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Lipari Landfill: Leachate Containment System—
Geotechnical Considerations

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SYNOPSIS: The Lipari Landfill, located near Pitman, New Jersey, is a 16-acre former sand and gravel and waste disposal site that operated from 1958 through early 1970. This site was ranked the number one site in the U.S. EPA's first National Priority List of uncontrolled hazardous waste disposal sites. Site investigations and analysis of contamination both on- and off-site began in late 1979. Design of the Phase I remediation, consisting of encapsulation utilizing a vertical barrier keyed into a relatively impermeable clay layer and a cover over the entire site, began in late 1982. Construction of the leachate containment system began in the fall of 1983 and was completed in November 1984 at a cost of approximately $2,205,000. U.S. EPA is about to implement the Phase II remedial actions consisting of batch flushing, extraction and treatment of contaminated groundwater and removal and treatment of stream and lake sediments contaminated by leachate migration through surface waters. This Phase II program is expected to cost about $12.3 million and take about 7-1/2 years to complete.

INTRODUCTION

Development and implementation of remedial measures for control and cleanup of the uncontrolled hazardous waste disposal site is unlike anything the geotechnical professional has previously faced. We are dealing with issues that require careful evaluation and understanding in order to implement effective remedial actions. The principal issues that require consideration include:

- Complex and continually changing regulatory environment at all levels of government—federal, state, and local.
- Federal legislation dealing with cleanup (CERCLA and SARA) has, as the principal basis for implementing cleanup, the concept of cost recovery from Potentially Responsible Parties (PRP). This means that the ultimate client for technical services in remedial actions implemented under this legislation is the lawyer.
- The public has greater awareness and interest in the cleanup of hazardous waste sites than any other technical issue facing society today. Citizen groups will monitor and question every step and decision in the remedial action process.
- The liability issues associated with design and construction of remedial measures are unknown at this point but are potentially monumental. Third party environmental damage suits could be enormous in terms of award and come decades after completion of remedial activities.
- There are no "standards of practice" for cleanup of hazardous waste sites. While we have standards for various elements of geotechnical practice, such as slurry walls and flexible membrane liner systems, we have not developed standards for the total remedial system. This situation is exacerbated by the public demand for "Complete and Total" cleanup of these sites.

The Lipari Landfill is a 16-acre site used as both a source of sand and gravel and a disposal facility for municipal and industrial wastes located near Pitman, New Jersey. This site, ranked first in U.S. EPA's National Priority List (NPL) in 1982, was the first "Superfund" site where design and initial remedial measures were implemented under the interagency agreement between the U.S. EPA and the U.S. Army Corps of Engineers (USCE). This paper describes the investigative work, feasibility and engineering studies, preparation of contract documents, and construction of the leachate containment system for the Lipari Landfill.

SITE CONDITIONS

History

The Lipari Landfill is located at the southwestern edge of the town of Pitman, New Jersey, approximately 4,500 feet north of U.S. Route 322 and 1-1/2 miles west of Glassboro State College. The eastern limit of the site is about 400 feet west of Chestnut Branch, which flows in a northerly direction toward Alcyon Lake, some 1,000 feet from the site. Chestnut Branch is a tributary of Mantua Creek, eventually discharging to the Delaware River. Features of the area surrounding the Lipari Landfill are shown on Figure 1.

The property was purchased in 1958 by Mr. Nick Lipari who then started a sand and gravel operation on the site. The use of the property for mining and processing of sand and gravel also made the site attractive for use as a landfill. The integration of these two activities began in 1958 with excavation of sand and gravel pits, subsequently filling each pit with waste. Materials from the site were used to cover waste asfilling proceeded and for final cover after each pit was filled. These operations were continued until the middle of 1971.

Liquid wastes were dumped from 1958 until approximately December of 1969, and solid wastes were dumped from 1958 through May of 1970, when the landfill was closed (Harrington, 1980).
wastes disposed of at the Lipari Landfill are unknown since detailed records were not kept. Estimates based on records of parties known to have disposed of material at the site suggest that about 12,000 cubic yards of waste are buried on site. Liquid wastes disposed of at the site are estimated at approximately 2.9 million gallons. In most instances, liquid wastes were disposed of uncontaminated, since drums were emptied and removed from the site for salvage and resale (Harrington, 1980).

Prior to 1971, the operation of the Lipari Landfill was considered to be both legally and environmentally sound by the various regulatory agencies involved. The landfill was inspected on a regular basis by the Department of Health and its successor, the Department of Solid Waste Management beginning in 1963. In 1970, the first signs of problems began to appear, as leachate was observed seeping from walls of the landfill. Official notification for correction was given the operator of the landfill in July, 1971. Attempts to contain and control the seeps had little impact, and the New Jersey Department of Environmental Protection (NJDEP) brought suit against the owners for the facility (Harrington, 1980).

Site Description

The physical characteristics of the landfill are shown on Figure 2. It is estimated that the actual disposal sites covered an area of about six acres, south of the present course of Rabbit Run. The highest point within the disposal area is approximately elevation 134. The disposal site is on a plateau about 30 feet above the Chestnut Branch drainage. The remainder of the plateau area, not disturbed for sand and gravel operations and disposal of wastes, was orchard. Residential areas developed to the east of the site, across the Chestnut Branch channel (Wright, 1980).

Leachate discharges into Rabbit Run were observed along the entire south bank and the stream channel bottom. Leachate was also observed discharging along the eastern wall of the plateau into Chestnut Branch. The leachate discharges occurred in both discrete and nondiscrete flows below elevation 105 (Wright, 1980).

Subsurface Conditions

The Lipari Landfill is underlain by relatively horizontal geologic units that strike northeast-southwest, and dip slightly to the southeast. The units of concern at the site include (in descending order) Cohansey Sand, Kirkwood Formation, Manasquan Formation, and the Vincentown Formation. Geologic cross-sections of the site are shown on Figure 3.

The landfill site is located in the Cohansey Sand at the northwest boundary of its outcrop. This unit consists of fine to medium silty sand with lenses of clay and gravel. The unit is stratified, with occasional layers of hard iron-cemented sandstone. Based on exploration, sampling and testing done at the site (Wright, 1981a), the Cohansey Sand can be differentiated into upper and lower units.

The upper unit of the Cohansey Sand is exposed in the plateau area of the Lipari Landfill. It generally occurs above elevation 100. This upper unit consists of orange-brown fine to coarse sand and fine to medium gravel, with traces of silt and clay. This unit is the source of sand and gravel mined at the site.

The lower Cohansey Sand outcrops along the eastern bank of the plateau, above the Chestnut Branch marsh. This unit, nearly horizontal, dips slightly to the southeast and is composed of greenish-gray fine to medium sand with some silt. No gravel was encountered in the borings (Wright, 1981a).

The Cohansey Sand is unconfined in the area of the Lipari Landfill, resulting in groundwater recharge through direct infiltration through the outcrop exposure. The water from the Cohansey unit has historically been used in the area for farm and rural domestic water supplies. However, high naturally occurring iron concentrations in the area have made this aquifer unsuitable for domestic use (Wright, 1980).

The Kirkwood Formation underlies the Cohansey Sand, and is approximately 75 feet thick in the area of the Lipari site. The Kirkwood Formation consists of an upper clay unit, ranging in thickness from 8 to 14 feet across the site plateau (Wright, 1981a), underlain by very fine to medium sand unit. The top of the Kirkwood Formation ranges from elevation 92 to about 80 across the plateau.
The outcrop of the Kirkwood Formation forms a band 2 miles wide, northwest of the site, extending through Alcyon Lake. Groundwater recharge to the Kirkwood Formation occurs through outcrops and by downward seepage from the Cohansey Sand. The Kirkwood is considered a minor aquifer in the area, yielding insignificant flows (Wright, 1980).

The Vincentown Formation underlies the Kirkwood Formation at the site, and is considered the shallowest major aquifer in the area other than the Cohansey Sand (Wright, 1980). The unit is approximately 18 feet thick beneath the site, and consists of fine to coarse sand lithified with clay and small amounts of calcite cement. The unit also contains traces of mica and fossilized shell fragments (Wright, 1981a).

Geologic units occurring beneath the Vincentown Formation are not believed to be threatened by contamination from the Lipari site (Wright, 1981a). Additional investigations are currently being conducted by U.S. EPA as part of the Phase II remedial activities for the site.

**Hydrogeology**

Contaminated groundwater moved from the disposal area through the Cohansey Sand, discharging as diffuse seepage along the eastern edge of the plateau in Chestnut Branch. This contaminant plume then moved via the surface water regime into Alcyon Lake. In addition, the downward gradient between the Cohansey Sand and the underlying Kirkwood Formation (sand unit) has introduced contaminants into the lower formation. Groundwater surface in the Cohansey Sand is shown in Figure 4, Piezometric levels in the Kirkwood Formation on Figure 5.

Hydrogeologic parameters used in various alternative analyses and for design of the leachate containment system are as follows (CH2M HILL, 1983):

- All inflow to the encapsulated area results in contaminated leachate.
- Flow through the Cohansey Sand to Chestnut Branch is between 20,000 and 62,000 gallons per day (Wright, 1981a).
- The encapsulation system should reduce flow through the Cohansey Sand by 90 percent.
- The Kirkwood Formation clay layer is approximately 14 feet thick, with a primary permeability of 1.0 x 10^-7 cm/sec (Wright, 1981a).
- Upgradient water level elevation of 120.
- Downgradient water level elevation of 100.
- Potentiometric level in the Kirkwood Formation sand unit of elevation 91.

A summary of leachate flows used in the analyses are shown on Table 1, and a summary of significant pollutants found in the Lipari Landfill leachate are listed in Table 2.

**INITIAL REMEDIAL MEASURES--BASIS OF DESIGN**

Investigations, evaluations, and development of remedial alternatives for the Lipari Landfill began in 1979 and
are ongoing today. Since U.S. EPA began coordinating activities at the site, some 15 different engineering and technical consultants have been engaged in these various investigations, studies, analyses and design.

These activities included site investigations, technical evaluation of abatement alternatives, and development of work scope and specifications for cutoff wall construction by R.E. Wright Associates, Inc. (Wright, 1980, 1981a, 1981b). In addition, Radian Corporation conducted a cost effectiveness assessment of remedial measures and an environmental assessment of the various remedies considered for the Lipari Landfill (Radian, 1982a, 1982b). CH2M HILL conducted detailed engineering analyses and developed plans and specifications for the Lipari Landfill leachate containment system, the Phase I remedial measures program for the site.

The Leachate Containment System for the Lipari Landfill consists of a vertical barrier founded in the Kirkwood Formation clay unit around the entire plateau area (see Figure 5), an impermeable cover system over the area contained by the vertical wall, and a permanent groundwater monitoring system to evaluate the effectiveness of the Phase I remedial program. The following discussion describes the Lipari Landfill Leachate Containment System.

Cover System

Cover systems for the site were evaluated based on the following criteria:

- The native soil at the site is highly permeable; a cover system will provide the only effective barrier to vertical recharge. The cover system shall have an equivalent permeability equal to or less than a 12-inch thick clay layer with a permeability of 1 x 10^{-7} cm/sec.

- Cover over the barrier shall protect it from vehicular traffic, vegetative root penetration, ultraviolet radiation, ozone degradation, oxidation, microbial attack, and from freeze-thaw and wet-dry cycles.

- The covered area shall have a minimum slope of 2 percent to promote surface runoff.

- All areas within the vertical seepage barrier shall be covered, and the area may be used for construction related activities both before and after cover placement.

- The cover will seal around all openings, such as monitoring wells, and shall seal against the vertical seepage barrier.

- The cover system will not contact contaminated soil or groundwater. Contaminated soil from the vertical seepage barrier construction will be placed within the containment area and covered with non-contaminated soil before construction of the cover system.

- Although a leachate collection and treatment system is not planned as part of the initial remedial measures, the cover system must be designed to accommodate such systems in the future.

Cover systems evaluated included soil-bentonite mixtures, natural clay, synthetic membranes, sprayed-on asphalt emulsion, and rigid systems. Based on detailed analysis and comparison to the design criteria discussed above, flexible synthetic membrane, compacted clay, and soil-bentonite were selected for detailed evaluation (CH2M HILL, 1983). Cost comparisons of these three systems are presented in Table 3.

Both the natural clay and flexible synthetic membrane liner options were designed, with bidders given the option to choose. Details of the cover system designs are shown on Figure 6.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill watershed (0.0717 sq. mi.)</td>
<td>87,000</td>
<td>74,000</td>
<td>183,000</td>
<td>62,000</td>
</tr>
<tr>
<td>Landfill (6 acres or 0.0094 sq. mi.)</td>
<td>8,100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landfill, plus polluted area between landfill and Chestnut Branch (16 acres or 0.0250 sq. mi.)</td>
<td>22,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rabbit Run</td>
<td></td>
<td></td>
<td>43,000 to 108,000</td>
<td></td>
</tr>
<tr>
<td>Diffuse leachage seepage</td>
<td>33,000 to 65,000</td>
<td>16,000 to 47,000</td>
<td>130,000 to 161,000</td>
<td>8,640 to 40,000</td>
</tr>
<tr>
<td>Leachate contribution to Rabbit Run</td>
<td></td>
<td></td>
<td></td>
<td>5,760 to 14,000</td>
</tr>
<tr>
<td>Vertical leakage through Kirkwood clay unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Beneath landfill area (6 acres)</td>
<td>550</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Beneath affected area (16 acres)</td>
<td>1,460</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Includes discharge to south side of Rabbit Run and to diffuse leachate seepage along Chestnut Branch.

2. Includes groundwater derived from infiltration onto landfill.

### TABLE 1
Leachate Flow Analyses (Wright, 1980)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>pH (units)</td>
<td>-</td>
<td>-</td>
<td>5.2</td>
<td>6.35</td>
</tr>
<tr>
<td>Calcium (mg/l)</td>
<td>-</td>
<td>-</td>
<td>27</td>
<td>-</td>
</tr>
<tr>
<td>Iron (mg/l)</td>
<td>-</td>
<td>-</td>
<td>10.4</td>
<td>352.6</td>
</tr>
<tr>
<td>Potassium (mg/l)</td>
<td>-</td>
<td>-</td>
<td>59.2</td>
<td>-</td>
</tr>
<tr>
<td>Sodium (mg/l)</td>
<td>-</td>
<td>-</td>
<td>43</td>
<td>-</td>
</tr>
<tr>
<td>Methylen chloride (mg/l)</td>
<td>0.7</td>
<td>2,890</td>
<td>990</td>
<td>2.8</td>
</tr>
<tr>
<td>1, 2-Chloroethane (mg/l)</td>
<td>-</td>
<td>1,338</td>
<td>5,800</td>
<td>-</td>
</tr>
<tr>
<td>Benzene (mg/l)</td>
<td>1,607</td>
<td>1,190</td>
<td>430</td>
<td>1,200</td>
</tr>
<tr>
<td>Toluene (mg/l)</td>
<td>15,500</td>
<td>12,700</td>
<td>3,100</td>
<td>17,500</td>
</tr>
<tr>
<td>Ethyl benzene (mg/l)</td>
<td>683.6</td>
<td>583</td>
<td>880</td>
<td>1,600</td>
</tr>
<tr>
<td>Bis (2-Chloremethyl)</td>
<td>210,000</td>
<td>23,000</td>
<td>20,000</td>
<td>440</td>
</tr>
<tr>
<td>Ether (mg/l)</td>
<td>4,387</td>
<td>2,400</td>
<td>5,500</td>
<td>1,000</td>
</tr>
</tbody>
</table>

### TABLE 2
Chemical Pollutants in Lipari Leachate
(CH2M Hill, 1983)
The vertical barrier should extend a minimum of 2 feet into the upper clay layer of the Kirkwood Formation, up to 55 feet below ground surface.

The vertical barrier should have an equivalent permeability equal to or less than a 2-foot thick soil barrier having a permeability of $1 \times 10^{-7}$ cm/sec.

Along most of the wall alignment, the groundwater and soil excavated will be contaminated. Spoil excavated from the trench can be disposed of on-site, beneath the cover system.

Two methods of vertical barrier wall construction were evaluated; the slurry trench method and the vibrating beam method.

The primary advantage of the slurry trench method is that the thickness of the wall and trenching method of construction ensure wall integrity and continuity. The primary disadvantage of the slurry trench method is that the continuity of the wall between adjacent panels is difficult, if not impossible, to ensure. Installing the H-pile to the best driving tolerances would result in pile plumbness within 1 percent. The installation of a 50-foot deep vibrated beam cutoff to this tolerance would result in a horizontal deviation of 6 inches at the base of the wall. Since the wall is nominally only 4 inches wide, a gap in the cutoff could easily result. Variation in subsurface materials, or natural or manmade obstructions could also cause deviations in vibrated beam panels.

The leachate constituents summarized in Table 2 were used to evaluate the effects of contaminated groundwater on various cutoff wall materials. Materials evaluated included soil-bentonite backfill, asphalt and emulsions, cement-bentonite mixes and concrete (CH2M HILL, 1983). Site-specific laboratory permeability tests for various wall materials were not conducted during the analysis and design phase because of extremely tight implementation schedules. However, information from review of literature (D'Appolonia, 1980 and Anderson, 1981) and of unpublished data collected from other sites was used to develop design recommendations.

Although preliminary engineering analyses and feasibility studies (Wright, 1981b, Radian, 1982a) recommended the vibrated beam method for construction of the vertical

### Table 3: Cost Comparison of Alternative Cover Systems (CH2M HILL, 1983)

<table>
<thead>
<tr>
<th>Description</th>
<th>Soil-Bentonite</th>
<th>Natural Clay</th>
<th>Synthetic Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permeability</td>
<td>$10^{-7}$ cm/sec</td>
<td>$10^{-7}$ cm/sec</td>
<td>$10^{-10}$ cm/sec</td>
</tr>
<tr>
<td>Cost</td>
<td>$1,270,000</td>
<td>$1,440,000</td>
<td>$1,145,000</td>
</tr>
</tbody>
</table>

The leachate constituents summarized in Table 2 were used to evaluate the effects of contaminated groundwater on various cutoff wall materials. Materials evaluated included soil-bentonite backfill, asphalt and emulsions, cement-bentonite mixes and concrete (CH2M HILL, 1983). Site-specific laboratory permeability tests for various wall materials were not conducted during the analysis and design phase because of extremely tight implementation schedules. However, information from review of literature (D'Appolonia, 1980 and Anderson, 1981) and of unpublished data collected from other sites was used to develop design recommendations.

Although preliminary engineering analyses and feasibility studies (Wright, 1981b, Radian, 1982a) recommended the vibrated beam method for construction of the vertical
cutoff barrier, the slurry trench method was selected for design. The selected design called for a nominal 30-inch wide slurry supported trench keyed 2 feet into the Kirkwood Formation clay layer and backfilled with a soil-bentonite mixture.

The soil-bentonite mixture was selected because it is conventional, proven technology and provides a plastic, low permeability backfill. The contract specifications required well graded materials with maximum particle size of 3 inches, mixed with a minimum 20 percent by weight of plastic fines. Uncontaminated on site material above the water table was acceptable for the basic backfill material. The plastic fines was imported material passing the No. 200 sieve having a Liquid Limit greater than 20 and a Plasticity Index greater than 4 [USCE, 1983].

INITIAL REMEDIAL MEASURES--CONSTRUCTION

Contract documents for the Lipari Landfill Leachate Containment System were prepared by CH2M HILL for the Kansas City District, U.S. Army Corps of Engineers (USCE) under a U.S. EPA Zone I Remedial Response Action Contract. The construction contract was advertised in May of 1983, with bids opened June 30, 1983.

On June 9, 1983, Slurry Systems, Inc., licensee of the vibrated beam method, filed a bid protest with the U.S. Comptroller General, claiming that their technology was unfairly, without authority and with no technical basis excluded from the project. The protest was based on the fact that the U.S. EPA Administrator's decision on containment strategies for the Lipari site incorporated the recommendations from the initial reports (Wright, 1981b) in the Record of Decision. A final decision was rendered by the Comptroller General on December 13, 1983, denying the protest. The denial was based in part on the fact that while various reports were used in development and preparation of the Record of Decision, it did not state that conclusions of any particular study was adopted (Comptroller General, 1983).

The contract for the leachate containment system was awarded to D'Appolonia Waste Management Services, Inc., with Construction beginning in August of 1983. The contractor selected the flexible synthetic membrane containment system. Work was essentially completed in November of 1984 for approximately $2,205,000. One claim concerning leachate overtopping of the vertical wall remains unsettled.

Resident engineering and construction management for the leachate containment system contract were provided by the Philadelphia District USCE, with design interpretations provided by Kansas City District personnel and support as needed from the CH2M HILL design team. In addition, U.S. EPA had oversight responsibilities.

FUTURE REMEDIATION

U.S. EPA has been monitoring performance of the leachate containment system since its completion in Late 1984. Detailed analyses of system performance are scheduled for publication in April of 1988. Preliminary indications are that the containment system is behaving as expected.

There are, however, several activities contemplated for the Phase II remedial measures at the Lipari site. These measures include on-site elements and off-site remedial activities. On-site measures are expected to include batch flushing and extraction and treatment of contaminated groundwater within the contained area. Off-site measures include removal and treatment of contaminated sediment in Rabbit Run, Chestnut Branch, and Alcyon Lake. It is also expected that extraction and treatment of contaminated groundwater from the lower Kirkwood Formation sand unit may be required. It is estimated that the Phase II programs will take about 7-1/2 years to complete and cost approximately $12.3 million. The U.S. EPA Administrator's Record of Decision for Phase II remedial measures is expected by April of 1988.

CONCLUSIONS

Approximately 14 years after leachate was first observed seeping from the Lipari Landfill, the construction of a containment system was completed. It is expected that "final" cleanup of this site will not be completed until some 25 years after the initial observation of seepage, at a total cost for remediation for the Lipari Landfill that will approach $15 million.

The technical issues associated with the cleanup of the Lipari Landfill are not overly complex and are, with reasonable expectations, simple to implement. What is difficult for the technologist to fully comprehend and implement in the design and construction process are the public's expectations for hazardous waste site cleanup. We cannot meet these expectations until technology can develop effective means to positively educate the public about the fallacy of "risk-free" solutions and 100 percent removal of contaminants. This situation is compounded by the plethora of public agencies, scores of consultants, and artificial separation of investigation, analysis, design and construction management responsibilities.

The geotechnical profession has made and will continue to make major contributions to cleanup and restoration of uncontrolled hazardous waste disposal sites. Limitations created by institutional constraints have not allowed the implementation of efficient, innovative geotechnical solutions to site remediation. The challenge to our profession is to educate both the regulator and the public to the benefits of two simple precepts--continuity of thought and the use of the observational method to efficiently and effectively remediate the uncontrolled hazardous waste disposal site.

ACKNOWLEDGEMENTS

This paper expresses the author's opinions and is not intended to represent either U.S. EPA or USCE positions concerning Lipari Landfill. The author wishes to thank Kevin Oates, U.S. EPA, Mat Beatty, USCE and Jim Howey of CH2M HILL for taking time to discuss details of the Lipari Leachate Containment System Project.

REFERENCES


