X	
	—		++ Bkgd	—	24. Crawford Sp. (Rise of Gasper R.)			X	X	
	—		+ Bkgd	—	25. Gasper R. @ Bucksville Rd.			X	X	
					26. Wire Hole Spring			X	X	X
	—		—	—	27. Crooked Run @ White Rd			X	X	
	—		—	—	28. Black Lick Cr. @ Ky. (73)			X	X	
12	—		++ Bkgd	—	Joe's Bug @ #21, but below Hall Sp	X	X			
	—		—	—	Crawford Blue Hole	X	X			

BUG SHEET -- Miscellaneous Sites

TEST Caldwell # 1, 2, & 3 RUN BY JQ + JR DATE 5/12/81

JAR #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Pesticide Analysis
(2)					1. Auburn Waterworks Blue Hole			X	X	X
					2. Pig Spring					
					3. Lee Spring					
					4. Lagoon Spring					
					5. Bitch Spring					
					6. Road Spring					
					7. Watersnake Spring					
					8A. Wigginton Cr. @ Cemetary Rd					
					8B. Mossy ~~Back~~ Spring					
					9. Mud R. @ old school					
					10. Briggs Cr. @ Ky (1588)					
					11. Mud R. @ Stevenson Mill Rd.			X	X	X
					12. Blue Spring			X	X	X
					13. Spring Acres Spring					
					14. Spring at Rise of Mud R.					
					15. Duncan Tiled Sp.					
					16. Duncan Pumping Well			X	X	
					17. Duncan Natural Well					
					18. Hulse Spring					
					19. Stamps Spring					
					20. Hall Spring					
					21. Black Lick Cr. above Hall Sp.					X
					22. Wigginton Cr. @ Ky. (103)					
					23. Gasper Cr. @ Ayers Rd.					
(2)					24. Crawford Sp. (Rise of Gasper R.)			X	X	
					25. Gasper R. @ Bucksville Rd.					
					26. Wire Hole Spring	X				
					27. Crooked Run @ White Rd					
					28. Black Lick Cr. @ Ky. (73)					
					29 Lagoon					X

BUG SHEET -- Miscellaneous Sites

53

TEST Caldwell #1, 2, & 3 RUN BY JAR DATE 5/15/81

Discharge plus Mea
S

J A R #	AY73 Fluor. Charcoal	Rhod. WT	OB Cotton	DY96	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	
(2) 1	—		—	—	1. Auburn Waterworks Blu Hole			XX	XX	
2	—		—	—	2. Pig Spring			X	X	
3	—		+++	—	3. Lee Spring			X	X	L
4	—		—	—	4. Lagoon Spring			X	X	L
5	—		—	—	5. Bitch Spring			X	X	L
6	—		—	—	6. Road Spring			X	X	L
7	—		—	—	7. Watersnake Spring			X	X	L
8	—		—	—	(8A) Wigginton Cr. @ Cemetary Rd	X	X			L
			—	—	8B. Mossy Spring			X	X	L
9	—		—	—	9. Mud R. @ old school			X	X	
10	—		—	—	10. Briggs Cr. @ Ky (158B)			X	X	
11	—		—	—	11. Mud R. @ Stevenson Mill Rd.			X	X	
12	—		—	—	(12) Blue Spring			X	X	X
(3) 13	—		—	—	13. Spring Acres Spring			XX	XX	
14	—		—	—	14. Spring at Rise of Mud R.			X	X	
15	—		+++	—	15. Duncan Tiled Sp.			X	X	
16	—		—	—	(16) Duncan Pumping Well	X	X			
17	—		+++	—	(17) Duncan Natural Well			X	X	
18	—		—	—	18. Hulse Spring			X	X	
19	—		—	—	19. Stamps Spring			X	X	
20	—	destroyed	—	dry	20. Hall Spring			X	X	
21	—		B+	—	21. Black Lick Cr. above Hall Sp			X	X	
22	—		—	—	22. Wigginton Cr. @ Ky. (103)			X	X	
23	—		—	—	23. Gasper Cr. @ Ayers Rd.			X	X	
(2) 24	—		B+	—	(24) Crawford Sp. (Rise of Gasper R.)			XX	XX	
2	—		B	—	25. Gasper R. @ Bucksville Rd.			X	X	
					~~26. Wire Hole Spring~~					
1	—		—	—	27. Crooked Run @ White Rd	X	X			
20	—		—	—	28. Black Lick Cr. @ Ky. (73)	X	X			
No Springs —			Not set		→ Downstream from #24 (3?)			X X X	X	

(8A) Move gunclogs to Last Sp. (8A). Mark location of LAST Sp. on Topo Map. Check for furth
(10-11) Sketch Hancock Lake onto topo map (also road) Measure SPC in ea
(12) Measure SPC of Blue Sp (5) & set gunclogs
(16) Turn off well water
(17) ~~Take compass bearing from Natural Well to House or barn. Record on~~
(24) Check for 3 possible springs on left @ 500', 1200', & 2200' downstream from Cr
Measure SPC & set gunclogs & bugsis > .1

BUG SHEET -- Miscellaneous Sites

TEST Caldwell #203 RUN BY JAR DATE 5/19/81

J A # R	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
(2) 10	-		-		1. Auburn Waterworks Blue Hole			X	X	
					2. Pig Spring					
					3. Lee Spring					
					4. Lagoon Spring					
					5. Bitch Spring					
					6. Road Spring					
					7. Watersnake Spring					
					8B. Mossy Spring					
					8C. E. Fork of Wigginton Cr. @ Mossy					
					9. Mud R. @ old school					
					10. Briggs Cr. @ Ky (1588)					
					11. Mud R. @ Stevenson Mill Rd.					
					12. Blue Spring					
					13. Spring Acres Spring					
					14. Spring at Rise of Mud R.					
					15. Duncan Tiled Sp.					
					16. Duncan Pumping Well					
					17. Duncan Natural Well					
					18. Hulse Spring					
					19. Stamps Spring					
					20. Hall Spring					
					21. Black Lick Cr. above Hall Sp.					
7	-		-		22. Wigginton Cr. @ Ky. (103)			X	X	
					23. Gasper Cr. @ Ayers Rd.					
(2) 19	-		Bt		24. Crawford Sp. (Rise of Gasper R.)			X	X	
					25. Gasper R. @ Bucksville Rd.					

Abbreviated schedule of pick ups because of 4-5" of Rain flooded everything. Mud River could not be reached.

BUG SHEET -- Miscellaneous Sites

TEST Caldwell #2 & 3 RUN BY VAR DATE 5/21/91

TRIP 65

JAR #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
(2)					~~1. Auburn Waterworks Blue Hole~~					
2	—		—		2. Pig Spring			X		
3	—		++++		3. Lee Spring			X		
4	—		—		4. Lagoon Spring			X		
5	—		—		5. Bitch Spring			X		
6	—		—		6. Road Spring			X	X	
7	—		—		7. Watersnake Spring			X	X	
8	—		—		8C. E. Fork of Wigginton Cr. @ BB			X	X	
1	—		—		8B. Mossy Spring			X	X	
9	—		—		9. Mud R. @ old school			X	X	
10	—		—		10. Briggs Cr. @ Ky (158B)			X		
11	—		—		11. Mud R. @ Stevenson Mill Rd.			X	X	
12	—		—		12. Blue Spring			X	X	
13	—		—		13. Spring Acres Spring			XX	XX	X?
14	—		—		14. Spring at Rise of Mud R.			X	X	
15	++++		++++		15. Duncan Tiled Sp.			X		
					~~16. Duncan Pumping Well~~					
17	+		++		17. Duncan Natural Well			X		
					~~18. Hulse Spring~~					
19	—		—		19. Stamps Spring			X		
20	—		—		20. Hall Spring			X		
21	—		B		21. Black Lick Cr. above Hall Sp.			X		
22	—		—		22. Wigginton Cr. @ Ky. (103)			X		
23	—		—		23. Gasper Cr. @ Ayers Rd.			X		
(2) 24	—		—		24. Crawford Down Sp. (Rise of Gasper R.)			X		
					~~25. Gasper R @ Bunkerville Rd~~			X		
					29 Moths Lick Cr @ 79			X		X
16	—		B		24. Crawford Sp (Up)					

BUG SHEET -- Miscellaneous Sites

Friday 66

TEST Caldwell #2, 3, 4, & 5 RUN BY JAR DATE 5/22/81

TA R #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
1	—		—		1 Auburn Waterworks Sp		X	X		
			+		3. Lee Sp			X		
13.	—		—		13. Spring Acres Sp (low)		X	X		
					13 Spring Acres Sp (High)			X		X
			+		15. Duncan Tiled Sp		X	X	X	
			+B		17 Duncan Natural Well		X	X	X	
18	—		—		18. Hulce Sp		X	X		
					30. Coy Blue Hole			X		X
					31. SE Fork, above Coy Sp			X		X
					32. Coy Sp			X		X
					33. NE Fork, above confluence			X		X
					34. NW Fork, above confluence			X		X
					35. Coy Natural Well			X		X
					36. Just above Onken Spring			X		X
					37. Green Boiling Hole			X		X
					K. Duncan Ponor					
					L. Onken Ponor					

Check for other springs near Duncan

Rig bucket @ Coy Wright Well?

Drop: ½ gal DY @ Duncan Ponor = K = Test #4

3 gal DY @ Onken Ponor = L = Test #5

Coy Wright's drilled well was not bugged because it doesn't get turbid after rains

BUG SHEET -- Miscellaneous Sites

Survey 67

TEST Caldwell #485 RUN BY VFQ DATE 5/24/81

JAR #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
				+	14, Sp. @ R. Lg of Mud R.			X		
				+	30. Cey Blue Hole			X		
				+	35 Cey Natural Well			X		

BUG SHEET -- Miscellaneous Sites

68

TEST Caldwell # 6 & 7 RUN BY JAR+VQ DATE 5/27/81

J A R #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
			=	=	1. Auburn Waterworks Blue Hole			X X	X X	
			—	—	2 Pig Sp			X	X	
			##	—	3 Lee Sp			X	X	
			—	—	4. Lagoon Sp			X	X	
			—	—	5. Bitch Sp			X	X	
			—	—	6. Road Sp			X	X	
See Map			—	—	39 Thomas Sp			X	X	
			—	—	7. Watersnake Sp			X	X	
			—	—	8B Mossy Sp			X	X	
			—	—	8C. E. Fork of Wigginton Cr @ 8B			X	X	
			—	+	9. Mud R. @ old school			X	X	
			—	—	10. Briggs Cr @ 158B	X	X			
			—	+	11. Mud R @ Stevenson Mill Rd			X	X	
			—	—	12. Blue Sp			X	X	
			=	=	13. Spring Acres Sp			X X	X X	
14	—		—	+?	14. Spring @ Rise of Mud R.			X	X	
15	+		##	—	15. Duncan Tiled Sp			X	X	
			#	—	37. Green Boiling Hole			X	X	
			/	/	16. Duncan Pumping Well			X	X	X
17	—		+Wo Strm	—	17. Duncan Natural Well			X	X	
					18. Hulse Sp			X	X	
			—	—	19. Stamps Sp			X	X	
			—	—	20. Wigginton Cr. @ 103			X	X	
Map			—	—	38. Sycamore Fork of Wigginton Cr			X	X	
			B-	—	24. Crawford Sp (Rise of Grasper R.)			X X	X X	
			—	—	23. Grasper Cr @ Ayers Rd	X	X			
			—	—	25. Grasper R @ Buckeville Rd	X	X			
			—	—	29. Motts Lick Cr @ (79)	X	X			
			B	+Tr	30. Coy (White) Blue Hole			X	X	
			—	—	31. SE Fork, above Coy Sp			X	X	
			—	—	32. Coy (Wright) Sp			X	X	
			—	—	33. NE Fork, above confluence			X	X	
			—	—	34 NW Fork, above confluence			X	X	
			—	—	35 Coy Natural Well			X	X	
			—	+	36 Just above Oakes Power			X		

BUG SHEET -- Miscellaneous Sites

TEST _____ RUN BY VFQ DATE 5/27/81

J A R #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
					40 Belcher Dug Well			X	X	X
					41 Belcher Fork			X	X	X
					42 Barrett Sp			X	X	X
					43 Barrett Ranging Well + Sp			X	X	X
					44 Charlotte Sp.			X	X	X

BUG SHEET -- Miscellaneous Sites

TEST Caldwell #6 & 7 RUN BY JAR DATE 5/30/81

J A # R	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Dro
1	–		–	–	1. Auburn Water works B.H			XX	XX	
2	–		–	–	2. Pig Sp		X	X		
3	–		+++	–	3. Lee Sp		X	X		
4	++++		–	–	4. Lagoon Sp			X	X	
5	–		–	–	5. Bifed Sp			x	x	
6			–	–	6. Road Sp			x	x	
39	–		–	–	39. Thomas Sp			X	X	
7	–		–	–	7. Waterworks Sp		X		X	X
8	–		–	–	8B. Mossy Sp		X		X	
9	–		–	–	8C. E Fork of Wiggington @8B		X		X	
	Shotgun fired				40. Balcher Dug Well	shotgun fired			X	
8	–		–	–	41. Balcher Fork				X	
9	–		–	–	9. Mud R @ old school	X	X			
11	–		–	–	11. Mud R @ Stevenson Mill Rd	X	X			
12	–		–	–	12. Blue Sp	X	X			
13	–		–	–	13. Spring Acres Sp	XX	XX			
14	–		–	–	14 Sp @ head of Mud R			X	X	
	No bug		–	–	36. Just above Oakes Ponds			X	X	
16	–		–	–	16. Duncan Pumping Well			X	X	
15	+		+++	–	15. Duncan Tiled Sp			X	X	
15	+		–	–	37. Green Boiling Hole			X	X	
17	–?		++	–	17. Duncan Natural Well			X	X	
18	–		–	–	18. Hulse Sp			X	X	
20	–		+	–	35. Coy Wright Natural Well			X	X	
21	+		+	–	30. Coy Wright Blue Hole			X	X	
23	–		–	–	32. Coy Wright Sp			X	X	
24	–		–	–	31. SE Fork above Coy Wright Sp			X	X	
4	+		–	–	33. NE Fork (camp Branch) above confluence			X	X	
5	–		–	–	34. NW Fork, above confluence	X	X			
19	–		–	–	19. Stamps Sp		X	X		
22	–		–	–	22. Wigginton Creek (103)			X	X	
7	–		–	–	38. Sycamore Fork of Wigg. Cr			X	X	
24	–		–	++	24. Branford Sp (Rich of Stage Rd)			XX	XX	
16	–		–	++	42. Bad well Sp			X	X	
18	–		–	–	43. Barnett Pumping well (Well house Sp.)			X	X	X
20	–		–	–	44. Charlotte Sp			X	X	

(12)

BUG SHEET -- Miscellaneous Sites

11

TEST _____ RUN BY VFQ DATE 6/2/81

J A # R	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cott-on	Hang Char-coal	Rig Gum Drop
9	—				Coy Wright Blue Hole				X	
11	—				Mossy Sp (8B)				X	
12	—				Wigginton Cr @ 8B				X	

BUG SHEET -- Miscellaneous Sites

TEST _____ RUN BY JAR DATE 6/3/81

JAR #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
			+++		3 Lee Spr			X		
→	++++		–		4 Lagoon Spr Locate ponor			X	X	
6	–		–		7 Watersnake Spr				X	
→ 1	? + ?		–		33 NE Fork, above conf Locate Spr			X	X	
13	–		–		35 Coy Wright Natural Well			X	X	
12	–		–		40 Belcher Dug Well from Jim M.		X		X	
9	–		–		32 Coy Wright Spr			X		
11	–		–		31 Craig Branch, above 32	X	X			
4	–		–		16 Duncan Pumping Well	X	X			
15	+		+++		15 Duncan Tiled Spr			X	X	
16	+		–		37 Green Boiling Hole			X	X	
17	–		+		17 Duncan Natural Well			X	X	
					48 Craig Blue Hole			X		X
					49 Craig Spr			X		X
					52 Gibbs Cave check Land Jim			X	X	X
					51 Cockrell Ent to Graham Cave			X		X
					46 Collins Spr			X		X
					47 Roaring River KW			X		X
	+ very faint		–	–	36 Just above Oakley Ponor			X	X	
14	–		–	–	14 Spr @ head of Mud R			X	X	
					13 Spring Acres Spr			XX		
7	–		–	–	1 Auburn Waterwork Spr		XX	XX		
					20 Hall Spr		X	X		
			B	–	21 Blackhich Graham Hall Spr		X	X		
8	–		–	+++	45 Well House Spr			X		
5	–		–	+	42 Barnett Spr			X		
10	–		–	–	44 Charlotte Spr			X		
3	–		–	–	43 Barnett Pumping Well	X	X			
22	–		–	–	22 Wigginton Cr @ 103			X	X	
24	–		B	+	24 Crawford Spr			XX	XX	
5				1gal	N Hughes Ponor	By Jean Scott				
9	Ask Jim to drop		3lbs		O Kinkaid Ponor					
Drops 10				1gal	P Chiley Ponor	with Jim			Rinsed	
→ 11	Ask Jim to drop		3lbs		Q Pulley Ponor marker mine					
12			1.5gal		L Oakley Ponor		(14)			

Hughes Ponor (N) set

Hi Dropp Kinkaid (O)

Chiley Ponor (P)

Pulley Ponor (Q) Jim

Oakley Ponor

BUG SHEET -- Miscellaneous Sites

TEST Caldwell RUN BY JAR DATE 6/?/91

JAR #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
			–	–	'Auburn Waterworks Sp.			XX	XX	
			##	–	2 Pig Sp = Atchley Sp	X	X			
			##	–	3. Lee Sp			X		
4	#		–	–	4. Lagoon Sp (corn + soybeans)				X	
6	–		–	–	6. Road Sp				X	
2	–		–	–	39. Thomas Sp	X	X			
7	–				7. Waterpark Sp	X	X			
8	–				8B. Moss Sp				X	
9	+ faint				8C. Wigginton Cr @ 8B				X	
1	–				41. Bulcher Fork	X	X	Bug dry (lots)		
13	–		–	–	35. Coy Natural Well	X	X			
3	+ faint		B	–	30 Coy Blue Hole			X	X	
			–	##	32 Coy Sp.			X		
15	+		##		15 Duncan Tile Sp			X	X	
17	–		+		17 Duncan Natural Well			X		
11	–		–	–	48 Craig BH (closest to 68)			X		
10	–		–	–	50 Craig Swamp Sp (from swamp)			X		
	water clear off tray	leaf off Rack	–	–	49 Craig Fish hole			X		
Get June Insect Recon			–	–	52 Gibbs Cave (Try)	X	X			
14	–		#	+	14 Rise of Mud R			XX	XX	
			#	+	13 Spring Acres Sp			X		
			#	+	51 Cochneil Sp			X		
			–	##	46 Colling Sp			X		
			#	–	47 Roaring R (Deep Igneous)			X		
			–	–	20 Hall Sp			X		
Could not recover; water too high					21 Black Lick Cr, Atom Hollow Sp			X		
			–	–	44 Charlotte Sp	X	X			
			–	##	42 Bassett Sp	X	X			
(15) could not recover; water too high					45 Well House Sp			X		
24	–		B+	–	24 Cleveland Sp			XX		
12	–		–	–	38 Sycamore Fork	X	X			
22	–		–	–	22 Wigginton Cr @ 103			X	X	
5	+		B	–	37 Green Boiling Hole				X	
Not done										

→ Dye Drop: Igneous @ Roaring River (some flow; you can't tell that Richland Creek was from Glover Work's seep)

→ Recon: ch Glover Ponor + Blue Hole for suitability of dye

BUG SHEET -- Miscellaneous Sites

TEST _____ RUN BY _____ DATE 3/9/82

J A R #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cott-on	Hang Char-coal	Rig Gum Dro;
					5 Auburn Water Works Sp	X				
					3 Lee Sp	X				
					4 Lagoon Sp	X				
					6 Road Sp	X				
					8B Mossy Sp	X				
					8C Wigginton Gr @ 8B	X				
					30 Coy Blue Hole	X				
					32 Coy Sp	X				
					33 Duncan Blue Hole Sp	X				
					17 Duncan Natural Well	X				
					48 Craig Blue Hole	X				
					49A Craig Swamp Sp	X				
					49B Craig Fish Hole	X				
					14 Rice of Mud R	X				
					13 Spring Acres Sp	X				
					46 Collins Sp	X				
					20 Hall Sp	X				
					21 Black Lick Gr, Hawthorne	X				
JS	it used?		Find out		45 Well House Sp	X	X			
					24 Crawford Sp	X				
					22 Wigginton Gr @ 103	X				
	1515				84833					
	11.				84717					
	6 hrs				116 miles					
					16					

BUG SHEET -- Miscellaneous Sites

TEST Ashley ~~Pig~~ Spring (Caldwell) RUN BY VAR DATE 4/12/82

J A # R	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
		42			Barnett Sp.			✓		
		45			Well house Sp			✓		
		24			Crawford Sp			✓		
		53			Black Lick Cr, @ Ponor			✓		
		20			Hall Sp			✓		
		21			Black Lick Cr, above Hall			✓		
		1			Auburn Waterworks, BH			✓		
		1			Auburn Waterworks, BH					
		54			Rte 68 Spring (Price)					
		55			Rte 68 Blue Hole (Robertson)					
		56			Ephemeral Pond (Lawrence)					
		~~56~~			~~Ephemeral Pond~~			✓		
		26			Wire Hole Sp			✓		
					~~(illegible)~~					

2) Measure Width level on Caldwell ~~Sp~~.

1) NR Leaves Property Inc
2) Other Monitor well
3) Old house by dye input

(This is a che

→ 1) Recon: A. Ponor of Lagoon Sp

B. Logan Sp + downstream thereof. There could be several springs (walk entire channel both Logan Sp confluence at Moss Sp + highway 1039.)

~~3) Sketch outline of Pond on topo~~

4) Get Name for Pig Sp (Property owner)

5) ~~Check accessibility of input above Dennettied Sp~~ Use 3¾ gallons ΔY

(17)

6) ~~Buy Uncle Hank St Bartram Place~~ Buy 2 bottles Rhodamine 6GX

BUG SHEET -- Miscellaneous Sites

TEST Atchley Sp (old Caldwell B.G Sp) RUN BY VMR DATE 4/15/82

J A # R	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
			–	–	42 B Arnett Sp	X	X			
			–	–	45 Well house Sp			X		
		B	–	+	24 Crawford Sp			X		
		B	+	–	53 Black Lick Cr, @ ponor	X	X			
			–	–	20 Hall Sp	X	X			
		B	+	–	21 Black Lick Cr, Adam Hall Sp	X	X			
			–	–	1 Auburn BH	X	X			
		B	+	–	54 Price Sp #2	X	X			
			–	–	55 Robertson Blue Hole	X	X			
			–	–	56 Flood-pond sink-point	X	X	– DRY ←		
			–	+	26 Wine Hole Sp			X		
			–	–	1 Auburn BH (#2)	X	X			

Measure water levels on Caldwell property

1) Near Recon Property line (Caldwell Obs. well #2
2) Other monitoring well (Caldwell Obs. Well #1
3) Old house by OB dye input (already measu

4-15-82
1530
1000
5½ hr

86871
86765
106 miles

(1) We mailed [illegible] (pulled all bugs)

(2) Can't go [illegible] but [illegible] weekend.

(3) [illegible]

18

Bud Shell - Miscellaneous Sites

Ashley

TEST ~~Pig~~ Spring (Caldwell) RUN BY VAR DATE 4/12/32

J A # R	AY73 Fluor. Charcoal	Rhod. WT Charcoal	QB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Dro
		42			Barnett Sp.			✓		
		45			Well house Sp			✓		
		24			Crawford Sp			✓		
		53			Black Lick Cr, @ Ponor			✓		
		20			Hall Sp			✓		
		21			Black Lick Cr, above Hall			✓		
		1			Auburn Waterworks BH			✗		
		1			Auburn Waterworks BH					
		54			Rte 68 Spring (Price)					
		55			Rte 68 Blue Hole (Robertson)					
		56			Ephemeral Pond (Twinches)					
		~~56~~			~~Ephemeral Pond~~			✓		
		26			Wire Hole Sp			✗		
					~~(illegible)~~					

2) Measure Water level on Caldwell ~~sp~~.

1) NR leaves Property In
2) Other Monitor well
3) Old house by dye input (This is a che

→ 1) Recon: A. Ponor of Lagoon Sp

B. Lagoon Sp + downstream thereof. There could be several springs (wolfe entire channel both Lagoon Sp confluence at Moss Sp + highway 1039.)

~~3) Sketch outline of Pond on topo~~

4) Get Name for Pig Sp (Property owner)

5) Check accessibility of input above Denominated Sp
Use 3¾ gallon DY

(17)

6) Buy ~~black paint at Bellefonte~~ Hdwe
~~2 bottles Rustoleum 6xx~~

BUG SHEET -- Miscellaneous Sites

TEST Atchley Sp (Caldwell old B & S Sp) RUN BY VAR DATE 4/15/82

J A R #	AY73 Fluor. Charcoal	Rhod. WT Charcoal	OB Cotton	DY96 Cotton	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Pig Gum Drop
			-	-	42 B Arnett Sp	X	X			
			-	-	45 Wolf Town Sp			X		
		B	+	+	24 Crawford Sp			X		
		B	+	-	53 Black Lick Cr, @ ponor	X	X			
			-	-	20 Hall Sp	X	X			
		B	+	-	21 Black Lick Cr, above Hall Sp	X	X			
			-	-	1 Auburn BH	X	X			
		B	+	-	54 Price Sp	X	X			
			-	-	55 Robertson Blue Hole	X	X			
			-	-	56 Flood-pond sink-point	X	X	- DRY		
			-	+	26 Wire Hole Sp			X		
			-	-	1 Auburn BH (#2)	X	X			

Measure water levels on Caldwell property

1) Near Reeves Property line (Caldwell Obs. well #2

2) Other monitoring well (Caldwell Obs. Well #1

3) Old house by OB dye input (already measu

4-15-82
1530
1000
5½ (D_)

86871
86765

106 miles

(1) We mail[illegible] pulled [illegible]

(2) Can't go [illegible] but [illegible] worked.

(3) [illegible]

18

BUG SHEET -- Miscellaneous Sites

TEST _____ RUN BY VFQ DATE 5/27/81

JAR #	AY73 Fluor.	Rhod. WT	OB	DY96	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Drop
	Charcoal		Cotton							
					40 Belcher Dug Well			X	X	X
					41 Belcher Fork			X	X	X
					42 Barnett Sp			X	X	X
					43 Barnett Ranging Well + Sp			X	X	X
					44 Charlotte Sp.			X	X	X

11

Bug SHEET -- Miscellaneous Sites

TEST Caldwell #6 v 7 RUN BY JAR DATE 5/30/81

J A R #	AY73 Fluor. Charcoal	Rhod. WT	QB Cotton	DY96	Location	Pull Gum Drop	Pull All Bugs	Hang Cotton	Hang Charcoal	Rig Gum Dro
1	—		—	—	1. Auburn Water works B.H			XX	XX	
2	—		—	—	2. Pig Sp		X	X		
3	—		+++	—	3. Lee Sp		X	X		
4	++++		—	—	4. Lagoon Sp			X	X	
5	—		—	—	5. Bitch Sp			X	X	
6			—	—	6. Road Sp			X	X	
3	—		—	—	39. Thomas Sp			X	X	
7	—		—	—	7. Waterworks Sp		X		X	X
8	—		—	—	8B. Mossy Sp		X		X	
9	—		—	—	8C. E Fork of Wiggington @ 8B		X		X	
	Shotgun fired				40. Balcher Dug Well	shotgun fired not pulled			X	
8	—		—	—	41. Balcher Fork				X	
9	—		—	—	9. Mud R @ old school	X	X			
11	—		—	—	11. Mud R @ Stevenson Mill Rd	X	X			
12	—		—	—	12. Blue Sp	X	X			
13	—		—	—	13. Spring Acres Sp	XX	XX			
14	—		—	—	14 Sp @ head of Mud R			X	X	
	No bug		—	—	36. Just above Oakes Ponds			X	X	
16	—		—	—	16. Duncan Pumping Well			X	X	
15	+		+++	—	15. Duncan Tiled Sp			X	X	
15	+		—	—	37. Green Barking Hole			X	X	
17	—?		++	—	17. Duncan Natural Well			X	X	
18	—		—	—	18. Hulse Sp			X	X	
20	—		+	—	35. Coy Wright Natural Well			X	X	
21	+		+	—	30. Coy Wright Blue Hole			X	X	
23	—		—	—	32. Coy Wright Sp			X	X	
24	—		—	—	31. SE Fork above Coy Wright Sp			X	X	
4	+		—	—	33. NE Fork, (camp Branch) above confluence			X	X	
5	—		—	—	34. NW Fork, above confluence	X	X			
19	—		—	—	19. Stamps Sp		X	X		
22	—		—	—	22. Wigginton Creek (103)			X	X	
7	—		—	—	38. Spicewood Fork of Wigg. Cr.			X	X	
24	—		—	++	24. Crawford Sp (Rich of Stamps Rd)			XX	XX	
16	—		—	++	42. Bedwell Sp			X	X	
					43. Brandt Pumping well			X	X	
18	—		—	—						
20	—		—	—	44. Charlotte Sp (12)			X	X	

BUG SHEET -- Miscellaneous Sites

TEST _____ RUN BY VFQ DATE 6/2/81

JAR #	AY73 Fluor.	Rhod. WT	OB	DY96	Location	Pull Gum Drop	Pull All Bugs	Hang Cott-on	Hang Char-coal	Rig Gum Drop
	Charcoal		Cotton							
9	—				Coy Wright Blue Hole				X	
11	—				Mossy Sp (BB)				X	
12	—				Wigginton Cr @ BB				X	

APPENDIX C

Copy of Water Level Measurements Made on behalf of Caldwell Lace Leather Co.

WELL RECORD FORM (Page 78) Accession No. Caldwell #151

Quadrangle Auburn NW NC NE X (mm) _____

Reconnaissance Date _____ WC C EC Y (mm) _____

Recorded By _____ SW SC SE

Resident _____ Ground Elevation 778

Owner Caldwell Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock (Unused) Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 706' 10" (100' below sandstone) Measured Depth to Water 516

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 726' 6" (Ground elevation minus measured depth)

Date 5-5-81 Measured by HAR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # Y (mm) Y (mm) _____

WELL RECORD FORM p. 379 Accession No. 52

Quadrangle Auburn NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JAR SW SC SE

Resident Yes Ground Elevation 791

Owner Jim Moats Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: (Domestic) Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 82'0" (62' below sandstone) Measured Depth to Water 29'0"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 762'0" (Ground elevation minus measured depth)

Date 5-5-81 Measured by JAR

791
79
796

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm) _____

WELL RECORD FORM (P. 80) Accession No. 73 54

Quadrangle Auburn (NW) NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JAR SW SC SE

Resident _____ Ground Elevation 785

Owner Thurston Kanler Aquifer _____

Well Type: (Drilled) Dug 15-18 gal day Date _____ Diameter 6 in

Use of Well: (Domestic) Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No sand bucket With owner absent? Yes No

Can well depth be measured: (Yes) No With owner absent? Yes No

Total Depth of Well 185'0" (150' below Sandstone) Measured Depth to Water 70 59'8" R M

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 725'4" (Ground elevation minus measured depth)

Date 5-5-81 Measured by JAR

784 12
59 8
725 4

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over (Mark Hudson)

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # X (mm) _____ Y (mm) _____

WELL RECORD FORM (P.88) Accession No. 74/54

Quadrangle Homer NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JAR SW SC (SE)

Resident _____ Ground Elevation 691

Owner Joe Neal Thompson I Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock (Unused) Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 89'6" Measured Depth to Water 46'6"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 644'6" (Ground elevation minus measured depth)

Date 5-5-81 Measured by JAR

691
46 6
644 6

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # X (mm) _____ Y (mm) _____

75

WELL RECORD FORM (p.82) Accession No. 35

Quadrangle Homer NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JAR SW SC SE

2 yrs ago — animal hair in well water.

Resident _____ Ground Elevation 675

Owner T.J. Logan Aquifer _____

Well Type: Drilled sulphur Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No 46 2"

Total Depth of Well 120 Measured Depth to Water 92

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 628'10" (Ground elevation minus measured depth)

Date 5-5-81 Measured by JAR

675
46 2
628 10

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # X (mm) _____ Y (mm) _____

WELL RECORD FORM (p.83) Accession No. ~~56~~

Quadrangle Homer NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JAR SW SC (SE)

Resident _____ Ground Elevation 710

Owner Everett Reeves Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6

Use of Well: (Domestic) Stock Unused Other _____ Small Supply

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

709 12 Total Depth of Well 60? Measured Depth to Water 13'3"

696 9 Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 696'9" (Ground elevation minus measured depth

Date 5-5-81 Measured by JAR

709 12

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm) _____

WELL RECORD FORM (p. 83) Accession No. 77 57

Quadrangle Homer NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JAR SW SC (SE)

Resident _____ Ground Elevation 769

Owner Wilburn Reeves Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: (Domestic) Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

768 12 2 7 3 7419

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: (Yes) No With owner absent? Yes No

Total Depth of Well 45 (15' below sandstone) Measured Depth to Water 35 27 R M

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 7419" (Ground elevation minus measured depth)

768 12 2 7 3 7419

Date 5-5-81 Measured by JAR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # X (mm) _____ Y (mm) _____

WELL RECORD FORM (P&S) Accession No. 78 58

Quadrangle Homer NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JMR SW SC SE

Resident _____ Ground Elevation 663 ~~665~~

Owner ? David Thomas ? Aquifer _____

Well Type: Drilled Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 78' Measured Depth to Water 15' 0"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 648'0" ~~650'0"~~ (Ground elevation minus measured depth)

Date 5-5-81 Measured by JMR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm) _____

79
SQ

WELL RECORD FORM (p. 86) Accession No. _____

Quadrangle Homer NW NC NE X (mm) _____

Reconnaissance Date 5-8-81 WC C EC Y (mm) _____

Recorded By JAR SW SC (SE)

Resident _____ Ground Elevation 690

Owner Dorthy appling Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock (Unused) Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 99'0" Measured Depth to Water 45'8"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 644'4" (Ground elevation minus measured depth)

690 12
45 8
644

Date 5-5-81 Measured by JAR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm) _____

WELL RECORD FORM (P-87) Accession No. 80 62

Quadrangle Homer NW NC NE X (mm) _____

Reconnaissance Date _____ WC C EC Y (mm) _____

Recorded By _____ SW SC SE

Resident _____ Ground Elevation 650

Owner Applings Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: (Domestic) Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: (Yes) No With owner absent? Yes No

Total Depth of Well 52'9" Measured Depth to Water 28'0"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 622'0" (Ground elevation minus measured depth)

Date _____ Measured by _____

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm) _____

WELL RECORD FORM (P. 88) Accession No. 81 BX

Quadrangle Auburn NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JAR SW SC SE

Resident _____ Ground Elevation 708

Owner Mike Roberson Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: (Domestic) Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well _____ Measured Depth to Water 59'7"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 648'5" (Ground elevation minus measured depth)

Date 5-5-81 Measured by JAR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # X (mm) _____ Y (mm) _____

WELL RECORD FORM (P.88) Accession No. 82 62

Quadrangle Auburn NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By HR SW SC SE

Resident _____ Ground Elevation 656

Owner Browder Lewis Woodard Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6

Use of Well: Domestic Stock (Unused) Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 51'4" Measured Depth to Water 28'6"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 627'6" (Ground elevation minus measured depth)

Date 5-5-81 Measured by HR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # X (mm) _____ Y (mm) _____

WELL RECORD FORM (P'90) Accession No. 83 83

Quadrangle South Kimo NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JAK (SW) SC SE

Resident _____ Ground Elevation 630

Owner Joe Stamps Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: (Domestic) Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No 36 10'

Total Depth of Well 62 Measured Depth to Water 37

12' Soil

Water found at (depth) 27' Elevation Top of Bowie

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 593'5" (Ground elevation minus measured depth)

Date 5-5-81 Measured by JAK

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # X (mm) _____ Y (mm) _____

84
84

WELL RECORD FORM (p.91) Accession No. 84

Quadrangle South Gwinn NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By JAK SW SC SE

8' lower than barn

Resident _____ Ground Elevation 647

Owner Rogers Aquifer _____

Well Type: Drilled Dug Date _____ Diameter 6

Use of Well: Domestic Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 110 Measured Depth to Water 28' 7

Water found at (depth) _____ Elevation +1 (approx)

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 618'5" (Ground elevation minus measured depth)

Date 5-5-81 Measured by JAK

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm) _____

WELL RECORD FORM (p.92) Accession No. 85 65

Quadrangle South Union NW NC NE X (mm) _____

Reconnaissance Date 5-5-81 WC C EC Y (mm) _____

Recorded By HHK (SW) SC SE

Resident Sulphur Ground Elevation 690

Owner Miller Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock (Unused) Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 145'9" Measured Depth to Water 38'9"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 651'3" (Ground elevation minus measured depth)

Date 5 5 81 Measured by HHK

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm) _____

86

WELL RECORD FORM (p.93) Accession No. 66

Quadrangle Homer NW NC NE X (mm) _____

Reconnaissance Date 5-7-81 WC C EC Y (mm) _____

Recorded By JAK SW SC (SE)

Resident _____ Ground Elevation 725

Owner Bobby Reiva Aquifer _____

Well Type: ~~Drilled~~ Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock (Unused) Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: (Yes) No Bad odor on probe - Sewage? With owner absent? Yes No

Total Depth of Well 82'1" Measured Depth to Water 54'3"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 670'9" (Ground elevation minus measured depth)

Date 5-7-81 Measured by JAK

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? (Yes) No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

X (mm)

Name is not #87 16

WELL RECORD FORM (p.94) Accession No. ~~67~~

Quadrangle Dennis NW NC (NE) X (mm) _____

Reconnaissance Date 5-7-81 WC C EC Y (mm) _____

Recorded By AHR SW SC SE

Resident _____ (pumping) Ground Elevation 652

Owner Duncan DUNCAN Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: (Domestic) Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No 5'6"

Total Depth of Well 32 Measured Depth to Water 10

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 646 8" (Ground elevation minus measured depth)

Date _____ Measured by AHR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Y (mm)

WELL RECORD FORM

There is No 88

~~88~~ 17

Accession No. ~~88~~

Quadrangle Dennis (P 95)

Reconnaissance Date 5-7-81

Recorded By AHR

NW NC (NE) X (mm) _____

WC C EC Y (mm) _____

SW SC SE

Resident _____

Owner Duncan natural Well

Well Type: Drilled Dug Date _____

Ground Elevation 665

Aquifer _____

Diameter _____

Use of Well: Domestic Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 15'0"

Measured Depth to Water 9'0"

Water found at (depth) _____

Elevation _____

Water rose to (depth) _____

Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 656'0" (Ground elevation minus measured depth)

Date 5-7-81

Measured by AHR

Well water conductivity _____ micromohs

Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs

Temperature _____ °C

Sampled for analysis on _____ by _____

89
WELL RECORD FORM (P.96) Accession No. 69

Quadrangle Dennis NW NC NE X (mm) _____

Reconnaissance Date 5-16-81 WC C EC Y (mm) _____

Recorded By HAR SW SC SE

Resident _____ Ground Elevation ~652

Owner A. Sowell Aquifer _____

Well Type: Drilled Dug Date 68-70 Diameter 6 in

Use of Well: Domestic Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 97'7" Measured Depth to Water 13'1"

Water found at (depth) 40-50 Elevation _____

Water rose to (depth) _____ Elevation _____

631 12
13 11
1
638

ELEVATION OF PIEZOMETRIC SURFACE 638'1" (Ground elevation minus measured depth

Date 5-16-81 Measured by HAR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes (Hog creek + Swamp) No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm)

90

WELL RECORD FORM (p.97) Accession No. 82

Quadrangle Dennis Quad NW NC (NE) X (mm) _____

Reconnaissance Date 5-16-81 WC C EC Y (mm) _____

Recorded By JAR SW SC SE

(Sept or Oct 1980 - sewage (looked & smelled) in water)

Resident _____ Ground Elevation 681

Owner Jack Eddings Aquifer _____

Well Type: Drilled Dug Date _____ Diameter 6in

Use of Well: Domestic Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? (Yes) No With owner absent? Yes No

Can well depth be measured: (Yes) No With owner absent? Yes No 79'8"

Total Depth of Well 100 Measured Depth to Water _____

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 601'4" (Ground elevation minus measured depth)

Date 5-16-81 Measured by JAR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes (No) Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes (No) Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

X (mm) Y (mm)

WELL RECORD FORM (p. 98) Accession No. 91 74

Quadrangle Dennis NW NC NE X (mm) _____

Reconnaissance Date 5-16-81 WC C EC Y (mm) _____

Recorded By JAR SW SC SE

Resident _____ Ground Elevation 653

Owner Steve Reynolds (CW) Aquifer _____

Well Type: Drilled Dug Gets dingy Date _____ Diameter 6 in

Use of Well: Domestic Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 38'6" Measured Depth to Water 15'8"

6 12 / 15 8 / 637 4

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 637' 4" (Ground elevation minus measured depth

Date _____ Measured by _____

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over (Blue Hole - neighbor)

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

X (mm) Y (mm)

92

WELL RECORD FORM (P.99) Accession No. 92

Quadrangle Dennis NW NC NE X (mm) _____

Reconnaissance Date 5-16-81 WC C EC Y (mm) _____

Recorded By JAK SW SC SE

Resident Yes Ground Elevation 645

Owner Oakes Aquifer _____

Well Type: Drilled Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

644'12
195
625'7

Can water be sampled? Yes No With owner absent? Yes No

Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 53'9" Measured Depth to Water 19'5"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 625'7" (Ground elevation minus measured depth

Date 8-16-81 Measured by JAK

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? (Yes) No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

X (mm) Y (mm)

WELL RECORD FORM (P. 100) Accession No. 93

Quadrangle Dennis NW NC NE X (mm) _____

Reconnaissance Date 5-16-81 WC C EC Y (mm) _____

Recorded By JAP SW SC SE

Resident _____ Ground Elevation 662

Owner _____ Aquifer _____

Well Type: Drilled Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock Unused Other _____ at old Horace Land

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

361 Method of Altitude Measurement: Map Location Altimeter

35 8 Can water be sampled? Yes No With owner absent? Yes No

626 4 Can well depth be measured: Yes No With owner absent? Yes No

Total Depth of Well 77' 10" Measured Depth to Water 35'8"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

ELEVATION OF PIEZOMETRIC SURFACE 626'4" (Ground elevation minus measured depth)

Date 5-16-81 Measured by JAP

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

X (mm) Y (mm)

WELL RECORD FORM (p.10) Accession No. 94 74

Quadrangle South Union NW NC NE X (mm) _____

Reconnaissance Date 5-16-81 WC C EC Y (mm) _____

Recorded By JAR SW SC SE

Resident VA Ground Elevation 655

Owner Rowe (Michigan) Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6 in

Use of Well: Domestic Stock (Unused) Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes (No) With owner absent? Yes No

Can well depth be measured: (Yes) No With owner absent? Yes No

Total Depth of Well 75'1" Measured Depth to Water 34'0"

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

655
-34
621

ELEVATION OF PIEZOMETRIC SURFACE 621'0" (Ground elevation minus measured depth

Date 5-16-81 Measured by JAR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes No Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes No Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm) _____

95

WELL RECORD FORM (p.102) Accession No. 76

Quadrangle South Una NW NC NE X (mm) _____

Reconnaissance Date 5-16-81 WC C EC Y (mm) _____

Recorded By JAR (SW) SC SE

Resident Yes Ground Elevation 629

Owner Woodward Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6in

Use of Well: Domestic Stock ~~Unused~~ Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes No

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? Yes (No) With owner absent? Yes No

Can well depth be measured: (Yes) No With owner absent? Yes No

Total Depth of Well 110 Measured Depth to Water 41 8'

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

628 12
-41 8
5874

ELEVATION OF PIEZOMETRIC SURFACE 5874' (Ground elevation minus measured depth)

Date 5-16-81 Measured by JAR

Well water conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes (No) Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes (No) Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) Y (mm) _____

WELL RECORD FORM (p.103) Accession No. ~~76~~

Quadrangle South Umia NW NC NE X (mm) _____

Reconnaissance Date 5-16-81 WC C EC Y (mm) _____

Recorded By JAR (SW) SC SE

Resident _____ Ground Elevation 662

Owner Jan Gipson Aquifer _____

Well Type: (Drilled) Dug Date _____ Diameter 6"

Use of Well: (Domestic) (Stock) Unused Other _____

If unused; Pump works? Yes No; Pump removed and hole is accessible? Yes N

Method of Altitude Measurement: Map Location Altimeter

Can water be sampled? (Yes) No With owner absent? Yes No

Can well depth be measured: (Yes) No With owner absent? Yes No 75'1"

Total Depth of Well 95'04 Measured Depth to Water _____

Water found at (depth) _____ Elevation _____

Water rose to (depth) _____ Elevation _____

661 12
75 1
586 11

ELEVATION OF PIEZOMETRIC SURFACE 586'11" (Ground elevation minus measured de

Date 5-16-81 Measured by JAR

Well water conductivity _____ micromohs Temperature _____

Sampled for analysis on _____ by _____

Sample # _____

Caves reported on property? Yes (No) Not asked Turn page over

Name _____ X (mm) _____ Y (mm) _____

Description _____

Cave stream present? Yes No Not asked

Springs on property? Yes (No) Not asked Turn page over

Conductivity _____ micromohs Temperature _____ °C

Sampled for analysis on _____ by _____

Sample # _____ X (mm) _____ Y (mm) _____

CALDWELL LACE LEATHER CO. WASTE DISPOSAL SITES
Logan Co., Kentucky

TRACED GROUNDWATER FLOW-ROUTES, DYE-INPUT AND DYE-MONITORING SITES, SPRINGS, AND WELLS MEASURED

LEGEND

- Flow route as determined by dye-traces and suggested by potentiometric contours, location of dye-recovery points, and orientation of topography influenced by joints (fractures)
- Inferred flow route based on field observations
- Sinkhole suitable for use as dye-input site
- Location along stream where dye-detectors were set during tracing tests
- Spring with stream that flows less than 100 feet before sinking underground
- Spring with stream that flows more than 100 feet
- Point at which stream sinks underground
- Interval over which stream seeps underground. There is no discrete sinking point.
- Pit with cave stream at bottom
- Major joint (fracture) in bedrock -- as interpreted on topographic maps from the distribution of sinkholes and the elongation of both sinkholes and valley segments. The topographic expression of the joint lies between the two arrow tips and parallel to their direction. Such joints can greatly influence the direction of groundwater movement. The effect of some major joints on the topography and groundwater movement is obscured by flow-lines drawn over them on this map. These joints are more clearly seen in Plate 3.
- Water well (Water level was measured)
- Pond on R. J. Stamps property
- Mapped cave passage, with stream (Mapped by Western Kentucky Speleological Survey)
- Mapped cave passage, without stream (Mapped by Western Kentucky Speleological Survey)
- Inferred groundwater divide and/or topographic divide of watershed of Hancock Lake, the back-up water supply for Russellville
- Landspreading site
- Old disposal site where waste was buried in trenches
- Big Clifty Sandstone (Underlain by Girkin Limestone. Bedrock in all other areas of inset map is Girkin Limestone. Compiled from published U. S. Geological Survey geologic maps of the Auburn, Dennis, Tomer, and South Union quadrangles.)

SCALE: 1 INCH = 3000 FEET

0 3000 6000 FEET

0 .5 1 MILE

CONTOUR INTERVAL 10 FEET

Datum is Mean Sea Level

1982

JAMES F. QUINLAN, Ph.D., BOX 8, MAMMOTH CAVE, KENTUCKY 42259

SCALE: 1 INCH = 600 FEET

0 600 FEET

DYE-MONITORING SITES

1. Waterworks Blue Hole
2. Atchley Spring
3. Lee Spring
4. Lagoon Spring
5. Bitch Spring
6. Road Spring
7. Watersnake Spring
8B. Mossy Spring Fork
8C. Long South Fork
9. Mud River School site
10. Briggs Creek
11. Mud River @ bridge
12. Blue Spring
13. Spring Acres Swimming Pool Spring
14. Mud River Spring
15. Duncan Tiled Spring
16. Duncan Pumping Well
17. Duncan Natural Well
18. Hulse Spring
19. Stamps Spring
20. Hall Spring
21. Black Lick Creek
22. Wiggington Creek
23. Gasper Creek
24. Crawford Spring
25. Gasper River
26. Wire Hole Spring
27. Crooked Run
28. Black Lick Creek @ 73
29. Motts Lick Creek @ 79
30. Coy Wright Blue Hole
31. Southeast Fork
32. Coy Wright Spring
33. Northeast Fork
34. Northwest Fork
35. Coy Wright Natural Well
36. Oakes Swallow Hole
37. Green Boiling Hole
38. Sycamore Fork
39. Thomas Spring
40. Belcher Dug Well
41. Belcher Fork
42. Barnett Spring
43. Barnett Pumping Well
44. Charlotte Spring
45. Wellhouse Spring
46. Collins Spring
47. Roaring Spring
48. Craig Blue Hole
49. Craig Fishhole Spring
50. Craig Swamp
51. Cockriel Entrance
52. Gibbs Cave
53. Black Lick Cr. Swallet
54. Price Spring
55. Robertson Blue Hole
56. Flood-pond Sink-point
57. Logan Spring Outlet (Tiled; not monitored)

WELLS MEASURED

16. Duncan Pumping
17. Duncan Natural
71. Caldwell Domestic
72. Moats
73. Kamler
74. Thompson
75. Logan
76. E. Reeves
77. W. Reeves
78. Thomas
79. D. Appling
80. Appling
81. Roberson
82. B. Woodard
83. Stamps
84. Rogers
85. Miller
86. B. Reeves
89. Sowell
90. Eddings
91. Reynolds
92. Oakes
93. Stall
94. Rowe
95. Woodward
96. Gipson
97. Caldwell Observation Well #2
98. Caldwell Observation Well #1 (Blocked)

SELECTED DYE-INPUT SITES

*A Caldwell Fluorescein
B Watrr Tank Sinkhole
C Reeves Sinkhole
D South Border Sinkhole
*E Caldwell Brightener
*F Wilson Sinkhole
G East Border Sinkhole
H Dry Stream Sinkhole
*J Black Lick Creek Swallet
*K Duncan Swallet
*L Oakes Swallet
*M Hall South Sinkhole
*N Hugnes Swallet
*O Kincade Swallet
*P Chiles Swallet
*Q Pulley Swallet
R Hall North Sinkhole
*S Atchley Spring

*Dye was injected only at these sites. The others are sites near the Caldwell property that are suitable for dye-inputs.

SPRINGS TO BE USED FOR ESSENTIAL MONITORING OF WATER QUALITY

WATERS THAT DRAIN FROM DISPOSAL SITES (Circled in Red)

Landspreading Site
3. Lee Spring
15. Duncan Tiled Spring or 37. Green Boiling Hole or 30. Coy Wright Blue Hole
14. Mud River Spring
45. Well House Spring

Old Disposal Site
4. Lagoon Spring
15. Duncan Tiled Spring or 37. Green Boiling Hole or 30. Coy Wright Blue Hole
8C. Long South Fork (Spring-fed stream)

WATERS TO BE USED FOR BACKGROUND CONTROL (Circled in Green)
13. Spring Acres Swimming Pool Spring
8B. Mossy Spring

PLATE 1

CALDWELL LACE LEATHER CO. WASTE DISPOSAL SITES
Logan Co., Kentucky

POTENTIOMETRIC SURFACE AND TRACED GROUNDWATER FLOW-ROUTES

LEGEND

-700-
-660-
Water Level Contours. Contour interval is 20 feet; datum is mean sea level. These contours depict the potentiometric surface, an imaginary surface that is defined by the level to which water would rise in a tightly cased well. In some respects the potentiometric surface is like a water table but water-flow is through a few discrete conduits rather than intergranular, as in a gravel aquifer. The location and shape of the potentiometric surface is influenced by the topography and by the transmissivity of the rock. The configuration of this potentiometric surface is determined by interpreting water-level elevations in wells, springs, and streams. The flow direction of water is downslope and theoretically perpendicular to the contour lines. Contours that are distal from the Caldwell sites are approximate and schematic. Accurate delineation of the potentiometric surface in these distal areas would require additional water-level data that would not have been justifiably collected within the scope of this study.

●87 Water well (Depth to water measured on behalf of Caldwell)

●G Water well (Depth to water obtained from U. S. Geological Survey files)

●n Water well (Depth to water not used for contouring potentiometric surface -- for various reasons)

Measured depth to water level, in feet below land surface; R = reported depth

Water well — 15-648 = Accession number — 87; 78 = Elevation of water level above sea level; Depth of well, in feet below land surface

Flow route as determined by dye-traces and suggested by potentiometric contours and location of dye recovery points

Inferred flow route, based on field observations

Sinkhole suitable for use as dye-input site

Location along stream where dye-detectors were set during tracing tests (#8B and #8C are sites for monitoring water quality; #29 is not shown on Plate 1)

Spring with stream that flows less than 100 feet before sinking underground

Spring with stream that flows more than 100 feet

Point at which stream sinks underground

Interval over which stream seeps underground. There is no discrete sinking point.

Pit with cave stream at bottom

Pond on R. J. Stamps property

Mapped cave passage, with stream (Mapped by Western Kentucky Speleological Survey)

Mapped cave passage, without stream (Mapped by Western Kentucky Speleological Survey)

Inferred groundwater divide and/or topographic divide of watershed of Hancock Lake, the back-up water supply for Russellville

Landspreading site

Old disposal site where waste was buried in trenches

SCALE: 1 INCH = 3000 FEET

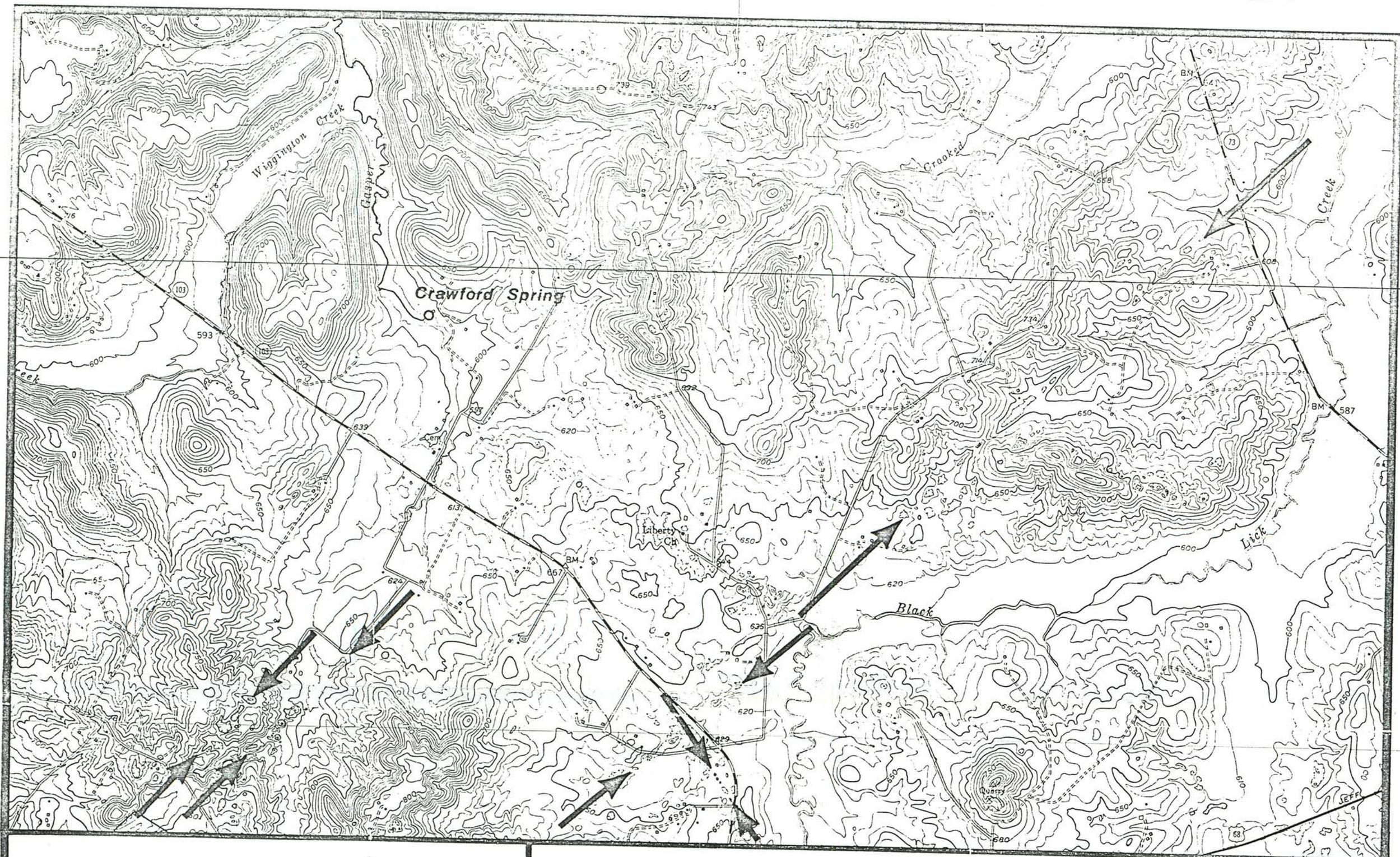
0 3000 6000 FEET

0 .5 1 MILE

1982

WELLS MEASURED	DYE-INPUT SITES	SITES ALONG KNOWN FLOW-ROUTES OF GROUNDWATER, AS PROVEN BY DYE-TRACES
16. Duncan Pumping	A Caldwell Fluorescein	2. Atchley Spring
17. Duncan Natural	E Caldwell Brightener	3. Lee Spring
71. Caldwell Domestic	F Wilson Sinkhole	4. Lagoon Spring
72. Moats	J Black Lick Creek Swallet	13. Spring Acres Swimming Pool Spring
73. Kamler	K Duncan Swallet	14. Mud River Spring
74. Thompson	L Oakes Swallet	15. Duncan Tiled Spring
75. Logan	M Hall South Sinkhole	17. Duncan Natural Well
76. E. Reeves	N Hughes Swallet	24. Crawford Spring
77. W. Reeves	O Kinkade Swallet	26. Wire Hole Spring
78. Thomas	P Chiles Swallet	30. Coy Wright Blue Hole
79. D. Appling	Q Pulley Swallet	32. Coy Wright Spring
80. Appling	S Atchley Spring	35. Coy Wright Natural Well
81. Roberson		37. Green Boiling Hole
82. B. Woodard	SPRINGS TO BE USED FOR ESSENTIAL MONITORING OF WATER QUALITY	42. Barnett Spring
83. Stamps		45. Wellhouse Spring
84. Rogers	WATERS THAT DRAIN FROM DISPOSAL SITES (Circled in Red)	46. Collins Spring
85. Miller	3. Lee Spring	47. Roaring Spring
86. B. Reeves	15. Duncan Tiled Spring	51. Cockriel Entrance
89. Sowell	14. Mud River Spring	
90. Eddings	45. Well House Spring	
91. Reynolds	4. Lagoon Spring	DYE-MONITORING SITE NOT SHOWN ON PLATE 1
92. Oakes	8C. Long South Fork (Spring-fed stream)	
93. Stall		29. Motts Lick Creek at Highway 79
94. Rowe	WATERS TO BE USED FOR BACKGROUND CONTROL (Circled in Green)	
95. Woodward	13. Spring Acres Swimming Pool Spring	
96. Gipson	8B. Mossy Spring	
97. Caldwell Observation Well #2		
98. Caldwell Observation Well #1 (Blocked)		

JAMES F. QUINLAN, Ph.D., BOX 8, MAMMOTH CAVE, KENTUCKY 42259



N

SCALE: 1 INCH = 2000 FEET

0 6000 FEET

CONTOUR INTERVAL 10 FEET

Datum is Mean Sea Level

1982

CALDWELL LACE LEATHER CO. WASTE DISPOSAL SITES

Logan Co., Kentucky

TOPOGRAPHIC ELONGATIONS INFLUENCED BY JOINTS (FRACTURES) IN BEDROCK: A CLUE TO THE LOCATION OF SUBSURFACE FLOW ROUTES

EXPLANATION

The topographic elongations lie between the arrow tips and parallel to their direction. The major northeast-trending joints and the minor northwest-trending joint that is nearly perpendicular to them, all caused erosion parallel to their orientation. These joints influenced not only the elongation of certain sinkholes and valley segments but also, most probably, the major directions and routes of groundwater flow beneath them. In the area of this map segment these northeast-trending joints and flow-routes function as feeder-tributaries nearly perpendicular to the northwest-trending major drainage axis that has pirated water from Black Lick Creek to Crawford Spring, at the headwaters of the Gasper River. Note the group of non-oriented sinkholes that extends 6000 feet northwestward from where Black Lick Creek abruptly changes its flow direction from north to east. This grouping of sinkholes is most probably a consequence of flushing of soil into a subjacent cave stream that pirates flood-water from Black Lick Creek to Crawford Spring.

JAMES F. QUINLAN, Ph.D., BOX 8, MAMMOTH CAVE, KENTUCKY 42259

APPENDIX B

GROUNDWATER FLOW IN THE VICINITY OF CALDWELL LACE LEATHER CO. INC. (EWERS)

GROUNDWATER FLOW
in the vicinity of
Caldwell Lace Leather Co. Inc.
Landspreading Site

Ralph O. Ewers, PhD.
Geologist, Hydrogeologist
President, Ewers Water Consultants Inc.

March 18, 1983

Ewers Water Consultants, Inc.

160 Redwood Dr. Richmond, Kentucky 40475

GROUNDWATER FLOW DIRECTIONS IN THE VICINITY OF CALDWELL LACE LEATHER COMPANY INC. LANDSPREADING SITE

Prepared By

Ralph O. Ewers, PhD.
Geologist, Hydrogeologist
President, Ewers Water Consultants Inc.

March 18, 1983

Geologic Setting

Lithology

The landspreading site is located along a ridge top underlain by Missippian rocks of the Chester and Meramec Series. These include the Big Clifty Sandstone Member of the Golconda Formation, the Girkin Formation, and the Ste. Genevieve Formation.

The Big Clifty Sandstone is a thick bedded, light brown, fine grained, crossbedded sandstone. At its base is a dark grey, somewhat silty shale referred to as the Fraileys by Pohl (1970). The thickness of this poorly exposed unit is of the order of two feet. The Big Clifty caps many flat-topped ridges throughout the region, including the western and central portions of the landspreading site.

The Girkin Formation consists primarily of a medium-light-grey to pale-yellow-grey limestone. It also contains discontinuous shale and sandstone units. It forms the heavily karstified lower slopes of the hill surrounding the site and floors all but the deepest valleys in the area.

The Ste. Genevieve Formation consists of light grey to light brown fine to coarsely detrital, oolitic limestone. It forms intensely karstified lowlands south-southeast of the landspreading site and outcrops along Mud River and Gasper River, the principal groundwater resurgence points.

Structure

The region lies in the southeast corner of the Illinois Basin. More specifically, it is at the east end of the Moorman Syncline, a structure bounded on the south by the Pennyrile Fault System, and on the north and east by the Rough Creek Fault System (Krausse and Treworgy, 1979). Dips are toward the north-northwest at approximately 40 feet per mile. No mapped faults are shown on the U.S.G.S. Geologic Quadranges in the immediate area of the landspreading site. However, five miles to the north-northwest on the Homer and South Union Quadrangles, a fault complex trending parallel to the strike is shown. Several lineaments do occur in the area which are subparallel to the fault complex. These are exhibited primarily by the alignment of elongated sinks but involveing straight reaches of streams and valleys as well. These lineaments are shown on the accompaning map. No stratigraphic offset can be demomstrated across these features but they are very strong and persist over distances as much as five miles. The landspreading site lies immediatly southeast of one of these lineaments.

Hydrology

Along ridge tops underlain by the Big Clifty Member the ground water is constrained, apparently by the basal shale, to lateral flow to the limit of its outcrop. Here it decends via vadose shafts into the Girkin Formation. East of the site, near Mamoth Cave, these vertical shafts often number 300 to 500 per lineal mile of outcrop (Brucker, et al, 1972). Intermittent surface flow occurs at elevations near the base of the Girkin Formation, presumably due to the discontinuous minor shale units which it contains. These surface flows quickly resume underground routes. The two major springs of the region discharge from the upper part of the Ste. Genevieve Limestone. One is located at the head of Mud River; the other is the source of the Gasper River (see accompaning map). Both have estimated discharges in excess of 10 cubic feet per second under late winter, early spring conditions. Chemical parameters of the springs with large to intermediate discharge indicate that they are fed by conduit flow (Fig. 1). This indicates that average groundwater residence time in the aquifer may be very short, of the order of a few days Schuster and White (1971).

Groundwater Flow from the Landspreading Site

Methodology

Given the presence of carbonate aquifers with conduit flow springs, dye tracing methods provide the simplest, quickest and most unequivocal determination of ground water flow. Consequently, a program of dye tracing was undertaken covering the period January 9 - March 11 using fluorescene and optical brightner, diphenol brilliant flavine 70GFF. These dyes were introduced into open sinks at four locations with a mixing tube and water provided by tank truck. A minimum of 1000 gallons of water was used at each dye insertion. A portion of the water, about one third of the total, was used first to wet the subsurface conduits. The dye was then introduced to the water stream and followed by a flushing with the remaining 50 percent. Dye detectors were placed at 10 spring sites surrounding the land spreading area. Activated coconut charcoal packets were utilized for detection of the fluorescene. Any absorbed dye in these detectors was eluted in the laobratory with ammonium hydroxide and propyl alcohol after the method of Smart (1972). Absorbant cotton detectors were used for the detection of the optical brightner after the method of Glover (1972). The results of these dye traces are presented in figure 2.

The following precautions were taken during the dye tests. Dye detectors were placed and changed by personnel

not directly involved with dye insertion in order to avoid possible contamination. Protective clothing, including disposable shoe covers, was worn by personnel handling the dyes. These articles and empty dye containers were doubly bagged in plastic for off site disposal or decontamination. Dye detectors and dyes were transported in separate doubly plastic wrapped packages. Detectors directly involved in the dye trace were recovered and evaluated by personnel supervised by Ewers Water Consultants Incorporated. Before each trace detectors were used to assess any dye background prior to tracing and between separate dye insertions.

The Flow Pattern

The subsurface and surface flow routes discussed in this section are shown on the accompanying map. The subsurface routes are shown as direct point to point paths, as any other method would reflect inference, not hard data.

Input Sites A, B, and C adjacent to the northwest, south, and east perimeters of the landspreading site, respectively, consist of open sinks near the shale/limestone contact. They are the inputs combining closeness to the landspreading site, accessibility, and suitability for dye injection, while fairly representing the physical limits of the landspreading operation. Dye from these sites flows southwestward to principle monitoring sites 3 and 4, a distance just under one mile. The discharge of these springs flows overland, again in a southwestward direction, a distance of Ø.25 miles and

sinks again. These waters resurge again Ø.25 miles to the southwest and continue overland for a straight line distance of 1 mile to a second sink point. This subsurface flow reaches its final rise at the source of Mud River (point 1), a straight line distance of 1.5 miles.

In all likelyhood the flow is actually conducted along the fractures or minor faults which have given rise to the lineaments previously mentioned. The source of Mud River lies immediatly northwest of this lineament.

These dye traces were executed during moderate flow conditions, with sections of overland flow as indicated above. It is possible that these overland flows are paralleled by subsurface flow and that waters from these three inputs could flow to Mud River in the absence of surface flow.

Flow rates are typical for karst regions. Tracers from the inputs reached Mud River, a straight line distance of four miles in three days. Karst aquifers typically exhibit a broad range of flow rates, depending upon stage. It is expected that this aquifer should react similarly. At high flow this distance may be traversed in less than 24 hours while at low flow two weeks may be required. Extreme flows were not tested and no special effort was made to determine flow rates.

The west and central portions of the landspreading site are underlain by the Big Clifty Member and do not show any sign of direct drainage through this caprock, such as sinks.

The extreme eastern portion is underlain directly by the limestone (Fig. 3). One sink, midway between points B and C has developed here. It is not an open sink and thus it could not be used for dye tracing without emplacement of a suitable dry well. Because this sink is in line with a north-trending valley which contains several active open sinks, it is at least possible that infiltration from the region of this sink could flow toward the active sinks. If it does, it then flows northward to principal monitoring point 8 and thence to point 9, the source of the Gasper River, as shown by the trace from point D. This straight line distance is 2.4 miles.

Summary

Flow from the landspreading site moves via a carbonate aquifer by conduit flow. It flows four miles to the southwest to the source of Mud River, paralleling or perhaps following a strong lineament. It is possible that some infiltration from the extreme eastern portion of the landspreading site may flow northward a distance of 2.4 miles to the source of the Gasper River.

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FIGURE 1 - CHEMICAL PARAMETERS FOR SELECTED SPRINGS

DATE

		Total H	pH	Conductivity
MUD RIVER RISE 1		186	7.1	400
POOL SPRING	2			
DUNCAN NEW	3			
DUNCAN OLD	4	207	7.4	430
BARN SPRING	5			
WATERWORKS SPR	6	196	6.6	400
STAMPS WINDOW	7			
WELLHOUSE WND	8	228	6.6	480
GASPER R. RISE	9	232	5.75	460
WIGGINGTON CK	10			

FIGURE 2 A - FLUORESCENE RECORD

DYE INSERTION		1/26 A				2/29 C		
DATE		1/26	1/29	2/7	2/13	2/18	3/6	3/9
MUD RIVER RISE	1	Ø	+	2+	Ø	Ø	Ø	/
POOL SPRING	2	Ø	Ø	Ø	Ø	Ø	Ø	/
DUNCAN NEW	3	Ø	4+	3+	+	Ø	+	/
DUNCAN OLD	4	Ø	Ø	Ø	Ø	Ø	3+	/
BARN SPRING	5	Ø	Ø	Ø	Ø	Ø	Ø	/
WATERWORKS SPR	6	Ø	Ø	Ø	Ø	Ø	Ø	/
STAMPS WINDOW	7	Ø	Ø	Ø	Ø	Ø	Ø	/
WELLHOUSE WND	8	Ø	Ø	Ø	Ø	Ø	/	Ø
GASPER R. RISE	9	Ø	Ø	Ø	Ø	Ø	Ø	/
WIGGINGTON CK	1Ø	Ø	Ø	Ø	Ø	Ø	Ø	/

Dates refer to recovery date of detector. Date and insertion point of each dye trace is also given. The symbol (/) denotes no detector recovered.

Ø =no dye detected
+ = weak positive
2+= good positive
3+= strong positive
4+= very strong positive

FIGURE 2 B - DIPHENOL BRILLIANT FLAVINE RECORD

DYE INSERTION		1/26 B				2/29 D		
DATE		1/26	1/29	2/7	2/13	2/18	3/6	3/9
MUD RIVER RISE	1	Ø	+	+	Ø	Ø	Ø	/
POOL SPRING	2	Ø	Ø	Ø	Ø	Ø	Ø	/
DUNCAN NEW	3	Ø	3+	2+	+	Ø	Ø	/
DUNCAN OLD	4	Ø	3+	2+	+	Ø	Ø	/
BARN SPRING	5	Ø	Ø	Ø	Ø	Ø	Ø	/
WATERWORKS SPR	6	Ø	Ø	Ø	Ø	Ø	Ø	/
STAMPS WINDOW	7	Ø	Ø	Ø	Ø	Ø	Ø	/
WELLHOUSE WND	8	Ø	Ø	Ø	Ø	Ø	/	3+
GASPER R. RISE	9	Ø	Ø	Ø	Ø	Ø	+	/
WIGGINGTON CK	1Ø	Ø	Ø	Ø	Ø	Ø	Ø	/

Dates refer to recovery date of detector. Date and insertion point of each dye trace is also given. The symbol (/) denotes no detector recovered.

Ø =no dye detected
+ = weak positive
2+= good positive
3+= strong positive
4+= very strong positive

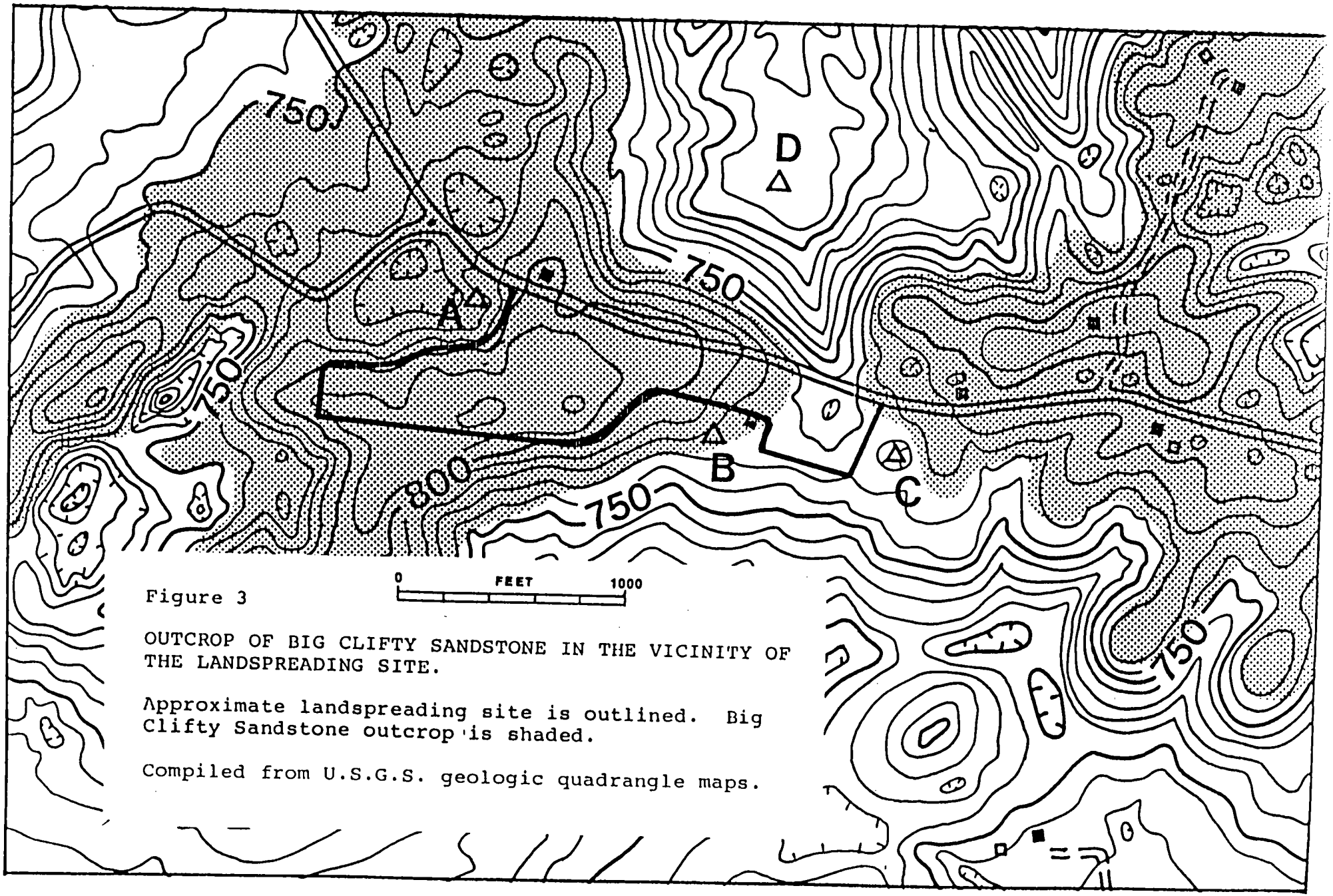

Figure 3

OUTCROP OF BIG CLIFTY SANDSTONE IN THE VICINITY OF THE LANDSPREADING SITE.

Approximate landspreading site is outlined. Big Clifty Sandstone outcrop is shaded.

Compiled from U.S.G.S. geologic quadrangle maps.

APPENDIX C
DYE TRACING TO DEFINE THE DIRECTION OF GROUND-WATER FLOW

USE OF DYE TRACING TO DEFINE THE DIRECTION OF GROUND-WATER FLOW FROM A SUPERFUND WASTE-DISPOSAL SITE IN KARST TERRANE, NEAR AUBURN, KENTUCKY

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 92-4195

Prepared in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY

USE OF DYE TRACING TO DEFINE THE DIRECTION OF GROUND-WATER FLOW FROM A SUPERFUND WASTE-DISPOSAL SITE IN KARST TERRANE, NEAR AUBURN, KENTUCKY

By D. S. Mull

U.S. GEOLOGICAL SURVEY

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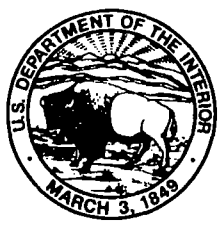

Louisville, Kentucky
1993

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

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CONVERSION FACTORS, VERTICAL DATUM, WATER QUALITY ABBREVIATIONS, AND MISCELLANEOUS ABBREVIATIONS

Multiply	By	To obtain
inch	25.4	millimeter
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
foot per minute (ft/min)	0.3048	meters per minute
gallon (gal)	3.785	liter
gallon per minute	0.06308	liter per second
mile	1.609	kilometer
acre	0.4047	hectare
square mile	2.590	square kilometer
gram	0.001	kilogram
pound	0.454	kilogram

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Seal Level Datum of 1929.

Abbreviated water quality units: Specific conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius (μS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius (μmho/cm), formerly used by the U.S. Geological Survey.

Miscellaneous abbreviations:

ppb - parts per billion
mL - milliliter

USE OF DYE TRACING TO DEFINE THE DIRECTION OF GROUND-WATER FLOW FROM A SUPERFUND WASTE-DISPOSAL SITE IN KARST TERRANE, NEAR AUBURN, KENTUCKY

By D. S. Mull

ABSTRACT

A series of dye-tracer tests were performed to determine the direction of ground-water flow and the location of natural discharge points (springs) for the karst aquifer system that drains a disposal site for leather-tannery waste. The springs that are shown to receive drainage from the waste-disposal site are appropriate sites to monitor for hazardous substances associated with the leather tannery waste that might be migrating from the disposal site. The dye-tracer test results would also determine if water from the waste site drains to a karst spring that is the source of water for the city of Auburn.

Observed variations in discharge and water turbidity indicate that ground-water flow at the waste site is primarily through enlarged subsurface conduits in carbonate rocks. Tracer tests used fluorescent dyes that were flushed into three sinkholes containing open drains (swallets) that receive surface runoff from parts of the waste site. Dye recovery was monitored at 12 springs and 2 streams. The pattern of dye recovery during three separate qualitative dye-tracer tests indicates that ground water from the waste site flows to 4 springs to the south and 2 springs northwest of the site. These springs are appropriate sites to monitor for hazardous substances associated with the leather tannery waste migrating from the waste site. Estimates of travel time during the dye-tracer tests indicate that a delay of 3 to 5 days may be needed for runoff that enters sinkholes in the vicinity of the site to arrive at the monitoring springs. Dye from tracer tests performed during this study did not drain to the Auburn water-supply spring.

INTRODUCTION

The Caldwell Lace Leather Superfund Site, located in the mature karst terrane of west-central Kentucky, was used for disposal of leather tannery waste during 1972-85. Surface drainage from parts of the waste site enters nearby sinkholes and swallets that are hydraulically connected to the karst aquifer system.

Research has shown that traditional ground-water monitoring techniques using monitoring wells only are often ineffective in detecting waste movement in ground water in karst terrane because one can not be certain that the monitoring wells tap the openings that are conveying the water. Springs that receive recharge from sinkholes and swallets draining a waste-disposal site provide additional sites for monitoring ground-water quality once those springs have been identified by tracer studies.

The U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency (USEPA) used dye-tracer tests to determine the direction of ground-water flow and the location of natural

discharge points (springs) for the karst aquifer system that drains the waste-disposal site. The USEPA is conducting a Remedial Investigation to characterize the environmental conditions in the vicinity of the disposal site. The springs identified as receiving drainage from the disposal site are appropriate for monitoring by the USEPA to determine if hazardous constituents, associated with the leather tannery waste, may be migrating from the waste site. The results of dye-tracer tests would also indicate if ground water from the waste-disposal site drains to the spring that supplies water for the city of Auburn.

Purpose and Scope

The purpose of this report is to present the results and interpretation of dye-tracer tests to define the direction of ground-water flow from the waste-disposal site. Only qualitative dye-tracer tests were performed during this study. The report also includes the results of a field reconnaissance to locate potential dye-injection points (sinkholes with swallets) and dye-recovery sites (springs or streams) at and near the waste-disposal site. Dye-injection sites for this study were limited to swallets at or topographically downgradient of the waste-disposal site that have the potential for receiving surface runoff from the waste-disposal area. The results of a detailed inventory of wells and springs located 1, 2, and 3 miles from the waste-disposal site are also reported (pl. 1). This inventory was performed to locate potential users of ground water in the vicinity of the waste site. Data from the inventory are listed in the "Supplemental Data" section of this report (tables 1-4).

Previous Investigations

The results of previous dye-tracer tests at the waste-disposal site provided a major contribution to this study. The results of these investigations are included in unpublished consultant's reports by Quinlan (1982) and Ewers (1983). Both reports are on file with USEPA, Region IV, Atlanta, Georgia. The USGS published detailed geologic maps at the scale of 1:24,000 for the following quadrangles that include the waste-disposal site and springs that were monitored for the recovery of injected dye during tracer tests (Gildersleeve, 1966; Klemic, 1963; Rainey, 1965a, 1965b).

Acknowledgments

The author is grateful to the many individuals who granted access to their property for the purpose of inspecting and sampling water from wells, springs, streams, and sinkholes. The Auburn Volunteer Fire Department hauled water for each dye injection and the Bowling Green Fire Department provided 900 feet of fire hose that was needed to flush water into one dye-injection sinkhole. The assistance and cooperation of these individuals and agencies contributed significantly to the successful completion of this investigation.

DESCRIPTION OF STUDY AREA

Location and Extent

The Caldwell Lace Leather Superfund Site is about 2.5 miles northwest of Auburn, in Logan County, west-central Kentucky (pl. 1). The site includes about 40 acres on a ridge along Kentucky Highway 1039. Dye-injection sites were on-site or near the waste-disposal site, but springs and streams as far as 4 miles from the site were monitored for the presence of dye during all tracer tests performed during this investigation.

Physiography

The study area is in the Mississippian Plateaus physiographic province of Kentucky (McFarlan, 1943) and includes broad gently rolling valleys and relatively narrow flat-topped ridges. The waste-disposal site is along the crest of an east-west trending ridge; the ridge top is about 170 feet above the valleys. In general, sinkholes with swallets are more common on the eastern part of the ridge.

Karst features such as sinkholes, springs, karst windows, and sinking streams are common in the broad valleys north and south of the ridge-top waste-disposal site. The karst features are developed on limestone and, for the most part, have formed as a result of the dissolution of carbonate bedrock by percolating ground water. Most karst features are hydrologically significant because of their unique relation to the ground-water system; that is, they collect and discharge water into, store and transmit, or discharge water from the ground-water system.

Sinkholes

Sinkholes are commonly the most typical evidence of karstification. As used in this report, the term sinkhole refers to a naturally occurring closed topographic depression caused from subsidence or collapse of the land surface resulting from karst processes. The principal cause of development of sinkholes in the study area is the transport of surficial material into solution-enlarged openings in bedrock. This process usually results in the formation of a funnel-shaped depression (sinkhole) in the land surface.

Mapped sinkholes in the vicinity of the waste-disposal site are circular to irregular in outline and range from less than 10 to about 500 feet in diameter. Most sinkholes are less than 20 feet deep but a few are as deep as 50 feet below the surrounding area. In general, sinkholes on the broad valleys are less deep but much larger in outline than sinkholes on the ridge near the waste-disposal site. For example, a sinkhole south of highway US 68 and about 2.5 miles southwest of the waste site is about 30 feet deep and 0.6 miles in diameter.

The drain (swallet) at the bottom of a sinkhole may be open or plugged with soil. Swallets are hydrologically significant because the openings are usually connected to subsurface conduits that lead directly to the

ground-water system. Thus, all surface runoff collected by the sinkhole is funneled directly into the ground-water system without enhancement of water quality which may occur as water drains through the sediment plug. Because of the direct hydraulic connection to the ground-water system and the fact that surface runoff from the waste-disposal site can drain into several sinkholes with open swallets, all dye-tracer tests performed during this study originated in those sinkholes with open swallets (sites A, B, and C, pl. 1).

Springs

A spring is a natural point of discharge from the ground-water system where the land surface intersects the water table or water-bearing conduits. Discharge from a spring may issue from openings ranging in size from less than an inch to many feet in diameter. Water may either discharge under gravity or rise under pressure to form small seeps or large rise pools. Springs in the study area range from a relatively small wet-weather resurgence that flows only during or after a period of rainfall (Green Boiling Spring, site 2, pl. 1) to relatively large springs that discharge from cave-like openings in limestone and are generally perennial (Mossy Spring, site 9, pl. 1).

The largest springs in the study area are Mud River Spring (site 8), Mossy Spring (site 9), Auburn Spring (site 14), and Crawford Spring (site 16). Each spring is fed by a converging subsurface drainage system that can be considered as a large branching pattern of pipe-like openings that collects water over an extensive area, funnels water to the main conduit of the spring, and then discharges water at the land surface at the mouth of the spring. Surface runoff funneled by sinkholes is a major source of recharge to these springs. Thus, the quality of water from a spring tends to reflect the surface activities in the basin. Springs may be appropriate and convenient points to monitor ground-water quality for a particular basin, because springs are the principal outlets for ground water in a karst ground-water basin. Before a spring can be considered as a valid monitoring site, it must be shown to drain a particular basin. This can be accomplished by performing dye-tracer tests.

Karst Windows

A karst window is a topographic depression formed by subsidence or collapse of the land surface which results in exposure of an underground stream. Karst windows range from pit-like sinkholes with water flowing at the bottom of the pit to large valley-like depressions containing streams flowing several hundred feet across the valley floor. Most karst windows in the study area are relatively small and have been characterized as pits with cave streams (Quinlan, 1982).

One karst window monitored during this study (site 13) is a steep-sided, funnel-shaped depression with water flowing in the bottom of the depression. The sinkhole is about 30 feet in diameter at the land surface and about 15 feet deep. During very low-flow conditions, the water does not rise in the sinkhole but only flows across the bottom of the sinkhole. As water levels rise, the ground water drains from the sinkhole through a series of horizontal

openings at different levels above the bottom of the sinkhole. During high-flow conditions, water rises in the sinkhole, and during intense storms the water surface is turbulent as a result of the force of water rising in the sinkhole. During this study, water did not overflow the top of the sinkhole.

Karst windows are hydrologically significant because the exposed streams provide a direct path to the subsurface for any contaminants placed in or allowed to enter the sinkhole. Also, and perhaps of greater importance within the context of this investigation, karst windows serve as convenient and appropriate ground-water monitoring sites because the exposed stream provides access to ground water within a major subsurface conduit. The stream in one karst window (site 13) was monitored for dye during all tracer tests performed during this investigation.

Geologic Framework

Only the near-surface geology is discussed in this report, because nearly all ground water in the study area is present at relatively shallow depths. The following discussion proceeds from younger or uppermost geologic units to successively older and deeper rocks; the descriptions have been taken from USGS published 7-1/2 minute geologic quadrangle maps that are listed in the references. Each geologic quadrangle map includes a detailed stratigraphic column, lithologic descriptions, and structural features. The geology of the surrounding area is discussed in detail by McFarlan (1943).

Near the waste-disposal site, bedrock is overlain by soil and residuum that is generally thin but variable in thickness. Soil depths, as determined by drilling, range from 0 to 43 feet (Quinlan, 1982). According to the Soil Survey of Logan County (Dye and others, 1975), soil depths near the waste-disposal site range from 40 to 48 inches and include the Linker series, a well-drained sandy clay loam derived from sandstone, and the Talbot series, a moderately deep, well-drained clayey soil derived from limestone.

The waste-disposal site is underlain by limestone, shale, and sandstone of Mississippian age that includes, in descending order, the Big Clifty Sandstone member of the Golconda Formation, the Girkin Formation, and the Ste. Genevieve Limestone. Most of the site is underlain by as much as 70 feet of the Big Clifty sandstone that is gray to light-brown, fine grained, massive to thin-bedded, cliff-forming, crossbedded, and locally shaley. The Big Clifty Sandstone caps many ridges throughout the region.

The Girkin Formation underlies the Big Clifty sandstone and crops out at the surface at the eastern and western ends of the waste-disposal site and underlies the intensely karstified lowlands that surround the ridge where the waste site is located. The Girkin Formation is about 170 feet thick and is mostly limestone, medium-light gray to pale-yellow gray, aphanitic to coarsely detrital, and oolitic. The beds are thin and irregular to very thick and ledge forming. Discontinuous shale and sandstone units that range from 0 to 5 feet in thickness are present about 45 feet above the base of the formation.

The Ste. Genevieve Limestone underlies the Girkin Formation and is light gray to light brown, fine to coarsely detrital and oolitic, and thin-bedded to very-thick bedded and massive. The Ste. Genevieve Limestone is about 200 feet thick and is the basal limestone in the study area, but crops out only near Mud River Spring (site 8) and southeast of Auburn. The Ste. Genevieve Limestone underlies extensive highly-karstified areas to the south and west of the study area.

Structural contours on the geologic quadrangle maps indicate that bedrock dips north-northwest at about 40 feet per mile. No mapped faults exist in the study area; however, a fault zone is mapped about 5-miles northwest of the waste-disposal site. Several lineaments are present in the study area and seem to be subparallel to the fault zone (Ewers, 1983).

Ground-Water Flow

Ground-water flow in bedrock underlying mature karst terrane is much different from that underlying non-karst terrane, primarily because of the presence of pipe-like openings or conduits that permit relatively rapid movement of water. It is the presence of these openings that contribute to the unique nature of ground-water flow in the study area.

Ground-water flow in karst aquifers is of two main types: diffuse (slow, laminar flow) and conduit (rapid, turbulent flow). Both types of ground-water flow can exist in the same karst aquifer. Diffuse flow typically occurs where dissolutional enlargement of primary openings in bedrock has not developed sufficiently to permit turbulent flow and most often occurs near the boundaries of ground-water basins and in the weathered and fractured uppermost zone of bedrock near the contact with the overlying residuum. In areas where ground-water flow is primarily diffuse, flow is usually not concentrated in particular zones of the aquifer; typical karst landforms, such as sinkholes, may be absent or poorly developed.

Conduit flow in carbonate bedrock occurs in solution-enlarged openings that range in size from less than an inch to cave-size, such as the opening that forms the cave-like conduit at Mossy Spring (site 9). These conduits are dendritic or trellised and develop along horizontal or vertical open fractures and bedding planes. Where conduit flow predominates, karst landforms are common and well developed. As mentioned earlier, the hydrologic significance of conduit flow is the rapid introduction and movement of water through the aquifer system. The relation between diffuse and conduit flow is shown by the generalized block diagram in figure 1 (Gunn, 1986).

In a mature karst aquifer, such as occurs in the study area, conduits concentrate water that enters the subsurface at discrete points, such as sinkholes, or by slow drainage from the overlying strata. In this way, contaminants placed on the land surface or disposed of in sinkholes have the potential for rapid transport into the subsurface and impairing ground-water quality downgradient from the input point.

EXPLANATION

1. Diffuse flow through soil, residuum, or unconsolidated surficial material
2. Flow through enlarged vertical conduits
3. Diffuse flow in bedrock
4. Surface streams draining into sinkholes
5. Horizontal and vertical flow to major conduit
6. Water-filled major conduit
7. Vadose conduit stream
8. Flow lines of diffuse phreatic flow

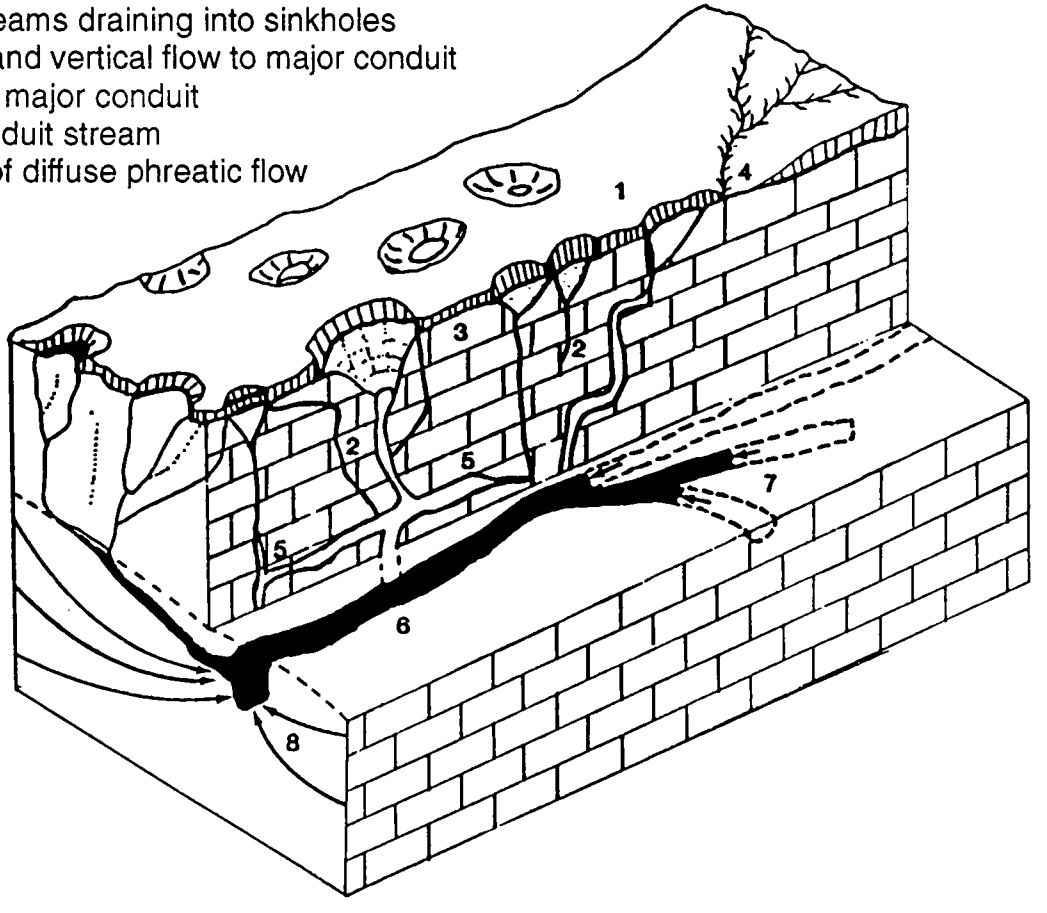

Figure 1.--Components of ground-water flow in a mature karst aquifer. (Modified from Gunn, 1986.)

Conduit flow in major conduits converge to the springs that serve as the natural discharge points for these conduits. Flow in major conduits is typically turbulent, with highly-variable turbidity and temperature, and has a relatively rapid response to precipitation. These are characteristics of several large springs--Mud River Spring, Mossy Spring, and the Auburn Spring--that are the discharge points of major conduits draining ground-water basins in the study area.

Ground water moves in response to hydraulic gradients from points of recharge to points of discharge. In the study area, most points of recharge are in the uplands and points of discharge are in valleys and streams. The general direction of ground-water flow can be estimated by drawing flow lines perpendicular to water-level contours of a potentiometric (water table) map. However, the local direction of ground-water flow at a specific site may differ from that of general regional flow because the water follows available routes whose orientation depends on the development of secondary openings and local structure, including dip of the rocks. For this reason, ground-water tracing is commonly the most accurate, or even the only method, of defining the direction of ground-water flow in karst terrane.

USE OF DYE TRACING TO DEFINE THE DIRECTION OF GROUND-WATER FLOW

The practice of tracing ground-water flow by adding distinctive substances to water draining underground and monitoring the down-gradient resurgence of that water has long been a useful tool in hydrologic investigations. Because of the unique hydrologic characteristics of karst terrane, dye tracing is generally the most practical and satisfactory method to provide information about the movement of water in karst aquifer systems. Perhaps the most common use of dye tracing is to identify point-to-point connections between discrete ground-water recharge points, such as sinkholes, and discharge points, such as springs or wells. In addition, analysis of dye-recovery data from dye-tracer tests can provide critical information for water managers, such as time of travel, peak concentration, and persistence of potential ground-water contaminants.

Dye tracing can generally be classified as qualitative, semiqualitative, or quantitative, depending on the method of dye recovery, extent and method of analysis of the dye-recovery data, the number of dye-tracer tests between the same dye injection and recovery points, and the hydrologic conditions during repeat dye-tracer tests. Typically, qualitative dye tracing involves the tagging of a discrete sample of water with dye and monitoring the passage of that water at various down-gradient ground-water resurgences. The arrival of dye is observed visually or by appropriate analysis of various passive detectors (dye accumulators) that have adsorbed the dye. Generally, semiquantitative and quantitative dye-tracer tests use instrumental analysis of water samples or various dye elutants to confirm the presence or precisely measure the concentration of a particular tracer. In addition, analysis of the results of repeated quantitative dye-tracer tests between the same input and recovery points during different flow conditions can be used to provide

information on time of travel, peak concentration, and persistence of a particular dye. These data can be used to estimate similar characteristics of a potential ground-water contaminant.

The primary purpose of dye-tracer tests performed during this study was to identify point-to-point connections between sinkholes near the waste-disposal site and down-gradient springs. Therefore, all dye-tracer tests were designed to be qualitative and did not include instrumental determination of dye except for definition of background concentration of a particular dye before injection during special conditions that are described later.

The following discussion briefly describes the procedures used for dye-tracer tests during this investigation. In general, the procedures were similar to those used in the Elizabethtown area of Kentucky by Mull and others (1988b) and described in detail in Mull and others (1988a). For convenience, the name and identification of various dye-injection swallets and dye-monitoring sites from previous investigations that could be correlated with similar features in this study are listed in table 5.

Types of Tracers

Several fluorescent dyes can be used for qualitative dye-tracer tests. Fluorescent dyes are generally superior to nonfluorescent dyes because they can be detected at concentrations ranging from one to three orders of magnitude less than those required for visual detection of nonfluorescent dyes. Thus, tracer tests with fluorescent dyes can usually be completed without the aesthetically unpleasant discoloration of a private or public water supply.

The fluorescent dyes used during this investigation were selected because they are generally the most convenient and practical tracers, are nontoxic, and are adsorbed on activated cocoanut charcoal or undyed cotton--materials commonly used in passive dye detectors. Because the selected dyes are adsorbed on different dye-detector materials, combinations of dyes were used because one particular dye did not interfere or impede the adsorption of a second dye during simultaneous dye tracings from different injection sites. During this investigation, tracer tests 1 and 2 were performed simultaneously, each using a different fluorescent dye injected at different swallets.

Because most dyes are available under different commercial names, the Colour Index (CI) Generic Name or Constitution Number of a dye is used in this report to avoid confusion (Society of Dyers and Colourists and American Association of Textile Chemists, 1971-82). The fluorescent dyes used during this investigation included fluorescein (CI Acid Yellow 73) and Direct Yellow 96 (DY 96).

Fluorescein is a reddish-brown powder that turns vivid yellow green in water. Fluorescein has a low sorptive tendency, is photochemically unstable, and may lose fluorescence in water with pH less than 5.0. It is one of the most widely used water tracers used in the United States for dye-tracer tests in karst terrane (Quinlan, 1986).

Table 5.--Correlation of sites used during this study with previous dye-tracer studies

[--, not used]

Dye-monitoring sites					
Site, plate 1	Name or description	Site and name, (Quinlan, 1982)		Site and name, (Ewers, 1983)	
1	Lagoon Spring	4	Lagoon Spring	5	Barn Spring
2	Green Boiling Spring	37	Green Boiling Hole	3	Duncan New
3	Duncan Tiled Spring	15	Duncan Tiled Spring	4	Duncan Old
4	Duncan natural well	17	Duncan natural well	--	
5	Duncan barn stream	--		--	
6	Coy Wright Blue Hole Spring	30	Coy Wright Blue Hole Spring	--	
7	Coy Wright Spring	32	Coy Wright Spring	--	
8	Mud River Spring	14	Mud River Spring	1	Mud River Spring
9	Mossy Spring	8b	Mossy Spring fork	--	
10	Long South Fork	8c	Long South Fork	--	
11	Cemetery Road Spring	--		--	
12	Barnett Spring	42	Barnett Spring	--	
13	Barnett Karst Window	45	Wellhouse Spring	8	Wellhouse window
14	Auburn Spring	1	Waterworks Blue Hole	6	Waterworks Spring
[1]15	Lee Spring	3	Lee Spring	--	
[1]16	Crawford Spring	24	Crawford Spring	9	Gasper River rise

Dye-injection sites					
(Note: Only sites A, B, and C were used for dye-injection during this study. Sites used by previous investigators are included for information.)					
A[2]	Not named	A[2]	Caldwell fluorescein	A[3]	Not named
B	Not named	--		--	
C	Not named	--		--	
D	Not named	A	Caldwell fluorescein	A	Not named
E	Not named	E	Caldwell brightener	B	Not named
F	Not named	--		C	Not named
G	Not named	F	Wilson sinkhole	D	Not named
H	Not named	M	Hall south sinkhole	--	
I	Not named	L	Oaks swallet	--	

[1]Not used during this study.
[2]Same sinkhole, but for this study dye was injected into a different swallet.
[3]Same swallet used by Quinlan (1982).

DY 96, a yellow dye, consists of fine-grained, yellowish-orange granules that produce a light-yellow color when dissolved in water. At low concentrations in water, DY 96 is usually invisible, but the dye imparts a bright canary-yellow color to undyed cotton when viewed under long-wave ultraviolet light. False positives resulting from the background presence of the dye are not a problem when using this dye as a tracer, because DY 96 does not occur naturally and is not commonly used in household products. The absence of DY 96 was verified before this dye was injected during tracer test 2.

Tracer Injections

The primary purpose of dye tracing during this study was to identify the resurgence sites for surface runoff that drains from the waste-disposal site and enters the ground-water flow system, only open swallets capable of receiving surface runoff from the site were selected for dye injection. In general, the selection of a particular swallet for dye injection was intended to supplement, but not duplicate, the results from previous dye-tracer tests. Further verification of the results of tracer tests completed by Quinlan (1982) was not required, in part, because this was accomplished by Ewers (1983). Although one dye-injection swallet (site A) was part of the same large sinkhole used for dye injection by Quinlan (1982), during this study, dye was injected in a swallet in the southwest edge of the sinkhole that, according to the landowner, was not present at the time of dye tracing by Quinlan.

The dye-injection swallets used in this and previous studies are identified on plate 1 and listed in table 5. Swallet A (pl. 1) is in the west-central part of the waste-disposal site. The swallet is a vertical shaft about 30 feet in diameter and 20 feet deep that has developed during the past year (1991), according to the landowner. Tracer test 1 of this study originated from this swallet.

Dye-injection swallet B (pl. 1) is in a steep-sided sinkhole about 50 feet deep and about 900 feet topographically downgradient from the west-central part of the waste-disposal site. About 900 feet of 2 1/2-inch diameter flexible fire hose was used to transport water from a tank truck on the ridge-top road to the injection swallet. The swallet is about 20 feet in diameter and is partly filled with fallen trees and brush. The mouth of the swallet was not seen because of the debris; however, the swallet is thought to be relatively open because water drained freely, without ponding, during the dye injection. During relatively heavy rainfall, surface runoff from the waste-disposal site probably drains directly into this swallet. Tracer test 3 originated from this swallet.

Dye-injection swallet C (pl. 1) is in a sinkhole that is topographically downgradient from the western part of the waste-disposal site and is about 10 feet deep. Surface runoff from the waste-disposal site drains into this swallet. Tracer test 2 originated from this swallet and was the first tracing attempted from this site.

The procedure used for all dye injections included hauling potable water from the Auburn public water system to the injection site in a fire department tank truck. The dye-injection procedure began by draining about 1,000 gal of water into the injection swallet. This first slug of water served as a wetting agent for subsurface conduits before the dye mixture was added. The particular dye to be injected was dissolved or mixed with water in a 10-gal plastic carboy and poured into the swallet as the remaining volume of water in the tank was added to the swallet. The remainder of the water, usually about 1,000 gal, served as a chaser to carry the dye into and through the ground-water flow system. Water and dye was injected in each swallet at the rate of approximately 50 gallons per minute. During each test, the dye mixture was poured directly into the swallet and special care was taken to ensure that the area around the injection swallet was not contaminated with dye. In the case of DY 96, hot water was used for the dye mixture to facilitate dissolution of the dye granules before injection.

Tracer Sampling

During qualitative dye-tracer tests, the presence of dye is determined visually and does do not require the use of instruments, such as fluorometers. Fluorometric analysis of water samples was used to detect any existing concentrations of fluorescein during this study because fluorescein was used for two separate, but consecutive dye-tracer tests (tracer tests 1 and 3).

All tracers used during this study were detected by passive dye detectors or "bugs" consisting of a fiberglass bag containing activated cocoanut charcoal or a swatch of undyed cotton, depending on the particular tracer being used. Each fiberglass bag, containing about 2 teaspoons of activated cocoanut charcoal (6-14 mesh) or a 2- by 2-inch swatch of undyed cotton, was attached to a length of wire imbedded in a gumdrop-shaped concrete anchor about 6 inches in diameter and 3 inches high (fig. 2). The gumdrop anchor was attached to the bank with a small nylon rope. The bag was fabricated from a 3- by 7-inch piece of fiberglass screening and was replaced each time the detectors were retrieved. During tracer tests involving the simultaneous use of different dyes, separate fiberglass bags containing charcoal and cotton were placed at all dye-monitoring sites.

Each passive dye detector was placed in the center of flow from a spring or stream to maximize exposure to the dye. The dye recovery packets were left in place from 1 to 7 days and were not reused. After the appearance of dye at a particular resurgence, dye monitoring was continued at all sites for a period of 2 weeks. The purpose of the continued monitoring was to monitor for additional dye at the same resurgence and to allow for dye to reach more distant resurgences. Dye detectors were placed, recovered, and analyzed to define the residual fluorescence before a particular dye was injected. This was especially necessary when using fluorescein because of its widespread use as a coloring agent in many home products, such as shampoos, various household cleaners, and engine antifreeze.

Initially, dye detectors were installed in selected springs that received dye during earlier dye-tracer tests by Quinlan (1982) and Ewers (1983). One dye-monitoring spring used by Quinlan (Lee Spring, site 15) could not be

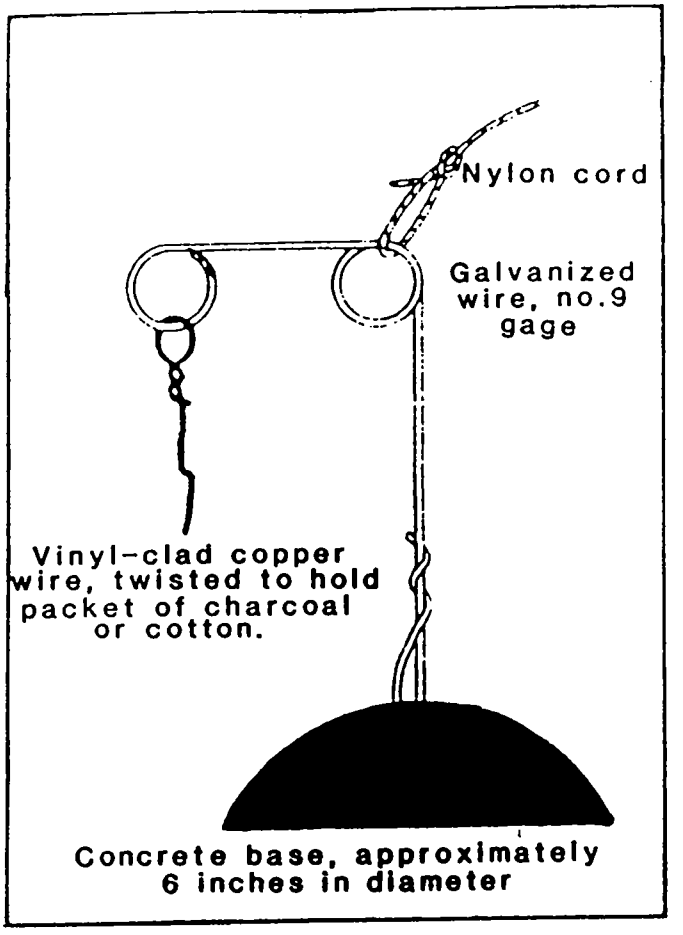

Figure 2.--Anchor used to suspend dye detectors (bugs) in springs or streams. (Modified from Quinlan, 1987, p. E-8.)

located, although the author and the landowner spent considerable effort attempting to locate the spring. Apparently, Lee Spring is a small ephemeral spring with little or no topographic expression, such as a rise pool or stream at its resurgence. During dye-tracer tests 1 and 2, a total of 12 sites were monitored for the presence of dye--11 springs and 1 stream. For the last dye-tracer test during this study (tracer test 3), 1 spring (site 11) and 1 stream (site 5) were added to the dye-monitoring network to further define the pattern of dye recovery. Thus, a total of 14 sites were monitored for dye recovery during dye-tracer test 3. The Auburn water-supply spring was monitored for the presence of dye during all dye-tracer tests performed during this study.

Various quality-control procedures were used during this investigation to prevent contamination of dye detectors from improper handling of dye, dye detectors, or water samples. All dye was transported to the injection site in lock-top plastic boxes or, in the case of premixed liquids, in plastic carboys. Dye-adsorbent activated cocoanut charcoal was stored and transported to the field in tightly-sealed glass containers, and cotton swatches were stored and transported in lock-top plastic bags. Prior to the time of dye injection, usually the day before, all dye detectors were fabricated and installed at all dye-monitoring sites before the dye containers were opened and dye was mixed or injected. Long-sleeved rubber or plastic gloves were worn during all dye-handling operations in the field.

When retrieved, each dye detector was rinsed to remove accumulated sediment and trash. Each recovered dye detector was placed in a lock-top plastic bag and marked with an identification number for return to the laboratory. The lock-top plastic bags were not reused.

All recovered dye detectors and water samples were transported to the laboratory in light-tight containers because some fluorescent dyes photodecay. If dye detectors (charcoal or cotton swatches) were not processed immediately upon arrival at the laboratory, they were stored in a freezer until processed. Fresh elutant was prepared for testing each batch of exposed dye detectors. Samples from each batch of fresh charcoal were tested to verify the absence of fluorescence that might be caused by contaminants. Such fluorescence might cause false positives.

Before being removed from the fiberglass bag in the laboratory, the charcoal was rinsed in a jet of water to remove sediment which can interfere with the analysis. The exposed charcoal from each recovered dye detector was processed in a 400-mL beaker that was covered with aluminum foil to prevent contamination from airborne contaminants. In addition, an uncovered blank of activated charcoal was processed at the same time to verify the absence of airborne contaminants in the detector-processing area in the laboratory.

Samples of injection water were tested fluorometrically to verify the absence of fluorescein. This was especially relevant during this study because of the possibility of unknown dye-tracer tests in the catchment basin of the Auburn spring or other areas. The fluorometer tests indicated that the residual concentration of fluorescein did not exceed 0.05 ppb in water from Auburn that was used for dye injection. This concentration of fluorescein is far below that sufficient to be observed in the qualitative dye-detection

procedure used during this study. Only glass bottles were used to collect and transport water samples to the laboratory for fluorometric determination of background concentration of fluorescein.

Tracer Analyses

The presence of fluorescein was determined by eluting the exposed charcoal in an alcohol-potassium hydroxide solution and visually checking for the characteristic yellow-green color in the elutant. Charcoal from the exposed detectors was placed in a 400-mL beaker and covered with about 20 mL of elutant. The elutant consists of 6 to 7 grams of potassium hydroxide dissolved in 100 mL of 70-percent isopropyl alcohol (rubbing alcohol). After the potassium hydroxide dissolves, the solution separates into a supersaturated solution and a saturated solution. Only the lighter saturated solution is decanted into containers with the charcoal.

In strongly positive tests, that is, the monitored resurgence is a major discharge point for the injected dye; the typical yellow-green fluorescein color develops almost immediately upon addition of the elutant. However, in cases where the dye recovery is less concentrated, the color is less obvious and the period of time the charcoal is exposed to the elutant is extended--in some cases during this investigation, as much as 24 hours before the color developed. Where the concentration of recovered fluorescein is low, the characteristic color caused by dye in the elutant may not be visible unless a beam of sunlight or artificial light (microscope lamp) is passed through the solution. The fluorescein color can be seen in the light beam.

The presence of DY 96 is indicated by the characteristic canary-yellow fluorescence when the exposed cotton swatch is viewed under long-wave length ultraviolet light. The fluorescence of DY 96 is enhanced if the exposed cotton is viewed in subdued lighting, such as a viewing box or darkened room. A positive dye recovery is indicated only if the entire cotton mass fluoresces relatively evenly. Scattered specks of fluorescence on the cotton was not interpreted as a positive dye recovery during this investigation.

Description of Dye-Tracer Tests

The qualitative dye-tracer tests completed during this study are summarized in table 6 and shown on plate 1. The dye-tracer tests are numbered sequentially 1 to 3 and are shown as straight lines on plate 1. The lines are not intended to indicate the exact path of ground-water movement, but only a subsurface connection between the various dye-injection swallets and dye-recovery sites. The results of selected dye-tracer tests from previous investigations in the study area (Quinlan, 1982 and Ewers, 1983) are also included in table 6 and shown as curved lines on plate 1.

Dye-Tracer Test 1

Dye-tracer test 1 originated from site A when 5 pounds of fluorescein was flushed into the swallet at 1530 hours on January 21, 1992. This test was

Table 6.--Summary of dye-tracer tests

[Note: Dye-tracer test and site identification refers to plate 1]

Dye-tracer test	Dye-injection sites	Dye-recovery sites	
		Number	Name
1	A	2	Green Boiling Spring
		3	Duncan Tiled Spring
		6	Coy Wright Blue Hole spring
		8	Mud River Spring
		9	Mossy Spring
		10	Long South Fork
2	C	1	Lagoon Spring
		2	Green Boiling Spring
3	B	3	Duncan Tiled Spring
		6	Coy Wright Blue Hole Spring
		8	Mud River Spring
		9	Mossy Spring
		10	Long South Fork
		11	Cemetery Road Spring
[1]Q-1	H	1	Lagoon Spring
[2]QE-1	D	2	Green Boiling Spring
		3	Duncan Tiled Spring
QE-2	E	2	Green Boiling Spring
		3	Duncan Tiled Spring
		4	Duncan Natural Well
		15	Lee Spring
[3]E-1	F	2	Green Boiling Spring
		3	Duncan Tiled Spring
QE-3	G	12	Barnett Spring
		13	Barnett Karst Window
		16	Crawford Spring
QE-4	I	8	Mud River Spring

[1]Quinlan (1982).
[2]Quinlan (1982) and Ewers (1983).
[3]Ewers (1983).

performed during relatively low-flow conditions. The discharge from all large springs (Mud River, site 8; Mossy Spring, site 9; and Auburn, site 14) was relatively low and nonturbid during this test, and Green Boiling Spring (site 2) was dry 1 week after the dye injection.

All dye detectors were installed on January 14, 1992 and left in place for a period of 1 week before dye injection on January 21 to detect any residual fluorescein before fluorescein was injected. All dye detectors were negative for fluorescein. One week after the dye injection, on January 28, 1992, the dye detectors from Green Boiling Spring (site 2), Duncan Tiled Spring (site 3), Coy Wright Blue Hole Spring (site 6), Long South Fork (site 10), and Mud River Spring (site 8) all tested positive for fluorescein. On the same day, water in the Coy Wright Blue Hole Spring was brilliant yellow green with fluorescein. A qualitative assessment of the color of the elutant of the dye detectors from the above-mentioned sites indicated that all were strongly positive for fluorescein except Mud River Spring and Long South Fork. Both sites are relatively distant from the dye-injection swallet and, thus, are subject to dilution from undyed water recharging the ground-water flow system and draining to the sites. This is the case at Mud River Spring (site 8) because results of tracing by Quinlan (1982) indicated that Mud River Spring receives water from the area due east of that spring. All of the above-mentioned sites were positive for dye from this injection through February 11, 1992 when dye monitoring for this test was discontinued.

Dye-tracer test 1 provided the first confirmation of multi-directional flow of ground water from the waste site. Review of the dye-recovery data of Quinlan indicates similar dye-recovery patterns during one of his dye-tracer tests (Q-1 from site H, 1982). However, Quinlan did not consider the results of that test conclusive because of the possible presence of dye residue from an earlier trace from site D. In light of the results of dye-tracer test 1, it seems likely that dye from the tracer test Q-1 (pl. 1) by Quinlan (1987) did follow multi-directional flow paths to drain to Mossy Spring (site 8), to Green Boiling Spring (site 2), and also to Duncan Tiled Spring (site 3).

The time of dye arrival at Mossy Spring during tracer test 1 is unknown because the fiberglass bag was shredded and the charcoal was missing on January 28, 1992, the earliest scheduled detector-recovery date. The detector did show that dye had arrived at Mossy Spring by February 4, 1992. A nearby site, Long South Fork (site 10), was positive for dye on January 28, 1992. Thus, it is likely that dye had arrived at Mossy Spring on January 28, 1992. Dye detectors in both Mossy Spring and Long South Fork were positive for fluorescein on February 4 and 11, 1992.

Dye-Tracer Test 2

Tracer test 2 began at 1630 hours on January 21, 1992, when 6 pounds of DY 96 was flushed into swallet C (pl. 1). The brilliant yellow color of the dye was seen in water from the Lagoon Spring (site 1) at 0910 hours the next day. All dye-monitoring sites south of the injection swallet were visited on January 22, 1992, but dye was seen only in water in Lagoon Spring. The visual detection of dye at Lagoon Spring was caused by a high concentration of dye draining to the spring during relatively low-flow conditions. The estimated

discharge from the Lagoon Spring was only 10 gallons per minute on January 22, 1992. Analysis of cotton swatches indicated that dye from this injection was present at Lagoon Spring through February 11, 1992.

The only other dye detector that tested positive for DY 96 during tracer test 2 was at Green Boiling Spring (site 2). At the time the detector was recovered, 0920 hours on January 28, 1992, the cotton swatch exhibited the bright-yellow color of the dye in natural light. This indicates that concentrated dye had drained to this site during the early part of this test when there was sufficient ground-water discharge to cause flow from the spring. However, on January 28 the spring was dry and remained so through February 11, 1992 when dye monitoring for tracer test 2 was terminated.

Dye-Tracer Test 3

Tracer test 3 began from swallet B (pl. 1) when 5 pounds of fluorescein was flushed into the subsurface at 1600 hours on April 28, 1992. Flow conditions during this test were similar to that during dye-tracer tests 1 and 2, that is, generally a period of limited rainfall and declining discharge from dye-monitoring springs. The Green Boiling Spring (site 2) was dry during the time of this test and estimated discharge at other springs was the lowest observed during this study. Dye detectors were maintained in Green Boiling Spring to provide monitoring in case precipitation might cause the spring to discharge during the test. This did not occur during the period of tracer test 3.

Because fluorescein was used for both tracer tests 3 and 1, it was necessary to verify that residual dye from test 1 was not present at the dye-monitoring sites during test 3. Fluorometric tests of water samples collected on April 14, 1992 and analysis of dye detectors collected April 20 and 28 (prior to injection) confirmed that fluorescein was not present. Background concentrations of fluorescein ranged from 0.09 to 0.52 ppb in water draining from the dye-monitoring sites. Apparently, several heavy thunderstorms and the elapsed time was sufficient to allow residual fluorescein from tracer test 1 to drain from the ground-water system.

As with tracer test 1, dye was not observed in the field during inspection of dye-monitoring sites the day after the dye injection for tracer test 3. However, the water in the Coy Wright Blue Hole Spring (site 6) was vivid yellow green with fluorescein 1 week later. This was the only site where the color of fluorescein was observed in the field during tracer test 3. Analysis of recovered dye detectors indicated that the pattern of dye dispersal during tracer test 3 was similar to tracer test 1, that is, the dye detectors from Duncan Tiled (site 3), Coy Wright Blue Hole (site 6), Mud River (site 8), and Mossy springs (site 9) were all positive for fluorescein 1 week after the dye injection in swallet B.

As with tracer test 1, the intensity of dye recovery at Mud River and Mossy springs seemed to be less than at Duncan Tiled and Coy Wright Blue Hole springs. Qualitative assessment of the dye color from the detectors recovered May 11, 1992 indicated that the dye recovery increased at Mossy Spring and also that the dye had reached the Cemetery Road Spring (site 11).

Detectors from all these sites tested positive for dye to the end of this test on May 19, 1992. The dye detector in Long South Fork (site 10) was not recovered on May 4, but was positive for dye on May 11, 1 week later. The detector at this site was negative for dye on May 19, 1992.

Results of Dye-Tracer Tests

The results of dye-tracer tests completed during this study, and also by previous investigators (table 6 and pl. 1), indicate that the waste-disposal site is along an east-west trending ground-water divide and that ground water flows from the vicinity of the waste-disposal site to springs south and northwest of the site. Dye was not recovered in springs northeast of the site except in earlier dye-tracer tests (Quinlan, 1982 and Ewers, 1983) when the dye was injected in swallet G near the head of a valley northeast of the site (pl. 1). A dye-tracer test was not performed from swallet G during this study. However, this is not to say that ground-water flow from the site will never flow in a northeasterly direction. It is possible that ground water from the waste site could overflow subsurface drainage divides and flow toward the northeast, especially during high-flow conditions. Additional dye-tracer tests conducted during high-flow conditions are needed to test this possibility.

Results of dye-tracer tests performed during this investigation were similar to the results reported by previous investigators and indicate that ground water flows from the vicinity of the waste-disposal site and discharges at several springs. The pattern of dye recovery in two separate dye-tracer tests (tests 1 and 3) indicates that ground water from the waste-disposal site flows in different directions to separate springs. In both dye-tracer tests 1 and 3, dye was present in water from Mossy Spring (site 9) and Long South Fork (site 10), both of which are northwest of the waste-disposal site, and also in water from Green Boiling Spring (site 2), Duncan Tiled Spring (site 3), Coy Wright Blue Hole Spring (site 7), and Mud River Spring (site 8), south of the site. Dye from tracer test 3 was also present in water from Cemetery Road Spring (site 11) which is near Mossy Spring (site 9) and northwest of the waste-disposal site. Dye from the tracer tests performed during this investigation was not detected in water from the Auburn water-supply spring.

The results of qualitative dye-tracer tests do not provide information on time of travel or velocity of ground-water flow, but because of the visual detection of dye issuing from some springs, an estimate of these characteristics is possible. For example, the dye was observed in Lagoon Spring (site 1), during tracer test 2, about 17 hours after the dye was injected in swallet C. On the basis of the elapsed time between time of injection and observation of dye and the straight line distance between the dye injection and recovery sites, the velocity of ground-water flow during this test was about 0.5 ft/min. Similarly, the visual observation of the dye in the Coy Wright Blue Hole Spring (site 6) during tracer tests 1 and 3 indicates that the time of travel was about 1 week and that the velocity of ground-water flow was about 0.7 ft/min.

For these estimates of travel time and velocity of ground-water flow, it is important to remember that the chance sighting of the dye in the field was

a function of the schedule for servicing dye detectors rather than an attempt to define the travel time. Because the leading edge of a dye cloud is usually invisible to the eye and arrives before the mass of dye sufficient to produce a strong color, it is likely that the actual travel time was much less and the flow velocity faster than the estimated value. Even so, the estimated velocity of ground-water flow during these dye-tracer tests is typical of conduit flow during relatively low-flow conditions and demonstrates the potential rate of travel and widespread dispersal once contaminants reach the ground-water flow system in karst terrane. The estimated ground-water velocities in the study area are similar to those reported by Mull and others (1988b, p. 71) in the Elizabethtown area of Kentucky--about 2 to 14 ft/min.

The results of dye-tracer tests completed during this study and by previous investigators have identified several springs that are hydrologically connected to the waste-disposal site. These springs are appropriate sites for monitoring the effects of the waste-disposal site on ground-water quality. To reduce the effect of mixing of water from different parts of the ground-water basin or from nearby basins, water-quality monitoring sites need to be as close to the waste-disposal site as possible. The following springs are suggested as the primary water-quality monitoring springs near the waste-disposal site: Lagoon Spring (site 1), Green Boiling Spring (site 2), Duncan Tiled Spring (site 3), and Mossy Spring (site 9). Mud River Spring (site 8) could be used during low-flow conditions when mixing of water from other ground-water basins is less likely. Because the direction of ground-water flow might change, especially during high-flow conditions, Barnett Spring (site 12), Barnett Karst Window Spring (site 13), and Auburn Spring (site 14) also need to be sampled. If flow conditions are such that Green Boiling Spring is flowing, sampling of Duncan Tiled Spring is unnecessary. If both Green Boiling Spring and Duncan Tiled Spring are dry, the Coy Wright Blue Hole Spring (site 6) should be substituted. If these springs are dry, Mud River Spring (site 2) should be sampled. Mud River Spring seems to be a major discharge point for the ground-water basin that includes the waste site. Because of the distance of the spring from the waste site, Mud River Spring is less desirable as a water-quality monitoring spring than Duncan Tiled Spring, except during relatively high-flow conditions.

Estimates of travel time for movement of tracers from the waste-disposal site to various springs indicate that sampling during, or immediately after a rainfall event, is not likely to produce water samples that are representative of drainage from the waste site. A delay of 3 to 5 days is suggested to allow sufficient time for water from the waste site to arrive at the springs. In the case of the most distant spring (Mud River Spring, site 8) more time may be required. The suggested delay period is based on qualitative assessments made during this investigation. The selection of the delay period is a function of the precipitation and hydrologic conditions at the time of the sampling. Observed increases in discharge and turbidity at a particular spring usually indicate that storm runoff has reached the spring.

In order to improve estimates of travel time between the waste-disposal site and a selected spring, especially during different flow conditions, quantitative dye-tracer tests are needed. Results of quantitative dye-tracer tests can provide estimates of travel time and the percentage of water

draining from the waste site to a particular spring. This is relevant because results of qualitative dye-tracer tests, completed during this study, indicate that ground water that flows from two separate swallets near the waste site drains in two different directions to two separate springs. The results of quantitative dye-tracer tests would improve the effectiveness of future sampling programs by ensuring that the particular time selected to collect water samples was appropriate for water-quality monitoring of drainage from the waste site.

Because of unique local conditions, springs may not always offer the only sites appropriate for monitoring of constituents in ground water draining from a waste-disposal site in karst terrane, especially in the study area, where the relatively long distances between the selected springs and the waste site increase the potential for the inflow of water from other ground-water basins. This water could cause dilution sufficient to prevent the detection of various hazardous constituents in water from the springs selected for monitoring.

As a supplement to the monitoring springs selected during this study, a network of shallow wells installed to bedrock and located topographically downgradient from the waste site would monitor the quality of ground water in the residuum overlying bedrock. Because of the nearness of the monitor wells to the waste site, the potential for dilution would be decreased. Dye-tracer tests would be needed to confirm the hydrologic connection between the monitor wells and the waste site.

SUMMARY AND CONCLUSIONS

The study area is in the Mississippian Plateaus region of west-central Kentucky and is underlain by as much as 70 feet of sandstone and shale overlying massive limestone units as much as 200 feet thick. The waste-disposal site is along a ridge that is about 170 feet above the surrounding valleys. Karst landforms, such as sinkholes with swallets, and springs, are common, especially in the broad valleys that generally surround the ridge.

In the study area, ground water is present and moves through primary and secondary openings in carbonate bedrock as well as through the overlying soil and residuum. Observed variations in spring discharge and the results of qualitative dye-tracer tests indicate that a major component of ground-water flow near the waste-disposal site is by way of solution enlarged openings or conduits in carbonate bedrock.

Results of qualitative dye-tracer tests indicate that the waste-disposal site is along a ground-water divide. Various fluorescent tracers that were injected in swallets, onsite or topographically downgradient from the waste-disposal site, were detected only in water from springs in valleys south and northwest of the site. None of the dye tracers used during this investigation were detected in water from springs due north of the waste site. However, several springs that drain to the north did receive dye during tracer tests performed by previous investigators, but only where the dye-injection swallet was on the northern side of the ridge where the waste-disposal site is located.

Dye-tracer tests performed during this investigation were designed to be qualitative and generally did not provide accurate time of travel information. However, visual field observation of dye in water from Coy Wright Blue Hole Spring (site 6) indicates that the apparent velocity of ground-water flow from the waste-disposal site to the dye-recovery spring was less than 1 ft/min. This rate is similar to apparent velocities of ground-water flow in other karst basins in the Mississippian Plateau region of Kentucky.

The most appropriate springs for monitoring the quality of ground water draining from the waste-disposal site are Lagoon Spring (site 1), Green Boiling Spring (site 2), Duncan Tiled Spring (site 3), Mossy Spring (site 9), Mud River Spring (site 8), Barnett Spring (site 12), and Barnett Karst Window Spring (site 13). To ensure sufficient time for water to travel from the waste-disposal site to selected water-quality monitoring springs, a delay period of 3 to 5 days is suggested to ensure that ground-water samples from the springs represent off-site flow from a particular rainfall event.

Results of quantitative dye-tracer tests during different flow conditions are needed to improve estimates of travel time and the percentage of water that drains in different directions from the waste site to different springs.

Because of the relatively large distances between the waste-disposal site and the springs where dye was recovered, a network of monitoring wells, installed near the site, might be more useful for water-quality monitoring than the distant springs. The wells need to be topographically downgradient from the waste site and installed to the top of bedrock. This would allow monitoring of the quality of water in the soil and residuum overlying bedrock and lessen the potential for dilution of potentially hazardous constituents as they travel to the springs.

Dye tracers used during this study were not detected in water from the spring used as a source of water by the city of Auburn. This indicates that ground water from the waste site does not enter the ground-water basin draining to that spring, at least during the relatively low-flow conditions present during this investigation.

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SUPPLEMENTAL DATA

Table 1.--Wells in 1-mile radius of waste-disposal site

[--, no data]

Map number	Latitude longitude	Owner	Depth of well (feet)	Depth to water (feet)	Date measured	Remarks
1.1	365248 864529	Barry Reeves	57	32	May 7, 1990	Jet pump
1.2	365242 864533	Bobby Reeves	81	54	May 9, 1990	No pump
1.3	365247 864549	Unknown	87	62	May 7, 1990	No pump
1.4	365252 864535	Barry Sears	99	40	May 17, 1990	No pump
1.5	365246 864519	W.D. Reeves	35	26	May 15, 1990	No pump
1.6	365253 864535	Barry Sears	90	17	May 17, 1990	No pump
1.7	365256 864527	Clyde Boggs	52	13	May 7, 1990	Jet pump
1.8	365222 864446	Caldwell domestic well	--	--	--	Locked
1.9	365306 864445	Buddy Wilson	47	26	May 16, 1990	No pump
1.10	365151 864524	Mrs. Dillard Duncan	17	6	May 18, 1990	Jet pump
1.11	365143 864503	H.T. Hulse	50	35	May 8, 1990	Jet pump
1.12	365157 864508	H.T. Hulse	75	35	May 8, 1990	Jet pump

Table 2.--Springs in 1-mile radius of waste-disposal site

[gal/min, gallons per minute; specific conductance as microsiemens per centimeter at 25 degrees Celsius]

Map number	Latitude longitude	Owner	Discharge (gal/min)	Specific conductance	Date	Use
1.13	365311 864530	David Thomas	25	370	May 15, 1990	Domestic
1.14	365208 864504	H.T. Hulse	1	280	May 16, 1990	Domestic
1.15	365208 864424	Marvin Hudson	1	440	May 16, 1990	Stock
1.16	365246 864451	Bobby Wilson	20	430	May 17, 1990	Stock
1.17	365250 864430	Bobby Wilson	4	340	May 17, 1990	Stock

Table 3.--Wells and springs in 2-mile radius of waste-disposal site

[--, no data; gal/min, gallons per minute]

Map number	Latitude longitude	Owner	Type	Remarks (Depth, discharge, use)
2.1	365307 864657	Carnell Mason	Drilled	Domestic
2.2	365306 864637	Appling	Drilled	51 feet
2.3	365218 864650	Unknown	Drilled	--
2.4	365214 864646	Earl Gipson	Drilled	Domestic
2.5	365149 864639	Eaton	Drilled	Domestic
2.6	365206 864625	Thomas	Drilled	Domestic
2.7	365202 864622	Floyd Gipson	Drilled	Domestic
2.8	365258 864610	Marion Pugh	Drilled	Domestic
2.9	365256 864609	Marion Pugh	Spring	25 gal/min, stock
2.10	365127 864613	Boyce Coles	Spring	Domestic
2.11	365142 864557	Coy Wright	Drilled	Pump inoperable
2.12	365134 864552	Joe Duncan	Drilled	Domestic
2.13	365128 864526	H. Craigs Farm	Drilled	Pump inoperable
2.14	365115 864508	Lillian Johnson	Drilled	Domestic
2.15	365116 864507	Weldon Price	Drilled	Unused
2.16	365116 864507	Willard Childrees	Drilled	60 feet, unused
2.17	365312 864347	Unknown	Drilled	No pump
2.18	365151 864422	Unknown	Drilled	No contact
2.19	365326 864423	Charlie Barnett	Drilled	Pump inoperable
2.20	365309 864313	Unknown	Drilled	Pump inoperable
2.21	365321 864413	Bobby Poor	Drilled	Domestic
2.22	365344 864411	Mae Lashley	Drilled	Domestic
2.23	365352 864410	Blewett	Drilled	Domestic
2.24	365355 864357	Barrett tenant	Drilled	75 feet, domestic
2.25	365357 864358	Barrett Dairy	Spring	450 gal/min
2.26	365140 864404	Roger Fielding	Drilled	Not for drinking
2.27	365342 864347	H. Poole	Drilled	Pump inoperable
2.28	365405 864507	Unknown	Drilled	No pump
2.29	365217 864323	Carl Hodges	Drilled	Not for drinking
2.30	365250 864314	Albert Summers	Drilled	Domestic
2.31	365129 864433	Unknown	Drilled	No contact
2.32	365223 864306	Albert Summers	Spring	Karst-window rise pool
2.33	365249 864257	Mrs. Stone	Drilled	Lawn watering only

Table 4.--Wells and selected spring in 3- to 4-mile radius of waste-disposal site

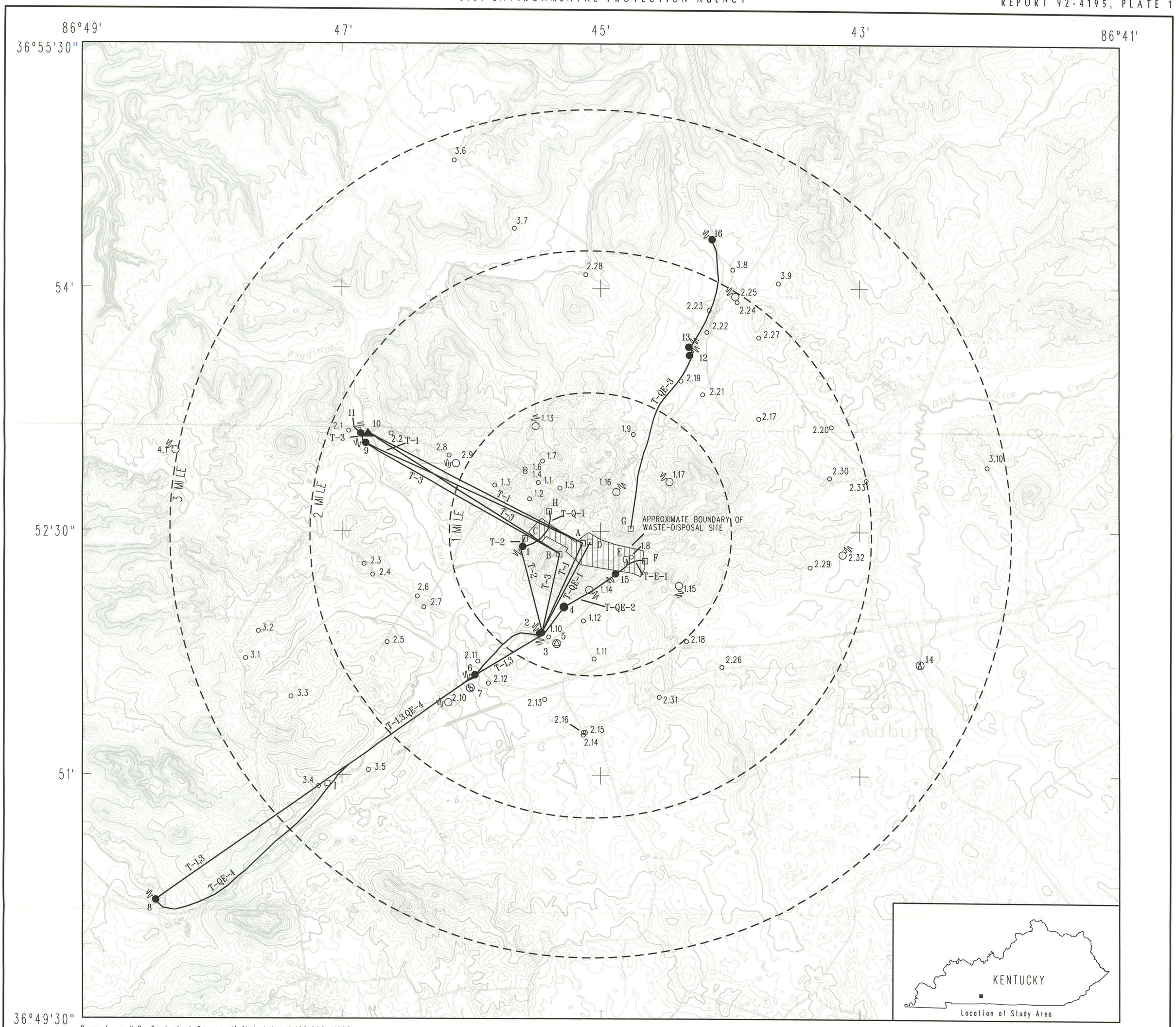
Map number	Latitude longitude	Owner	Type	Remarks (Depth, discharge, use)
3.1	365143 864745	Junior Gilliam	Drilled	122 feet, domestic
3.2	365153 864739	Junior Gilliam	Drilled	102 feet, domestic
3.3	365129 864724	James Gamble	Drilled	130 feet, domestic
3.4	365056 864711	Unknown	Natural well	dry
3.5	365102 864648	G.W. Oakes	Drilled	80 feet, domestic
3.6	365447 864608	Minor Adams	Drilled	123 feet, not used
3.7	365422 864540	I.C. Coles	Drilled	94 feet, not used
3.8	365407 864359	J.C. Crawford	Drilled	45 feet, not used
3.9	365402 864338	Terry Barrett	Drilled	75 feet, domestic
3.10	365254 864201	Minor Woodford	Drilled	84 feet, domestic
4.10	365259 865320	McPherson	Spring	Not used

★U.S. GOVERNMENT PRINTING OFFICE: 1993-0-752-497

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY

WATER-RESOURCES INVESTIGATIONS
REPORT 92-4195, PLATE 1



Base from U.S. Geological Survey digital data, 1:100,000, 1983
Universal Transverse Mercator Projection, Zone 16
Contours from U.S. Geological Survey
Auburn 1951, Dennis 1952, Homer 1951, and
South Union 1951.

SCALE 1:24,000

1 0 1 MILES

1 0 1 KILOMETERS

CONTOUR INTERVAL 10 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

DYE-TRACER TEST AND IDENTIFIER

T-1,3 — 1-3 THIS STUDY
T-QE-4 — Q QUINLAN(1982), E EWERS(1983)

LOCATION OF DYE-INJECTION SITE AND IDENTIFIER

A — DYE-INJECTION SITE

LOCATION OF DYE-RECOVERY SITE AND IDENTIFIER

4 — WELL
6 — SPRING
10 — STREAM

LOCATION OF DYE-MONITORING SITE AND IDENTIFIER

14 — SPRING
5 — STREAM

LOCATION OF SELECTED WELLS AND SPRINGS AND IDENTIFIERS

2.43 — WATER WELL
3.10 — SPRING

DYE-TRACER TESTS, SPRINGS, AND WELLS IN THE VICINITY OF A SUPERFUND WASTE-DISPOSAL SITE, NEAR AUBURN, KENTUCKY

by
D.S. Mull

1992

Mull, D.S., 1992, Use of dye tracing to define the direction of ground-water flow from a superfund waste-disposal site in karst terrane, near Auburn, Kentucky: U.S. Geological Survey Water-Resources Investigations Report 92-4195

APPENDIX D
WELL/SPRING INVENTORY 1991

United States Department of the Interior

GEOLOGICAL SURVEY

WATER RESOURCES DIVISION

TAKE PRIDE IN AMERICA

2301 Bradley Avenue
Louisville, Kentucky 40217
April 19, 1991

Ms. Beth Brown
Kentucky/Tennessee Section
Superfund Branch
U.S. Environmental Protection Agency
Region IV
345 Courtland Street, NE
Atlanta, GA 30365

Beth
Dear Ms. Brown:

As you requested during our recent telephone conversations, I have enclosed a copy of the map and tables showing results of our well/spring inventory at the Caldwell Lace Leather waste disposal site near Auburn, Kentucky. Copies are also going to Mary Jo Penick, Tony Able, and Jim Gray.

If you have any questions about the data, please contact me at FTS 352-5241.

FOR THE DISTRICT CHIEF

Woody
Donald S. Mull

Donald S. Mull
Hydrologist

Enclosures

DSM/bjs

#212

COPY

WATER RESOURCES DIVISION

2301 Bradley Avenue
Louisville, Kentucky 40217
July 2, 1990

Mr. Jim Gray
U.S. Environmental Protection Agency
Environmental Services Division
College Station Road,
Athens, Georgia 30613

Dear Mr. Gray:

I have enclosed a map and tables showing wells and springs within a 3-mile radius of the Caldwell Lace Leather waste disposal site near Auburn, Kentucky. The map is digitized from 7 1-2 minute topographic maps at the scale of 1:24000.

As we discussed by telephone May 14, 1990, all wells and springs in 1-mile radius of the site were inventoried. That is, each site was visited and depth of the well, depth to water, temperature, and specific conductance were measured. Spring discharge was estimated. Information on type of pump, use of water, and ownership was also collected. These data are listed in tables 1 and 2. For sites 1 to 2 and 2 to 3-miles from the site, only general information was collected, mainly, the location and type (well or spring) and, in some cases, owners name and use of water. These data are listed in tables 3 and 4.

Although a few sites remain to be visited, especially in the 3-mile radius of the site, the available data are forwarded for your use and evaluation. If you have any questions or suggestions about the data, please contact me at FTS 352-5241.

For the District Chief,

Donald S. Mull
Hydrologist

Enclosures

cc: Mary Jo Penick

Table 1.--Inventoried wells in 1-mile radius of waste disposal site.

Map number	Latitude longitude	Owner	Depth of well (feet)	Depth to water (feet)	Date measured	Remarks
1.1	365248 864529	Barry Reeves	57.5	31.7	May 7, 1990	Jet pump
.2	365242 864533	Bobby Reeves	81.	53.5	May 9, 1990	No pump, open
1.3	365247 864549	Unknown	87.	61.6	May 7, 1990	do
1.4	365252 864535	Barry Sears	99.	40.	May 17, 1990	do
1.5	365246 864519	W.D. Reeves	35.	26.4	May 15, 1990	do
1.6	365253 864535	Barry Sears	90.	17.4	May 17, 1990	No pump, open
1.7	365256 864527	Clyde Boggs	52.3	13.4	May 7. 1990	Jet pump
1.8	365152 864446	Caldwell domestic well	--	--		Locked cover
1.9	365306 864445	Buddy Wilson	47.	26.	May 16, 1990	No pump, open
1.10	365151 864524	Mrs. Dillard Duncan	17.	6.5	May 18, 1990	Jet pump
1.11	365202 864517	Mrs. Dillard Duncan	14.	9.3	May 16, 1990	No pump, open
1.12	365143 864503	H.T. Hulse	50.	35.	May 8, 1990	Jet pump
1.13	365157 864508	H.T. Hulse	75.	35.	May 8, 1990	do

Table 2.--Inventoried springs in 1-mile radius of waste disposal site.

(Specific conductance as microsiemens per centimeter at 25 degrees Celsius)

Map number	Latitude longitude	Owner	Discharge (gal/min)	Specific conductance	Date	Use
1.14	365311 864530	David Thomas	25.0	370	May 15, 1990	Domestic
1.15	365208 864504	H.T. Hulse	1.	280	May 16. 1990	do
1.16	365208 864424	Marvin Hudson	0.5	440	do	Stock
1.17	365246 864451	Bobby Wilson	20.	430	May 17, 1990	do
.18	365250 864430	Bobby Wilson	4.	340	do	do
.19	365224 864537	Bobby Reeves	50.	280	April 12, 1990	Unused

Table 3.--Wells and springs in 1 to 2-mile radius of waste disposal site.

Map number	Latitude longitude	Owner	Type	Remarks (Depth, in feet; discharge)
2.1	365307 864657	Carnell Mason	Drilled	Domestic use
2.2	365304 864653	Mossy Spring	Spring	200 gal/min
2.3	365306 864637	Appling	Drilled	51
2.4	365218 864650	Unknown	do	do
2.5	365214 864646	Earl Gipson	Drilled	Domestic use
2.6	365149 864639	Eaton	do	do
2.7	365206 864625	Thomas	do	do
2.8	365202 864622	Floyd Gipson	Drilled (2)	do
2.9	365258 864610	Marion Pugh	Drilled	do
2.10	365256 864609	Marion Pugh	Spring	25 gal/min, stock
2.11	365127 864613	Boyce Coles	do	do
2.12	365133 864601	Wright Blue Hole	Spring	75 gal/min
2.13	365137 864558	Coy Wright	do	0.5 gal/min
2.14	365142 864557	Coy Wright	Drilled	Pump inoperable
2.15	365134 864552	Joe Duncan	do	Domestic use
2.16	365128 864526	H. Craigs Farm	do	Pump inoperable
2.17	365115 864508	Lillian Johnson	do	Domestic use
.18	365116 864507	Weldon Price	do	Unused
.19	365116 864507	Willard Childrees	do	do, 60 ft.
.20	365312 864347	Unknown	do	No pump

2.21	365151	864422	Unknown	do	No contact
2.22	365326	864423	Charlie Barnett	do	Pump inoperable
2.23	365336	864418	Charlie Barnett	Spring	Unused
2.24	365339	864418	Charlie Barnett	do	do
2.25	365309	864313	Unknown	Drilled	Pump inoperable
2.26	365321	864413	Bobby Poor	do	Domestic use
2.27	365344	864411	Mae Lashley	do	do
2.28	365352	864410	Blewett	Drilled	do
2.29	365355	864357	Barrett tenant	do	do, 75 ft.
2.30	365357	864358	Barrett Dairy	Spring	450 gal/min
2.31	365140	864404	Roger Fielding	Drilled	Not for drinking
2.32	365342	864347	H. Poole	do	Pump inoperable
2.33	365405	864507	Unknown	do	No pump
2.34	365217	864323	Carl Hodges	Drilled	Not for drinking
2.35	365250	864314	Albert Summers	do	Domestic use
2.36	365129	864433	Unknown	do	No contact
2.37	365223	864306	Albert Summers	Spring	Karstwindow rise pool
2.38	365249	864257	Mrs. Stone	Drilled	Lawn watering only

Table 4.--Wells and springs in 2 to 3-mile radius of waste disposal site.

Map number	Latitude longitude		Owner	Type	Remarks (Depth, in feet; discharge)
3.1	365143	864745	Junior Gilliam	Drilled	122, jet pump
3.2	365153	864739	Junior Gilliam	do	102, jet pump
3.3	365129	864724	James Gamble	do	130, jet pump
3.4	365056	864711	Unknown	Natural well	Dry
3.5	365102	864648	G.W. Oakes	Drilled	80, domestic
3.6	365447	864608	Minor Adams	do	123, no pump
3.7	365422	864540	I.C. Coles	do	94
3.8	365407	864359	J.C. Crawford	do	45
3.9	365402	864338	Terry Barrett	do	75, domestic use
3.10	365141	864232	Auburn Blue Hole	Spring	Public supply, 600 gal/min
3.11	365254	864201	Minor Woodford	Drilled	84,jet pump

APPENDIX E
SOIL BORINGS 1992
BOREHOLE LOGS

Soil Classification System used in describing the soils is the "Unified Soil Classification" (Corps of Engineers, Department of the Army; and Bureau of Reclamation).

The soil samples were identified by an eight digit code. The following is an example sample number: CL-SB-01-07. Where,

CL: Caldwell Lace Leather
SB: Soil Boring
01: Location Number
07: Split Spoon Number

Each split spoon number was equal to 1.5 feet of sampling depth.

CLIENT : USEPA		TOTAL DEPTH	: 46.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-01		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/10/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/10/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-1	1			Lean clay, CL	7.5 YR 5/4	FRM	MST	1 1 1 0		BROWN ANALYTICAL SAMPLE TAKEN, CL-SB-01-01
-2	2		66	Lean clay, CL	10 YR 5/3	FRM	MST	1 2 4 0		BROWN
-3	3		66	Lean clay, CL	7.5 YR 4/4	FRM	MST	1 3 5 0		DARK BROWN
-4	4									
-5	5		66	Lean clay, CL	7.5 YR 4/4	FRM	MST	2 1 1 0		DARK BROWN, VERY DARK BR.
-6	6		66	Lean clay with sand, CL	7.5 YR 5.8	FRM	MST	4 9 13 0		STRONG BROWN
-7	7									
-8	8		66	Lean clay with sand, CL	7.5 YR 5/8	FRM	MST	4 7 9 0		STRONG BROWN
-9	9		100	Lean clay with sand, CL	7.5 YR 4/4	STF	MST	6 7 10 0		DARK BROWN, ANALYTICAL SAMPLE TAKEN, CL-SB-01-07.
-10	10									
-11	11		66	Lean clay with sand, CL	7.5 YR 4/4	STF	MST	5 5 7 0		
-12	12		100	Lean clay with sand, CL	7.5 YR 5/8	STF	MST	4 8 10 0		STRONG BROWN
-13	13									
-14	14		86	Lean clay with sand, CL	5 YR 5/8	STF	MST	6 7 9 0		YELLOWISH BROWN
-15	15		100	Lean clay with sand, CL	5 YR 5/3	STF	MST	6 11 30 0		REDDISH BROWN
-16	16									
-17	17		26	Clayey sand, SC	7.5 YR 7/6	STF	MST	100 0 0 0		REDDISH YELLOW
-18	18			Not Classified - Incomplete Data						
-19	19									
-20	20									

CLIENT : USEPA		TOTAL DEPTH	: 46.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-01		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/10/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/10/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Not Classified - Incomplete Data						
-21	21									
-22	22		33	Lean clay, CL	10 YR 7/4	FRM	WET	50 0 0 0		VERY PALE BROWN, 50 SPT BLOWS/3"
-23	23		66	Sandy lean clay, CL	10 YR 5/1	FRM	WET			BROWN/YELLOW, 50 SPT BLOWS/2"
-24	24									
-25	25		33	Poorly graded sand, SP	10 YR 8/2	LSE	MST			WHITE, 50 SPT BLOWS/3"
-26	26		66	Sandy lean clay, CL		FRM	MST	11 12 30 0		
-27	27									
-28	28			Lean clay with sand, CL	2.5 YR 3/6	STF	MST	22 17 56 0		DARK RED
-29	29		33	Poorly graded sand, SP	10 YR 7/4	STF	MST	50 0 0 0		VERY PALE BROWN, 50 SPT BLOWS/5"
-30	30									
-31	31		20	Poorly graded sand, SP	10 YR 8/4	STF	MST			VERY PALE BROWN, 50 SPT BLOWS/5"
-32	32		20	Poorly graded sand, SP	10 YR 8/3	STF	MST	25 50 0 0		VERY PALE BROWN, 50 SPT BLOWS/3"
-33	33									
-34	34		33	Poorly graded sand, SP	10 YR 8/4	FRM	MST	40 50 0 0		VERY PALE BROWN, 50 SPT BLOWS/4"
-35	35		66	Poorly graded sand, SP	10 YR 7/8	FRM	MST	9 17 50 0		YELLOW/REDDISH BROWN
-36	36									
-37	37		33	Poorly graded sand, SP	10 YR 8/4	FRM	MST	50 0 0 0		VERY PALE BROWN, 50 SPT BLOWS/4"
-38	38			Poorly graded sand, SP	7.5 YR 7/6	FRM	MST	44 50 0 0		YELLOWISH BROWN, 50 SPT BLOWS/4"
-39	39									
-40	40		86	Poorly graded sand, SP	10 YR 7/8	FRM	MST	27 27 37 0		YELLOW/RED 50 SPT BLOWS/5" ANALYTICAL SAMPLE TAKEN, CL-SB-01-28.

CLIENT : USEPA		TOTAL DEPTH	: 46.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-01		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/10/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/10/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Poorly graded sand, SP	10 YR 7/8	FRM	MST			YELLOW/RED 50 SPT BLOWS/5" ANALYTICAL SAMPLE TAKEN, CL-SB-01-28.
-41	41			Poorly graded sand, SP	7.5 YR 7/8		MST			REDDISH YELLOW 50 SPT BLOWS/5"
-42	42									
-43	43		33	Poorly graded sand, SP	10 YR 8/2	FRM	MST	27 44 50 0		WHITE, 50 SPT BLOWS/5"
-44	44		66	Poorly graded sand, SP		FRM	MST	10 40 50 0		
-45	45									
-46	46									
-47	47									
-48	48									
-49	49									
-50	50									
-51	51									
-52	52									
-53	53									
-54	54									
-55	55									
-56	56									
-57	57									
-58	58									
-59	59									
-60	60									

Borehole Log **ROY F. WESTON, Inc.**

CLIENT : USEPA		TOTAL DEPTH	: 16.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-02		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/12/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/12/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-1	1		66	Fill	5 YR 5/8	SFT	MST	3 4 2 0		YELLOWISH RED ANALYTICAL SAMPLE TAKEN, CL-SB-02-01.
-2	2		5	Poorly graded sand with clay, SP-SC	10 YR 6/6	LSE	MST	3 4 7 0		BROWNISH YELLOW
-3	3		100	Clayey sand, SC	10 YR 4/4	SFT	MST	4 7 11 0		DARK YELLOWISH BROWN, SAND: EXTREMELY FINE
-4	4									
-5	5		100	Poorly graded sand, SP	10 YR 5/6	SFT	MST	7 11 11 0		YELLOWISH BROWN
-6	6		100	Poorly graded sand, SP	10 YR 6/4	SFT	MST	25 37 47 0		LIGHT YELLOWISH BROWN
-7	7									
-8	8		66	Poorly graded sand, SP	10 YR 7/4	LSE	MST	30 44 50 0		VERY PALE BROWN. CONTAINS CEMEMENTED SAND/GRAVELS SAND: EXTREMELY FINE
-9	9		66	Clayey sand, SC	7.5 YR 5/8	SFT	MST	10 15 17 0		REDDISH YELLOW/VERY DARK ANALYTICAL SOIL SAMPLE TAKEN, CL-SB-02-07.
-10	10									
-11	11									
-12	12									
-13	13									
-14	14									
-15	15		100	Sand, Gravely	10 YR 5/6	FRM	DRY	17 34 50 0		YELLOWISH BROWN, LIGHT GRAY. ROCK AT 16.50 FT. ANALYTICAL SAMPLE TAKEN, CL-SB-02-08.
-16	16									
-17	17									
-18	18									
-19	19									
-20	20									

Borehole Log **ROY F. WESTON, Inc.**

CLIENT : USEPA		TOTAL DEPTH	: 10.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-03		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/12/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/12/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
			80	Fill	7.5 YR 4/4	FRM	MST	2 3 3 0		STRONG BROWN ANALYTICAL SAMPLE TAKEN, CL-SB-03-01.
-1	1									
			33	Fill	5 Y 5/8	LSE	MST	2 1 2 0		YELLOWISH RED, SAND: EXTREMELEY FINE
-2	2									
-3	3		100	Poorly graded sand, SP	10 YR 7/8	SFT	MST	1 17 37 0		YELLOW/VERY DARK GRAY SAND: EXTREMELY FINE
-4	4									
			100	Lean clay, CL	7.5 YR 5/8	LSE	MST	1 17		STRONG BROWN
-5	5			Poorly graded sand, SP	7.5 YR 4/0	LSE	SAT	30 0		GRAY
-6	6		100	Poorly graded sand, SP	7.5 YR 4/0	LSE	SAT	50 0 0		GRAY
-7	7			Poorly graded sand, SP	7.5 YR 6/8	LSE	MST	0		
			100	Poorly graded sand, SP	7.5 YR 7/8	LSE	MST	30 57 0 0		YELLOWISH RED
-8	8									
-9	9			SAND	7.5 YR 6/8	FRM	MST			YELLOWISH RED. ANALYTICAL SAMPLE TAKEN, CL-SB-03-07
-10	10		100	Rock	7.5 YR 4/0	STR		26 15 23 0		DARK GRAY WEATHERED ROCK, REFUSAL AT NEXT SPOON.
-11	11									
-12	12									
-13	13									
-14	14									
-15	15									
-16	16									
-17	17									
-18	18									
-19	19									
-20	20									

Borehole Log — *ROY F. WESTON, Inc.*

CLIENT : USEPA		TOTAL DEPTH	: 38.00
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-04		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/13/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/14/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-1	1		66	Fill	7.5 YR 4/4	SFT	MST	2 3 3 0		BROWN ANALYTICAL SOIL SAMPLE TAKEN, CL-SB-04-01.
-2	2		66	Clayey sand, SC	7.5 YR 4/4	SFT	MST	4 6 9 0		BROWN, SAND: EXTREMELY FINE
-3	3		100	Sandy lean clay, CL	7.5 YR 4/4	FRM	MST	9 13 22 0		BROWN
-4	4									
-5	5		100	Poorly graded sand with clay, SP-SC	2.5 YR 5/8	FRM	MST	19 27 37 0		RED
-6	6		100	Poorly graded sand, SP	2.5 YR 5/8	FRM	MST	21 31 40 0		RED, SAND: EXTREMELY FINE
-7	7									
-8	8		66	Clayey sand, SC	2.5 YR 5/8	LSE	MST	50 0		RED
				Poorly graded sand, SP	7.5 YR 7/8	LSE	MST	0		REDDISH YELLOW
				Poorly graded sand, SP	7.5 YR 7/8	LSE	MST	0		REDDISH YELLOW
-9	9		66	Not Classified - Incomplete Data	2.5 YR 5/8	LSE	MST	39 50		RED ANALYTICAL SAMPLE TAKEN, CL-SB-04-07.
-10	10			Poorly graded sand, SP	7.5 YR 7/8	LSE	MST	0 0		REDDISH YELLOW, SAND: VERY FINE
-11	11		100	Poorly graded sand, SP	5 YR 6/8	SFT	MST	21 46 30 0		REDDISH YELLOW
-12	12		100	Poorly graded sand, SP	5 YR 6/8	LSE	MST	9 17 27 0		REDDISH YELLOW/RED
-13	13									
-14	14		100	Clayey sand, SC	2.5 YR 5/8	FRM	MST	12 12 15 0		RED/REDDISH YELLOW, SAND: EXTREMELY FINE
-15	15									
-16	16									
-17	17									
-18	18									
-19	19									
-20	20		100	Clayey sand, SC	2.5 YR 4/8	FRM	MST	9 10 14 0		RED

CLIENT : USEPA		TOTAL DEPTH	: 38.00
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-04		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/13/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/14/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Clayey sand, SC	2.5 YR 4/8	FRM	MST			RED
-21	21									
-22	22									
-23	23									
-24	24									
-25	25		66	Clayey sand, SC	2.5 YR 3/6	FRM	MST	9 12 21 0		RED/REDDISH YELLOW
-26	26									
-27	27									
-28	28									
-29	29									
-30	30		100	Clayey sand, SC	2.5 YR 4/8	FRM	MST	8 11 13		RED
-31	31			Lean clay, CL	7.5 YR 5/4	SFT	MST	0		BROWN
-32	32									
-33	33									
-34	34									
-35	35		66	Lean clay with gravel, CL	7.5 YR 5/4	FRM	MST	9 11 14 0		BROWN, ANALYTICAL SOIL SAMPLE TAKEN, CL-SB-04-14. BEDROCK AT 38.0'
-36	36									
-37	37									
-38	38									
-39	39									
-40	40									

CLIENT : USEPA		TOTAL DEPTH	: 61.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-05		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/15/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/15/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
			80	Fill	7.5 YR 4/4	FRM	MST	2 1 3 0		BROWN, ANALYTICAL SAMPLE TAKEN, CL-SB-05-01.
-1	1									
			66	Silt, ML	7.5 YR 4/4	FRM	MST	1 2 5 0		BROWN
-2	2									
-3	3		100	Silt, ML	7.5 YR 4/4	SFT	MST	3 7 8 0		BROWN
-4	4									
			100	Clayey sand, SC	5 YR 4/6	FRM	MST	2 4 10 0		SAND: EXTREMELY FINE YELLOWISH RED
-5	5									
-6	6		100	Sandy lean clay, CL	2.5 YR 4/6	FRM	MST	5 9 10 0		RED
-7	7									
			66	Clayey sand, SC	2.5 YR 4/8	FRM	MST	3 9 11 0		SAND: EXTREMELY FINE
-8	8									
-9	9		66	Clayey sand, SC	2.5 YR 6/8	FRM	MST	5 7 6 0		RED, SAND: EXTREMELY FINE ANALYTICAL SAMPLE TAKEN, CL-SB-05-07.
-10	10									
			80	Clayey sand, SC	2.5 YR 4/6	FRM	MST	5 7 8 0		RED, SAND: EXTREMELY FINE
-11	11									
-12	12		80	Clayey sand, SC	2.5 YR 4/6	FRM	MST	6 6 9 0		RED, SAND: EXTREMELY FINE
-13	13									
			66	Clayey sand, SC	2.5 YR 4/6	FRM	MST	6 8 14 0		RED, SAND: EXTREMELY FINE
-14	14									
-15	15		100	Clayey sand, SC	2.5 YR 4/6	FRM	MST	8 6 11 0		RED
-16	16									
			100	Sandy silt, ML	2.5 YR 4/6	FRM	MST	4 5 8 0		RED
-17	17									
-18	18		100	Clayey sand, SC	2.5 YR 4/6	FRM	MST	5 6 8 0		RED, SAND: EXTREMELY FINE
-19	19									
			86	Clayey sand, SC	2.5 YR 4/6	FRM	MST	5 8 9 0		RED
-20	20									

CLIENT : USEPA		TOTAL DEPTH	: 61.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-05		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/15/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/15/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Clayey sand, SC	2.5 YR 4/6	FRM	MST			RED
-21	21									
-22	22									
-23	23									
-24	24									
-25	25									
-26	26									
-27	27									
-28	28									
-29	29									
-30	30									
-31	31									
-32	32									
-33	33									
-34	34									
-35	35									
-36	36									
-37	37									
-38	38									
-39	39									
-40	40		100	Clayey sand, SC	2.5 YR 4/6	FRM	MST	6 8 9 0		RED

CLIENT : USEPA		TOTAL DEPTH	: 61.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-05		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/15/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/15/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Clayey sand, SC	2.5 YR 4/6	FRM	MST			RED
-41	41									
-42	42									
-43	43									
-44	44									
-45	45		86	Clayey sand, SC	2.5 YR 4/6	FRM	MST	7 9 9 0		RED
-46	46									
-47	47									
-48	48									
-49	49									
-50	50		80	Silty sand, SM	2.5 YR 4/6	FRM	MST	6 8 13 0		RED, SAND: EXTREMELY FINE
-51	51									
-52	52									
-53	53									
-54	54									
-55	55									
-56	56									
-57	57									
-58	58									
-59	59									
-60	60		100	Clayey sand, SC	2.5 YR 4/6	FRM	MST	7 7 9 0		RED, ANALYTICAL SAMPLE TAKEN, CL-SB-05-19.

CLIENT :	USEPA	TOTAL DEPTH :	61.50
SITE NAME :	CALDWELL LACE AND LEATHER	LOGGER :	C. SZLUHA
WELL ID :	CL-SB-05	DRILLING COMPANY :	BOYLE BROTHERS
NORTHING :	0.0000 estimated	DRILLING RIG :	SYMCO 8000 ATV
EASTING :	0.0000 estimated	DATE STARTED :	12/15/92
ELEVATION :	0.000 estimated	DATE COMPLETED :	12/15/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-61	61			Clayey sand, SC	2.5 YR 4/6	FRM	MST			RED. ANALYTICAL SAMPLE TAKEN, CL-SB-05-19.
-62	62									
-63	63									
-64	64									
-65	65									
-66	66									
-67	67									
-68	68									
-69	69									
-70	70									
-71	71									
-72	72									
-73	73									
-74	74									
-75	75									
-76	76									
-77	77									
-78	78									
-79	79									
-80	80									

Borehole Log — *ROY F. WESTON, Inc.*

CLIENT : USEPA		TOTAL DEPTH	: 21.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-06		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/16/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/16/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-1	1		100	Clayey sand, SC	7.5 YR 5/6	SFT	MST	1 3 6 0		STRONG BROWN. ANALYTICAL SAMPLE TAKEN, CL-SB-06-01
-2	2		100	Clayey sand, SC	5 YR 4/6	FRM	MST	8 9 11 0		YELLOWISH RED
-3	3		100	Clayey sand, SC	2.5 YR 4/6	FRM	MST	3 15 19 0		RED
-4	4									
-5	5		66	Clayey sand, SC	2.5 YR 4/6	FRM	MST	3 8 12 0		RED, SAND: VERY FINE
-6	6		66	Clayey sand, SC	7.5 YR 5/6	SFT	MST	10 15 18 0		STRONG BROWN, SAND: VERY FINE
-7	7									
-8	8		66	Sandy lean clay, CL	5 YR 5/6	FRM	MST	10 13 14 0		REDDISH YELLOW/LIGHT GRAY
-9	9		66	Clayey sand, SC	2.5 YR 5/6	FRM	MST	10 14 42 0		RED/YELLOW. ANALYTICAL SAMPLE TAKEN, CL-SB-06-07.
-10	10									
-11	11		66	Clayey sand, SC	2.5 YR 5/6	FRM	MST	14 16 25 0		RED
-12	12		66	Clayey sand, SC	5 YR 5/6	FRM	MST	10 14 22 0		REDDISH YELLOW.
-13	13									
-14	14									
-15	15		100	Clayey sand, SC	2.5 YR 7/4	FRM	MST	5 10 5 0		PALE YELLOW
-16	16									
-17	17									
-18	18									
-19	19									
-20	20		80	Sandy lean clay, CL	7.5 YR 4/4	FRM	MST	5 6 9 0		SAND: VERY FINE ANALYTICAL SAMPLE TAKEN, CL-SB-06-11.

CLIENT : USEPA		TOTAL DEPTH	: 21.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-06		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/16/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/16/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-21	21			Sandy lean clay, CL	7.5 YR 4/4	FRM	MST			SAND: VERY FINE ANALYTICAL SAMPLE TAKEN, CL-SB-06-11.
-22	22									
-23	23									
-24	24									
-25	25									
-26	26									
-27	27									
-28	28									
-29	29									
-30	30									
-31	31									
-32	32									
-33	33									
-34	34									
-35	35									
-36	36									
-37	37									
-38	38									
-39	39									
-40	40									

CLIENT : USEPA		TOTAL DEPTH	: 23.00
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-07		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/16/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/17/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-1	1			Clayey sand, SC	7.5 YR 5/4	SFT	MST	1 2 3 0		BROWN. ANALYTICAL SAMPLE TAKEN, CL-SB-07-01.
-2	2		66	Clayey sand, SC	10 YR 5/4	SFT	MST	3 3 6 0		YELLOWISH BROWN, SAND: EXTREMEMLY FINE
-3	3			Fill		SFT	MST	4 5 6 0		BLACK, STRONG ODOR
-4	4									
-5	5			Clayey sand, SC	10 YR 6/2	SFT	MST	6 17 13 0		LIGHT BROWNISH GRAY STRONG ODOR OF WASTE
-6	6			Poorly graded sand with clay, SP-SC	10 YR 6/2	SFT	MST	8 12 43 0		LIGHT YELLOWISH BROWN STRONG WASTE ODOR
-7	7									
-8	8		66	Poorly graded sand, SP	7.5 YR 7/8	SFT	MST	30 36 17 0		YELLOWISH RED
-9	9		66	Poorly graded sand, SP	2.5 YR 7/2	SFT	MST	37 62 29 0		LIGHT GRAY. ANALYTICAL SAMPLE TAKEN, CL-SB-07-07.
-10	10									
-11	11		66	Lean clay, CL	5 YR 4/6	FRM	MST	18 20		YELLOWISH RED
				Poorly graded sand, SP	5 YR 6/6	SFT	MST	30 0		REDDISH YELLOW
-12	12		66	Poorly graded sand, SP	2.5 YR 4/6	FRM	MST	23 52 56 27 0		RED
-13	13									
-14	14			Poorly graded sand, SP		SFT	MST	35 145 135 0		
-15	15									
-16	16									
-17	17									
-18	18									
-19	19									
-20	20			Lean clay with sand, CL	10 YR 5/8	FRM	MST	9 11 5 0		YELLOWISH BROWN ANALYTICAL SAMPLE TAKEN, CL-SB-07-11 BEDROCK AT 23.0'

CLIENT : USEPA		TOTAL DEPTH	: 23.00
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-07		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/16/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/17/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-21	21			Lean clay with sand, CL	10 YR 5/8	FRM	MST			YELLOWISH BROWN ANALYTICAL SAMPLE TAKEN, CL-SB-07-11 BEDROCK AT 23.0'
-22	22									
-23	23									
-24	24									
-25	25									
-26	26									
-27	27									
-28	28									
-29	29									
-30	30									
-31	31									
-32	32									
-33	33									
-34	34									
-35	35									
-36	36									
-37	37									
-38	38									
-39	39									
-40	40									

CLIENT : USEPA		TOTAL DEPTH	: 21.00
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-08		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/17/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/17/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-1	1			Sandy clay, CL	7.5 YR 5/6	SFT	MST	2 0 0 0		STRONG BROWN, SAND: EXTREMELY FINE ANALYTICAL SAMPLE TAKEN, CL-SB-08-01.
-2	2		66	Clayey sand, SC	10 YR 5/4	SFT	MST	4 5 12 0		YELLOWISH BROWN
-3	3		66	Clayey sand, SC	10 YR 5/4	SFT	MST	15 12 13 0		YELLOWISH BROWN, SAND: EXTREMELY FINE
-4	4									
-5	5		66	Silty sand, SM	10 YR 5/4	SFT	MST			YELLOWISH BROWN
-6	6		100	Clayey sand, SC	10 YR 5/8	FRM	MST	8 12 23 0		YELLOWISH BROWN, SAND: EXTREMELY FINE
-7	7									
-8	8		80	Poorly graded sand, SP	7.5 YR 6/8	SFT	MST	52 58 22 0		REDDISH YELLOW
-9	9		100	Poorly graded sand, SP		SFT	WET	35 43 45 0		WASTE LAYER ANALYTICAL SAMPLE TAKEN, CL-SB-08-07.
-10	10									
-11	11		66	Poorly graded sand, SP	7.5 YR 7/8	SFT	MST	40 55 32 0		REDDISH YELLOW
-12	12									
-13	13									
-14	14		100	Poorly graded sand, SP	10 YR 8/4	FRM	MST	35 50 150 0		VERY PALE BROWN, SAND: EXTREMELY FINE
-15	15									
-16	16									
-17	17									
-18	18									
-19	19									
-20	20		66	Lean clay, CL	10 YR 7/2	STF	MST	35 60 100 0		LIGHT GRAY ANALYTICAL SAMPLE TAKEN, CL-SB-08-10.

CLIENT : USEPA		TOTAL DEPTH	: 21.00
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-08		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/17/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/17/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-21	21			Lean clay, CL	10 YR 7/2	STF	MST			LIGHT GRAY ANALYTICAL SAMPLE TAKEN, CL-SB-08-10.
-22	22									
-23	23									
-24	24									
-25	25									
-26	26									
-27	27									
-28	28									
-29	29									
-30	30									
-31	31									
-32	32									
-33	33									
-34	34									
-35	35									
-36	36									
-37	37									
-38	38									
-39	39									
-40	40									

CLIENT : USEPA		TOTAL DEPTH	: 61.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-09		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/20/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/20/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-1	1		80	Fill	5 YR 4/6	SFT	MST	2 8 8 0		YELLOWISH RED ANALYTICAL SAMPLE TAKEN, CL-SB-09-01.
-2	2			Clayey sand, SC	10 YR 4/4	SFT	MST	4 6 8 0		DARK YELLOWISH BROWN, SAND: EXTREMELY FINE
-3	3		86	Clayey sand, SC	10 YR 4/4	SFT	MST	8 15 19 0		DARK YELLOWISH BROWN
-4	4									
-5	5			Silt with sand, ML	7.5 YR 5/6	SFT	MST	8 9 51 0		STRONG BROWN, SAND: EXTREMELY FINE
-6	6			Clayey sand, SC	7.5 YR 4/6	SFT	MST	9 9 10 0		STRONG BROWN, SAND: EXTREMELY FINE
-7	7									
-8	8		66	Clayey sand, SC	7.5 YR 4/6	SFT	MST	7 11 12 0		
-9	9									
-10	10		100	Clayey sand, SC	7.5 YR 5/6	SFT	MST	7 7 9 0		STRONG BROWN, ANALYTICAL SOIL SAMPLE TAKEN, CL-SB-09-01, SAND: EXTREMELY FINE.
-11	11									
-12	12									
-13	13									
-14	14									
-15	15		100	Silty sand, SM		SFT	MST	6 9 15 0		STRONG BROWN, SAND: EXTREMELY FINE
-16	16									
-17	17									
-18	18									
-19	19									
-20	20		86	Clayey sand, SC	10 YR 8/3	SFT	MST	6 9 8 0		VERY FINE BROWN, SAND: EXTREMELY FINE

CLIENT : USEPA		TOTAL DEPTH	: 61.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-09		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/20/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/20/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Clayey sand, SC	10 YR 8/3	SFT	MST			VERY FINE BROWN, SAND: EXTREMELY FINE
-21	21									
-22	22									
-23	23									
-24	24									
-25	25		66	Clayey sand, SC	10 YR 7/2	FRM	MST	6 6 9 0		LIGHT GRAY, SAND: MEDIUM FINE
-26	26									
-27	27									
-28	28									
-29	29									
-30	30			Clayey sand, SC	10 YR 7/1	FRM	MST	7 8 15 0		LIGHT GRAY, SAND: MEDIUM FINE
-31	31									
-32	32									
-33	33									
-34	34									
-35	35		66	Poorly graded sand, SP	10 YR 8/8	FRM	MST	25 60 90 0		YELLOW, SAND: EXTREMELY FINE
-36	36									
-37	37									
-38	38									
-39	39									
-40	40		80	Poorly graded sand, SP	10 YR 8/8	SFT	MST	43 20 16 0		YELLOW

CLIENT : USEPA		TOTAL DEPTH	: 61.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-09		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/20/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/20/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Poorly graded sand, SP	10 YR 8/8	SFT	MST			YELLOW
-41	41									
-42	42									
-43	43									
-44	44									
-45	45		86	Poorly graded sand, SP	10 YR 8/8	FRM	MST	14 12 14 0		WHITE, SAND: CEMENTED LAYERS
-46	46									
-47	47									
-48	48									
-49	49									
-50	50		66	Clayey sand, SC	10YR 8/8	FRM	MST	4 5 5 0		PALE BROWN
-51	51									
-52	52									
-53	53									
-54	54									
-55	55		33	Clayey sand, SC	10 YR 8/8	FRM	MST	4 2 4 0		PALE BROWN
-56	56									
-57	57									
-58	58									
-59	59									
-60	60		66	Sand	10 YR 4/3	SFT	MST	1 1 2 0		BROWN, SAND: EXTREMELY FINE, ANALYTICAL SOIL SAMPLE TAKEN, CL-SB-09-17

CLIENT : USEPA		TOTAL DEPTH	: 61.50
SITE NAME : CALDWELL LACE AND LEATHER		LOGGER	: C. SZLUHA
WELL ID : CL-SB-09		DRILLING COMPANY	: BOYLE BROTHERS
NORTHING : 0.0000 estimated		DRILLING RIG	: SYMCO 8000 ATV
EASTING : 0.0000 estimated		DATE STARTED	: 12/20/92
ELEVATION : 0.000 estimated		DATE COMPLETED	: 12/20/92

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
-61	61			Sand	10 YR 4/3	SFT	MST			BROWN, SAND: EXTREMELY FINE, ANALYTICAL SOIL SAMPLE TAKEN, CL-SB-09-17
-62	62									
-63	63									
-64	64									
-65	65									
-66	66									
-67	67									
-68	68									
-69	69									
-70	70									
-71	71									
-72	72									
-73	73									
-74	74									
-75	75									
-76	76									
-77	77									
-78	78									
-79	79									
-80	80									