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FINAL DESIGN ANALYSIS

HELEVA LANDFILL SITE
LEHIGH COUNTY, PENNSYLVANIA

PREPARED FOR:

U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
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APRIL 1988
SEC JOB NO. F-1536

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I. GENERAL

A. BACKGROUND

This design analysis provides the backup information used in the design of the cap and gas collection system for the final landfill cover at the Heleva Landfill Superfund Site. It provides basic criteria for design decisions, project design criteria selected, and major design calculations. The following summary provides a chronology of the eventual design selected.

- Initial design efforts involved the gathering of site survey information and other pertinent data concerning the physical condition of the site.

- Based on review of previous studies and physical conditions at the site, various capping concepts were evaluated, all that would meet the intent of 40 CFR 264.310. Guidance document EPA/540/285/002, Covers for Uncontrolled Hazardous Waste Sites provides recommended guidance for capping systems and acknowledges that alternative designs can also meet the five basic requirements without the use of the "standard RCRA cap." In the course of the investigation, two major factors had to be considered. The amount of subsidence has historically been significant and based on the available information, this will be a continuing problem at the site. In addition, the initial survey of borrow material and available clay material identified no practical local areas where acceptable capping material could be expected. Historically, this has presented a problem in the Pennsylvania area. After discussions with the COE, it was determined that an initial concept design memo would be generated addressing these two problems and providing grading plan options to reduce the amount of borrow material required for general grading and minimize the loading on the landfill area. Initial investigations were also made of possible stabilization and compaction methods.

- The preliminary design information was provided to US EPA and COE for review and a meeting to discuss the options was held. Based on the information presented, US EPA requested a preliminary cost estimate (30 percent) for two options. The first involved the standard RCRA cap and the second involved an alternative design using a synthetic liner as the basic impermeable layer. After review, SEC was directed to proceed with an alternate design using the synthetic liner that would, to the degree possible, meet the following criteria:

- Provide long-term minimization of migration of liquids through the closed landfill.

- Function with minimum maintenance.

- Promote drainage and minimize erosion or abrasion of the cover.

- Accommodate settling and subsidence so that the cover's integrity is maintained.

- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

Since subsidence may be an ongoing problem, the following considerations were incorporated into the design.

- Minimize the amount of final cover above the liner so that should a repair be necessary, the area could be uncovered with a reasonable amount of effort.

- Select materials that would be sufficiently resistant to damage during construction, but provide enough expansion capability to allow for some degree of subsidence. HDPE was selected as the liner material and a synthetic drainage net. The drain net provides a reduction in the total thickness and weight of the cap system and will better maintain its integrity as a drainage blanket then would a sand/gravel layer should local subsidence occur.

- Utilize the SEC recommended alternative for grading (Option No. 3 of the Concept Design Memo) for the site plan work.

- In addition, prior to finalizing the 30 percent design, results from the predesign study indicated areas outside the original cap designation with TCE contamination. After review of this information, EPA directed SEC to extend the limits of the cap along portions of the southern boundary.

- The comments from the 30 percent design submittal were discussed and incorporated into a 95 percent design submittal. After initial review, EPA and the COE requested that the capping area be returned to the original RI/FS designation and the boundary of the cap be designed along the southern edge to allow for eventual extension of the cap. Design options were evaluated and a review meeting was held to finalize the concepts for resubmittal of the 95 percent design documents. Concerns were raised by the COE about anchoring the liner in trash or fill areas and an alternative extending the cap over the TCE area but allowing a soil venting system to be installed at a later data though the liner was formulated and selected. Evaluation of pre-installation boots being incorporated into the liner for installation of the soil vent system was investigated, but contacts with Terra-Vac indicated that the spacing would vary based on several factors. For this reason additional boots could be installed later, if required. Final design has proceeded in this manner.

B. BASIC DESIGN ANALYSIS CRITERIA

The landfill site is owned by Steven D. and Louis M. Heleva. Arthur J. Heleva and Martha Klugh own the adjacent property.

During the initial stages of the design effort, it became clear that the final design efforts could not proceed until certain conceptual decisions were made. Certain complications occur with this site that made a conceptual submittal necessary. The existing topography across the landfill is extremely variable and significant subsidence has occurred. Based on preliminary information, settlement will be an ongoing problem at the site. Initial concepts were addressed in the concept design memo submitted in October 1987.

The landfill cap was designed to provide long-term minimization of migration of liquids through the closed waste site. The cap was designed to conform with the following objectives of 40 CFR 264.310:

- Provide long-term minimization of migration of liquids through the closed waste site,
- Function with minimum maintenance,
- Promote drainage and minimize erosion or abrasion of the cover,
- Accommodate settling and subsidence so that the cover's integrity is maintained, and
- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

To create a cap system that minimized the migration of liquids through the closed waste site, the landfill would have to be regraded to allow runoff to be transported off the site. Initially four options were presented in the conceptual design memo issued October 30, 1987 based on the existing topography at this site. Option No. 1 involved filling the landfill site to form a dome allowing rainfall to run across the cap to either Todd Lake or the Northeast pond. A ridge would be made at the high point of the landfill near Todd Lake. A great deal of fill would have been required for this option and runoff would have been allowed to run across the cap for long distances. The second option consisted of creating a ridge in the center of the landfill and allowing runoff to run away from the center and towards the sides of the cap. This option proved to require twice as much fill as the first option. The fourth option was to create a dome to shed runoff to the nearest cap edge. This option required five times the amount of fill that Option No. 1 required. Option No. 3 was selected based on the lesser amount of fill, the ease of construction, and the reduced cost when compared with the other three options.

Option No. 3 has limited changes relative to the existing contour layout. A north-south ridge will be graded to direct runoff toward either Todd Lake or to the northwest pond. The flow that will be directed towards the northeast pond will be channeled into engineered ditches that will be lined with rip rap and tied into the landfill cap by a 60 mil HDPE liner. These ditches will discharge the runoff to the northeast pond. It is assumed that some high spots can be lowered and that some cutting into the existing landfill material can occur.

After the initial common fill is placed so that adequate slopes are attained for drainage, a 6-inch layer of select fill is placed. This select fill will not contain any organic material, any rocks larger than ¼ inch or objects that may puncture the HDPE liner. A geotextile is placed on top the select fill to provide a cushion and protection for a 60 mil HDPE liner. The 60 mil HDPE liner will be set on top of the cushion geotextile to prevent runoff from entering the refuse. A drainage net is placed on top of the HDPE membrane to allow runoff to flow off the landfill. This rigid plastic net would provide drainage as well as support for the cap system if settlement should occur. These materials have been used in similar applications several times in the past. A filter fabric is to be placed on top of the drainage layer to keep soil particles from entering the drainage net and clogging it. The top of the cap will consist of a 12-inch layer of select fill and a 6-inch layer of topsoil to allow grass to grow so that erosion of the cap can be minimized. There is 12 inches of select fill necessary because HDPE membrane manufacturers require a minimum of 12 inches of material on top of the membrane before equipment can be driven on the liner.

Due to design constraints a 3 to 5 percent slope, as required for RCRA standards, was not possible. The landfill surface would have to be lowered significantly to allow a 3 to 5 percent slope. This lowering would require a large amount of excavation into the refuse which may contain hazardous materials. Using the designed slopes it was verified that the soil loss would be an acceptable amount by utilization of the Universal Soil Loss Equation.

Through conversation with the Soil Conservation Service, the soil erosion should be less than 2 tons/acre/year using the Universal Soil Loss Equation. Carl Hellerick (215-398-4910) of the Allentown Area Soil Conservation Service supplied the regional factors for this equation. These factors include an R (rainfall) factor of 175; a K (soil type) factor of 0.28 based on a readily available topsoil for that region; a C (crop) factor of 0.02 based on grass with low maintenance; a P (farming practice) factor of 1.0 based on no conservation practices being initiated. John Case of the Greenville Soil Conservation (803-242-2756) received the plans and determined an average slope of 6 percent (for LS factor) and an average slope length of 700 feet (for LS factor). By utilizing an LS chart with a slope length of 700 feet and a slope percent of 6, the US factor is 1.8.

The Universal Soil Loss Equation consists of the following:

$$SL = (R)x(K)x(C)x(P)x(LS)$$

where:

SL = Soil Loss
R = Rainfall factor (175 for Allentown, PA Area)
K = Soil Type Factor (0.28 for soil in Allentown Area)
C = Crop factor (0.02 for grass with low maintenance)
P = Farming Practice Factor (1.0 for no farming conservation practices being initiated)
LS = Slope-length factor (1.8 for this site)

Therefore the Soil Loss is:

SL = (175)x(0.28)x(0.02)x(1.0)x(1.8) = 1.76 tons/Acre/Year

By the utilization of the Universal Soil Loss Equation the soil loss at this site will be 1.76 tons/acre/year which is less than the 2.0 tons/acre/year that is allowable.

Before construction of the cap can occur, several items will have to be addressed. Several pieces of equipment are going to have to be relocated so that the cap construction will not be obstructed. Near the entrance to the site are junked cars and trucks. Further into the site are several cars, trucks, bulldozers, earthmovers, trailers and various other items that will have to be relocated prior to cap construction. The existing power line is to be relocated so that the pole near the building is not in the landfill. The building shown on the plans is to remain on the site. The cap was designed to avoid removal of this building at US EPA's request.

Several monitoring wells are located in the landfill capping area. These monitoring wells are to be closed per the specifications. The existing TCE area has been fenced in. This fence will be removed as will a power pole located inside the fenced TCE spill area. The on-site collection pond will have to be pumped dry prior to fill being placed in this area.

Additional survey work conducted by Sirrine Environmental Consultants revealed that the parking area, turnaround laydown area, washdown area, and trailer location, would have to be relocated to a more level area as shown on the plans. The washdown area was relocated so that only the equipment that needs to be washed will have to drive over the washdown area. The washdown area was placed between the parking lot and the turnaround area so that equipment that is to be washed will not be hindered by construction equipment and construction materials that are placed in the laydown area. The washdown area is to be made of gravel due to the lower cost when compared to the cost of a concrete pad. Additionally when the cap is completed the laydown turnaround area and the equipment washdown area are to be removed and a gravel washdown area will be easier and cheaper to remove than one made of concrete. The equipment washdown area is a drainable wash area that directs flow to a sump. A portable pump is utilized to pump the washdown water from the sump to an above ground tank. Solids that get washed into the sump will have to be removed by hand. The ground surface where the laydown turnaround parking area, trailer location, and washdown area are located is generally flat. This area will have to be sloped to allow runoff to drain towards the existing ditches. These two ditches will be lined with rip rap to minimize erosion. This rip rap will remain after the cap is constructed.

The other ditches that are on the cap were designed to collect the runoff and channel it towards the offsite pond. These ditches were placed to follow the natural contours of the site. The slope of the ditches was adjusted with stair steps to keep runoff velocities low enough that the rip rap will not be disturbed. Construction of the ditches may involve excavation into the refuse. This excavation may encounter large objects such as automobiles or appliances. Construction should be phased so that any large objects and any refuse excavated can be placed in the collection pond area prior to the fill being placed on the pond area. The ditch excavation may need to be cut deeper than shown so that suitable backfill can be placed and compacted to provide a good base for the ditches. Calculations for the ditch design are included in Section IV of the Design Analysis.

Gas vents are required to collect the methane produced under the cap and direct it to the surface. Several sources were utilized for the design of the gas vents. EPA manual 540/2-85/002, Cover for Uncontrolled Hazardous Waste Sites, p. 4-46 specifies that gas vents should be placed at 30-60 feet centers. Gas vents were not placed over the collection pond due to the fact that 15-25 feet of fill are to be placed in this area. Gas vents also were not placed around the ditches because of interference with ditch placement and the high concentration of runoff in these areas.

The gas vents are designed so that the screw on PVC riser can be removed and replaced with a manifold if the gas is to be collected and treated. The gas vents were placed 6 feet above the cap surface so that anyone visiting the site would not be overcome by methane. The vent base is grouted to provide stability. Boots and bentonite are required to prevent moisture from entering the borehole. Where the PVC protrudes through the HDPE liner, the liner has been raised above the drainage layer so that the protruding part is above the drainage layer and thus further minimizing the chance of runoff getting into the gas vent. Methane will collect in the slotted PVC and rise to the surface. Wells will be drilled after the completion of the rough grading so that all cuttings can be placed under the cap.

Settlement monuments are placed to allow settlement to be periodically checked. These monuments will be constructed so that a known elevation can be set and recorded with the screw on cap and then welded permanent.

The entire landfill cap is to be enclosed by a security fence. The entrance gate is placed so that access to the drive that leads to a barn would not be blocked. The security fence was laid out so that clearing of trees could be minimized. Most of the trees near the site are less than 10 inches with a few larger trees near Hill street.

The entire site is to be hydro-seeded. During construction an erosion control mat will be needed on slopes larger than 5 percent or in any areas that should receive this mat so as to allow a good strand of grass to grow. Silt fences will be required perpendicular to surface flow patterns.

C. FEDERAL, STATE, AND LOCAL ENVIRONMENTAL PROTECTION CRITERIA AND ENVIRONMENTAL PERMITS

The purpose of this section is to summarize permitting requirements for the proposed construction at the Heleva landfill cap.

A zoning permit is required by the North White Hall Township, where the landfill is located. This is the only local permit required. The cost of the permit is $0.50 per thousand dollar cost of construction. There is a 2-week processing time for the permit. A copy of the permit is included in Appendix A.

The following areas of state permitting regulations have to be addressed: air quality, well closures, earth disturbance, and landfill closure.

An air quality permit may be required due to the methane gas or VOC's being vented from the site. To determine whether this permit is required, a "Request for Determination of Requirement for Plan Approval" application should be submitted to the Pennsylvania Department of Environmental Resources, Bureau of Air Quality Control. If an air quality permit is required, 90 days should be allowed for processing. There is no fee at this time for air permits. A copy of the application for plan approval is included in Appendix A.

There are no permits or abandonment requirements issued by the Bureau of Topographic and Geologic Survey under the Pennsylvania Water Well Drillers Licensing Act 610 of 1956. A letter of confirmation is included in Appendix A.

An earth disturbance permit will be required if more than 25 acres of land are disturbed in a contiguous project. A copy of the policy and procedure for this permit are included in Appendix A. The fee is $200 and the processing time is approximately 90 days. The earth disturbance permits are applied for through the County Conservation District. They also will coordinate review of plans with other agencies, such as the Bureau of Water Quality Management, and others, as may be required.

The Bureau of Solid Waste Management requires a letter of approval to be issued for a landfill closure. Chapter 75 of the Pennsylvania Solid Waste Regulations contain the applicable regulations. These regulations are in the process of being revised, with the new issue being due in March, 1988.

II. POTENTIAL SETTLEMENT EVALUATION AND COMPACTION CONSIDERATIONS

The following section summarizes the efforts to date, conducted to evaluate the potential settlement at the site and the conceptual alternatives to reduce the risk of cap settlement. Section 2.1 presents a summary of site conditions based on available information, a summary of mining activities and possible conditions of mined openings, a summary of conditions within the landfill. Section 2.2 presents a discussion of potential sources of settlement of the proposed cap at the landfill site, a discussion of the estimated magnitude of potential settlement, and mitigation possibilities for that settlement. The final section presents a summary of potential settlement at the site, the risk associated with that settlement to the proposed RCRA cap, mitigation possibilities, and recommendations for additional information that would be required to fully evaluate the final design.

A. BACKGROUND INFORMATION

The Heleva Landfill site is a 20-acre landfill located immediately west of Ormrod in North Whitehall Township, Lehigh County, Pennsylvania. The landfill consists of mixed refuse, paper, wood, and orchard wastes from the Allentown area and incudes an undetermined amount of industrial wastes including TCE's. The landfill began operation as a sanitary landfill in 1967 and apparently continued until it was ordered closed by PADER in 1981. The landfill received on the order of 250 to 350 tons/day of refuse which was placed in an abandoned open-pit mine developed in the late 1800s and early 1900s during iron-ore mining in the area. The current topography of the landfill area is flat or gently sloping, the landfill surface is weed-covered and includes irregular depressions suggesting differential settlement on the order of 2 feet or more. The landfill surface is partially covered with fine-grained soil apparently placed as a cover. This material has apparently been eroded and completely removed in some areas.

Methane gas, ground water at temperatures of approximately 100 degrees fahrenheit, and foul odors were encountered during investigations of the landfill.

The subsurface conditions at the Heleva Landfill site as revealed by existing subsurface information include:

- 1 to 2 feet of soil cover overlying,
- Approximately 30 feet of refuse fill containing layers of soil fill overlying,
- 50 to 120 feet of fine-grained soils described as clay, silty clay, silty sand, and clay with trace of gravel, overlying,
- Dolomitic bedrock.

The bedrock surface appears to be highly irregular and one boring encountered thin rock ledges 20 feet above the top of bedrock surface. The bedrock is soluble and the information suggests it contains solution cavities and collapse features typical of karst terrain.

Ground water generally occurs at or below the elevation of the base of the refuse fill. Therefore, ground water is generally encountered within the upper portion of the fine-grained clayey soils at the site. Ground-water contours based on well data obtained during July, 1986 suggest a ground-water gradient to the southeast across the landfill. This ground-water gradient follows a general dip of the top-of-rock surface in the same direction.

Mining activities which produced the open pit that was backfilled during operation of the landfill are described in Chapter 3 of the report by Lawler, Matusky & Skelly Engineers. Mining in the area was for iron ore, began in the 1820s, and continued until about 1915 when it ended due to competition from other sources. Mining began as shallow surface excavations, progressed to full-fledged open-pit mining, and entered a final stage of underground mining after open-pit mining became uneconomical.

Based on existing information, it appears that mining in the immediate area of the Heleva landfill included three adjacent, open pit mines. These mines were developed over a 40-year period until the overall dimensions of the three pits were 2,000 feet long (east/west direction), 800 feet wide (north/south direction), and 90 feet deep (approximately El. 400 to 410 feet).

Underground mining was conducted from about 1900 to 1915. Available information suggests that underground mining occurred below at least three locations of the Heleva Landfill. This information does not provide much detail regarding the mine layout, mining levels, or backfilling practices, if any. Available information suggests that underground mining was conducted on multiple levels, that drifts were approximately 7 feet high, that the interburden left between successive drifts was 5 to 6 feet, that mined openings were developed and supported with timbers and wood lagging, that drifts were developed to follow ore seams, and that the support was removed from each mining level and additional ore was removed during "retreat" from each level.

Available information suggests that underground mining occurred below the bottom of the open-pit and that vertical shafts were developed for mine access, ore removal, and ventilation. In addition, slopes were developed from the deepest mining levels to the ground surface adjacent to the open pit for access to the "washery." Finally, available figures suggest that mine spoils were dumped into the open-pit from a trestle.

No definitive information such as mine plans are available to show the location of active mined areas below the bottom of the open-pit. No information is available as to the number of levels developed along individual ore seams, the depth of the deepest drift, the depth below the bottom of the open-pit to the shallowest drift, or the type of material in which the underground mine openings were developed.

It is surmised for the purpose of this evaluation that open-pit mining operations were carried down to approximately the ground-water elevation, that underground workings extended into the fine-grained soils below El. 400 to 410 feet and possibly into underlying highly fractured dolomite. It is also surmised that active dewatering of underground mined openings was required during underground mining activities.

Finally, it is surmised that the underground mining operations were abandoned abruptly, with no reclamation or other remedial efforts because the underground mining operations were abandoned in 1915 due to competition from other sources.

Two general approaches are proposed for a RCRA cap for the Heleva Landfill. Conceptually all the options evaluated incorporate one of these approaches. The first includes recontouring the existing ground surface such that the landfill surface slopes gently inward from the perimeter and gently northeastward to direct surface runoff toward Pond 1. This approach appears to require removal of some existing soils to achieve the desired contours below the proposed cap materials.

The second approach involves some degree of recontouring of the existing ground surface at the landfill to a mound with a high point near the center of the landfill with gentle slopes to the perimeter of the landfill and a gentle slope northeastward to direct runoff toward Pond 1. This option will require addition of up to 10 feet or more of random fill above the existing ground surface to achieve the planned final site contours.

For the purpose of this evaluation, it is assumed that the RCRA cap will be 2 to 3 feet of clay material below 1 foot of sand and gravel, below 2 feet of soil to support vegetation.

2.2 ANALYSIS OF POTENTIAL SETTLEMENT

Based on review of existing information, several sources of potential settlement of the proposed RCRA cap have been identified and include:

- Compaction of the refuse fill from surcharge loading imposed by placement of the cap materials.

- Settlement resulting from consolidation and compaction of fine-grained soils below the refuse fill and above the bedrock.

- Settlement from collapse features or subsidence from sinkhole development in dolomite bedrock below the landfill.

- Settlement from subsidence over mined openings developed below the landfill and/or from access shafts and slopes developed for ore removal, ventilation and mine access.

The following sections include a discussion of the settlement mechanisms, an estimate of the magnitude of potential settlement, a description of means to mitigate the potential settlement, and a description of additional information that would help in further evaluating the potential settlement.

2.2.1 Settlement of Refuse Fill

Predicting potential settlement of refuse fills is difficult because of problems obtaining geotechnical information to characterize refuse fill, and because it is difficult to predict what decomposition of the organic fraction will produce in reduction of the fill mass. Existing boring logs from subsurface explorations in the landfill contain few descriptions of the nature of the refuse fill and almost no "blow count" information from within the refuse fill. The borings indicate that the refuse fill is generally about 30 feet thick, and contains intermediate thin soil layers presumably placed as temporary covers during landfill operation. One boring, Boring 1, included standard penetration test data within the refuse fill. These data indicate a range of N-values of 36 to 42 blows per foot with an average of 38 blows per foot. Ground water generally occurs at or below the base of the refuse fill, however several boring logs described the refuse fill as wet in the lower portion of the fill.

A conceptual level estimate of the settlement of the refuse fill must consider potential settlement from two sources; settlement from compaction of the refuse fill from surcharge loads imposed by cap materials, and settlement from decomposition and consequent loss of volume of the organic fraction.

Settlement from compaction of the refuse fill can be estimated based on case histories and experience with similar materials reported in the literature. The potential surcharge load from the proposed RCRA cap is assumed to vary from a maximum of 16 feet to a minimum of 6 feet of soil depending on the final approach. Based on experience from two case histories where a surcharge was added to an existing sanitary landfill, the predicted settlement from surcharge loading imposed by the proposed RCRA cap materials is as follows:

- 16 foot cap thickness - settlement of 2 to 4 feet.
- 6 foot cap thickness - settlement of 1 to 2 feet.
- Differential settlement - 2 to 3 feet.

Differential settlement may occur due to the non-homogenous nature of the trash fill. The above determination is an estimate of potential differential settlement based on settlement data in case histories.

Settlement resulting from continued decomposition of organic materials within the refuse fill is difficult to estimate. Boring logs in the refuse fill do not describe the types and fraction percentage of various types of refuse contained within the landfill. Because methane was encountered during drilling, elevated ground-water temperatures were encountered, bad odors were encountered, and differential settlement was observed on the existing landfill surface, active decomposition of organic materials within the landfill is apparently occurring at the present time. Typical percentages of various materials for municipal wastes include; paper 40%, metal 10%, food wastes 15%, yard wastes 15%, glass 10%, rocks, ash and dust 4%, plastics 3%, cloth 2%, and wood 1%.

Assuming that the food wastes, yard wastes, cloth, and wood represent the fraction that will actively decompose, approximately 33 percent of the refuse fill volume will change due to decomposition. If paper is added, then 73 percent of the refuse fill volume will change due to decomposition. Information from long-term settlement of refuse landfills suggests that this mix of materials will undergo significant settlement without addition of external or surcharge loads. The magnitude of this potential settlement is high, on the order of several feet, and the potential for differential settlement is high because of the non-homogenous nature of the refuse fill.

Risk of settlement of the refuse fill by the two mechanisms described above is high. Settlement is anticipated as a result of surcharge loads imposed by the proposed RCRA cap and through continued decomposition of the organic fraction of the refuse fill. Settlement potential from these two sources is high, on the order of several feet, and differential settlement potential is also high, also on the order of several feet.

Measures to mitigate this potential settlement include modification of the existing conditions within the refuse fill, and staging construction of the proposed RCRA cap such that the majority of compaction settlement occurs prior to placement of the impervious and upper sections of the cap. Possible methods to modify the existing conditions of the refuse fill in order to minimize settlement potential include:

- o Removal and controlled replacement of the refuse fill
- o Dynamic deep compaction.
- o Grouting using a cement, sand and/or fly ash grout.

Removal and replacement of the refuse fill is considered unacceptable because it is logistically impractical to remove the refuse, store it temporarily, and place it back in the original area using controlled compaction and moisture content conditions. This option is impractical and too costly.

Dynamic deep compaction could be used to densify the existing refuse fill and therefore reduce future settlement due to surcharge loading. This method consists of dropping a heavy weight from specified heights to impart compaction energy into the ground. Although the process could densify in-place refuse material, it is not recommended because of its high cost and uncertainties associated with compaction of the organic fraction of the refuse fill. Depending on the resolution of the issue of a staged closure, this option may warrant additional consideration.

Grouting could be used to fill existing voids within the refuse fill and, if sufficient grout could be placed, to compact and densify the refuse fill. Grouting of refuse fills using cement, sand, and fly ash grouts have been effective in reducing settlements of refuse fills, particularly where the grout can be injected under confined conditions such that some compaction and densification of the refuse fill results from grout placement. Another potential advantage of grouting is that it decreases the relative percentage of organic materials within the refuse fill by adding inorganic material. Unfortunately, grouting of the entire landfill would be very costly. Complete grouting of the Heleva Landfill would require an estimated 225,000 cubic yards of grout. At an estimated $50.00 per yard delivered into the ground, grouting the entire landfill could cost approximately 10 million dollars. For this reason, it is not presently considered feasible.

2.2.2 Settlement from Consolidation and Compaction of Fine-Grained Soils Below the Refuse Fill and Above the Bedrock

Predicting potential settlement in fine-grained soils can be done using well-established principals of soil mechanics. Consolidation of fine-grained soils results from an increase in stress within a soil mass located below the water table and occurs slowly as pore water is expelled from the soil and the soil particles compact. The amount of consolidation that occurs in a soil mass is a function of its geotechnical properties and the previous stress history of the soil.

At the Heleva Landfill, the fine grained soils are described primarily as clayey soils with a minor gravel fraction. Other descriptions include silty clay and silty sand. Previous reports indicate that the clays may be glacial till. This is important because if the soils are glacial till, they are highly over consolidated due to the large loads imposed during deposition and glacial advance. Generally, the clayey soils below Heleva Landfill occur at between El. 440 feet and 450 feet and extend 60 to 120 feet to the top of rock. Ground water occurs at between El. 405 and 430 feet, therefore all but the top 20 to 30 feet of the clayey soils are submerged. Three standard penetration tests were taken in borings which penetrated the clayey soils within the landfill area and produced N-values of 39, 46, and 52. Generally, Standard Penetration Tests in clayey soils from borings located beyond the perimeter of the landfill at depths of greater than 20 feet resulted in N-values of between 20 and 50. The consistency of fine-grained soils with N-values in this range would be described as stiff to hard.

Close evaluation of available information about the mining activity at the Heleva Landfill suggests that the clayey materials above El. 410 consist of mine spoils dumped into the open pit after processing at the washery. These were dumped from a trestle and no spreading or compaction is believed to have occurred during placement of this material in the open pit.

Any settlement in the clayey soils from surcharge loads imposed by the proposed RCRA cap would come from the soils above El. 410 feet. Below El. 410 feet, it is likely that the soils are over-consolidated from glacial activity or original topography at the site. No settlement is anticipated from the clayey soils below El. 410 feet from placement of the RCRA cap. Some settlement is possible from clayey soils above El. 410 feet due to compaction in clayey soils above the ground water or to consolidation of clayey soils below the ground water. An approximate estimate of this potential settlement is one to 6 inches. Compaction settlement of soils above ground water would occur during and immediately after placement of cap materials. Settlement resulting from consolidation of soils below ground water would extend for a considerable period of time after placement of cap materials It is anticipated that differential settlement from this material will be small.

The risk that this settlement will occur is high if some of the clayey materials are dumped mine spoils If all clayey materials below the landfill are "in-situ," then potential settlement is low due to the over-consolidated condition of these soils.

Measures to mitigate the potential settlement from the fine-grained soils below the refuse fill include:

- Placement of wick drains in the clayey soils below ground water and above El 410.

- Phased construction of the proposed RCRA cap.

Wick drains placed at approximately 10 foot centers would minimize the time required for clayey soils to consolidate. The cost of installing wick drains is approximately $0.50 per square foot of treated surface area. The approximate cost for wick drains based on available ground-water data would be $250,000. However, prior to proceeding with this option, consideration would have to be given to the contaminated nature of the extracted ground water and its ultimate disposal.

Phased construction of the proposed RCRA cap would allow for some of the anticipated settlement to occur prior to placement of impervious cap materials. Phased construction would consist of placing a surcharge onto the landfill surface, waiting several months, monitoring the settlement, and then removing some of the surcharge and placing impervious and special cap materials.

2.2.3 Settlement from Collapse or Subsidence from Sinkhole Development in Bedrock

Settlement of RCRA cap materials could result from collapse or subsidence from sinkhole development in the dolomitic bedrock. Existing information suggests that the bedrock below most of the landfill area is soluble, and solution features have been identified in the general site vicinity. One boring log (FW-4) suggests a collapse feature or highly irregular top of rock surface as several thin rock ledges were encountered 20 feet above the top of rock. Ground-water levels within the landfill generally occur 20 to 100 feet above the top of the bedrock surface.

The amount of settlement that could result from collapse or development of a sinkhole is not prudent to estimate It is sufficient to say that development of a new sinkhole or collapse feature would potentially result in large settlement of cap materials, on the order of several feet, within a zone above and surrounding the subsurface collapse feature.

Generally, development of sinkholes in karst terrain are associated with changes in ground-water levels. Both an increase and decrease in ground-water levels are attributed to dramatic development of sinkholes in regions underlain by soluble rock formations. Therefore the risk of settlement from this mechanism is high only if increases or decreases in ground-water levels occur. Increases in ground-water levels are not anticipated from anticipated future activity at the landfill site. Decreases in ground-water levels could result from well pumping to contain contaminant flow.

As suggested in the previous report, mitigation of the risk of damaging the RCRA cap due to settlement from collapse or subsidence from sinkhole development consists of placing cap materials after ground-water levels had been drawn down to any anticipated steady state levels for several months.

2.2.4 Settlement from Subsidence Over Mined Openings Below the Refuse Fill

Evaluating potential settlement from subsidence over mined openings below the landfill is difficult because accurate mine maps are not available in the area of the landfill. Existing information suggests that earlier mining operations included underground workings below the open pit mines in the area, and seismic exploration work identified underground openings or zones of low density materials in the landfill area.

General descriptions of mining methods suggest that once the open pit mine reached El. 400 to 410 feet, mining went underground to recover deeper ore. The underground mines were developed along ore seams as multiple drifts, each approximately 7 feet high and 8 to 12 feet wide, separated by interburden of 5 to 6 feet. Access, ventilation and ore recovery was accomplished through vertical shafts or slopes. Generally, the shafts appear to have been developed within the confines of the pit, while the slopes extended from the lowest underground level to a washery at ground surface adjacent to the pit.

It is difficult to determine exactly how deep the underground workings were taken and in what materials the mined openings were developed. Existing information indicted that all shafts and underground openings were timber supported and continuously lagged. This suggests that the underground workings were developed within the clayey soils or highly fractured dolomite indicated by borings taken below the landfill material. Description of mining methods indicted that as multiple drifts were developed away from a central access shaft along an ore seam, the openings were continuously supported using timber and wood lagging. After the drifts were fully developed, support was shot down and additional ore was robbed from the perimeter of each opening as mining retreated back to the access shaft. The deepest mined opening was described as 150 feet deep and the longest drift was described as 300 feet.

Based on the available information about underground mining below the Heleva Landfill, the potential for settlement of cap materials because of ongoing subsidence over mined openings is considered either low or high. Potential settlement is considered low if the mined openings collapsed after mining operations ceased in 1915 because wood support was removed, or because wood supports decayed. If wood supports were removed by either mechanism surface subsidence has probably already occurred and future subsidence is unlikely.

Potential settlement is considered high if mined openings have not collapsed completely and collapse could occur in the future. If this is possible, the magnitude of surface settlement above collapsed openings could range from 0.25 to 0.75 times the height of the opening. Therefore, for three levels developed with 7 feet openings on each level, surface settlement resulting from collapse of these openings could be between 5 and 15 feet.

Mitigation of potential settlement from subsidence over mined openings, could be accomplished by finding and backfilling the openings with grout or soil mixtures. The cost of backfilling could quickly reach several million dollars because of potential for large volumes of material, and lack of control over where the material would go once injected underground.

Clearly, a better understanding of the location and current condition of mined openings within the perimeter of the landfill is required to fully assess the potential for settlement from this source.

2.3 CONCLUSIONS AND RECOMMENDATIONS

Potential settlement and differential settlements of proposed RCRA cap materials is on the order of several feet. Four separate mechanisms exist below the landfill surface that may contribute to significant future settlement of cap materials during and after placement. These mechanisms include compaction and biological degradation of refuse fill, consolidation and compaction of clayey soils between the refuse fill and the rock, settlement from collapse or subsidence from sinkhole development in the bedrock, and settlement from subsidence over mined openings developed below the landfill.

Table 1 presents a summary of the estimated magnitude of potential settlement, the timing of that settlement with respect to placement of proposed RCRA cap material, and a subjective evaluation of the risk or likelihood that the settlement will occur.

To fully design the facility, consideration should be given to supplementing the present database with the following types of information.

- Additional geotechnical information on the refuse fill and underlying clayey soils.

- Data to differentiate between clayey soils above and below El. 400 to 400 feet.

- Undisturbed samples of the clayey soils underlying the refuse fill to allow a laboratory determination of previous stress history.

- Additional information on the make-up of the refuse fill, including an estimate of organic material and the degree of biological decomposition at present.

- Location of mined openings below the landfill and to determine the current condition of mined openings.

- Some consideration may want to be given to establishing a test section on the landfill to determine the magnitude and timing of settlement resulting from placement of the maximum anticipated surcharge load associated with the proposed RCRA cap.

The table below summarized observed settlement and time for several points measured during embankment construction.

TABLE 1

CDOH SETTLEMENT OBSERVATIONS

Phase 1 Construction

Settlement Point	Total Settlement (in.)	Time	Total Settlement (in.)	Time
1	3	End emb. const.	6	Several mos. after Phase 1 const.
2	20	End emb. const.	21.5	Several mos. after Phase 1 const.
3	32.5	End emb. const.	34	Several mos. after Phase 1 const.

Phase 2

Settlement Point	Total Settlement (in.)	Time	Total Settlement (in.)	Time
1	10	End Phase 2 const.	?	4 mos. after Phase 2 const.
2	28	End Phase 2 const.	?	4 mos. after Phase 2 const.
3	39	End Phase 2 const.	42	4 mos. after Phase 2 const.

SETTLEMENT CALCULATIONS

OBJECTIVES: CONCEPTUAL LEVEL-OF EFFORT THROUGHOUT

1 EVALUATE SETTLEMENT & DIFFERENTIAL SETTLEMENT POTENTIAL UPON PLACEMENT OF PROPOSED RCRA CAP.

2. DETERMINE POTENTIAL SOURCES OF SETTLEMENT
   a) TRASH FILL
   b) FINE-GRAINED SOILS BELOW TRASH FILL AND ABOVE ROCK
   c) SINKHOLE DEVELOPMENT IN ROCK
   d) SUBSIDENCE FROM MINED OPENINGS BELOW BOTTOM OF OLD OPEN PIT MINE, SHAFTS & RAISES FROM ORE HANDLING.

3. ESTIMATE POTENTIAL SETTLEMENT FROM EACH SOURCE IN #2 ABOVE

4. PROVIDE CONCEPTUAL-LEVEL COST ESTIMATES FOR POSSIBLE MITIGATION MEASURES.

* SETTLEMENT POTENTIAL IN TRASH FILL:

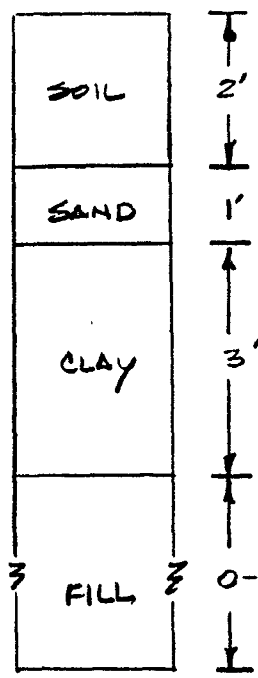
FACTS

- TRASH FILL IS FROM SANITARY LANDFILL OPERATION WHICH BACKFILLED AN OLD IRON OPEN PIT MINE.
- SANITARY LANDFILL IS ABOUT 30 FT THICK, CONSISTS OF MUNICIPAL REFUSE WITH LAYERS OF SOIL USED AS INTERMEDIATE SOIL COVERS DURING LANDFILL OPERATION
- FIVE N-VALUES ARE AVAILABLE FROM EXISTING INFORMATION (B-1) AND INDICATE A RANGE OF N-VALUES FROM 36 TO 42, AVG 38 BLOWS WITHIN THE UPPER 17 FT OF THE TRASH FILL.
- GROUNDWATER LEVELS IN THE SANITARY LANDFILL ARE AT ELEVATION 405 TO 430 (DATA ON JULY 7, 1986). THIS CORRESPONDS ROUGHLY TO THE BASE OF THE TRASH FILL, OR LOWER, WITHIN UNDERLYING FINE-GRAINED SOILS.

  NO INFORMATION AVAILABLE ABOUT SEASONAL GROUND WATER FLUCTUATIONS.

- MAXIMUM CAP THICKNESS IS ABOUT: 3 FT FOR OPTION 1
  10 FT FOR OPTION 2

POTENTIAL SURCHARGE FROM PROPOSED CAP:



STRESS @ BASE OF CAP:

ASSUME AVG. UNIT WEIGHT OF SOILS = 125 #/FT³

$\sigma_{B_{max}} = (125\ \#/FT^3)(2+1+3+10\ FT) = $ 2000 #/FT² or 1 TON/FT²

$\sigma_{B_{min}} = (125\ \#/FT^3)(2+1+3+0\ FT) = $ 750 #/FT² OR 0.375 TON/FT²

NOTE: ASSUMMED THICKNESS OF CAP:

MAX = 2+1+3+10 = 16 FT.
MIN = 2+1+3+0 = 6 FT.

ESTIMATE OF POTENTIAL SETTLEMENT FROM TRASH FILL:

① COLORADO DEPT. OF HIGHWAYS EXPERIENCE, SHERIDAN BLVD & I-76 (Ref. T. LYMAN pers. communication Nelson Chou, Brandy Gilmore, CDOH)
SETTLEMENT ≅ 10% OF EMBANKMENT HEIGHT.

GIVEN: TRASH FILL 20-30 FT THICK
TRASH FILL 20-30 YEARS OLD
GROUNDWATER NEAR OR BELOW BOTTOM OF TRASH FILL.
LOCATION NORTHWESTERN - METRO DENVER, COLORADO

HELENA SETTLEMENT SUGGESTED FROM ABOVE:
MAXIMUM PREDICTED SETTLEMENT = (16 FT)(12 IN/FT)(0.10) = 19.2 INCHES

MINIMUM PREDICTED SETTLEMENT = (6 FT)(12 IN/FT)(0.10) = 7.2 INCHES

② FROM CHAPTER 10 - FOUNDATIONS ON DIFFICULT SOILS; BRAJA M. DAS "PRINCIPLES OF FOUNDATION ENGINEERING".

SETTLEMENT RATE (METERS/MO) $m = .0268 - 0.0116 \log t_1$ (for fill heights from 12-24 meters)
if fill complete in 1940; $t_1 \cong (1987-1981)(12) = 72$ months
$m = .0268 - 0.0116 \log 72$
$m = 0.028$ m/mo
$m = (.028)(39.37\ in/m) = $ 1.1 IN/MO

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(3) FROM SOWERS (1973), SETTLEMENT OF WASTE DISPOSAL FILLS.

$$\Delta H = \frac{\alpha H_f}{1+e} \log\left(\frac{t''}{t'}\right)$$

Where: H_f = Fill Height
e = void ratio
α = Coefficient for settlement
t'', t' = times (months)
ΔH = Settlement between times t' & t''

$\alpha = 0.09e$ for conditions favorable for decomposition

$\alpha = 0.03e$ for conditions unfavorable for decomposition.

Assume:

$\alpha = 0.06e$
$H_f = 30$ ft
$e = 1.3 - 7.0$ (ref. York et. al. "Terminal Development on a Refuse Fill Site, ASCE, Geot. Practice for Disposal of Solid Waste Materials", 1977)
$t'' = 1987$
$t' = 1981$

$$\Delta H = \frac{(0.06)(7.0)(30\text{ ft})}{1+7.0} \log 72 = \underline{\underline{2.9\text{ FT}}}$$

(4) FROM RAO ET AL, "SETTLEMENT OF REFUSE LANDFILLS", ASCE GEOTECHNICAL PRACTICE FOR DISPOSAL OF SOLID WASTE MATERIALS, 1977.

a) DATA FROM TEST SECTION: 60 x 90 ft area
1000 psf load applied to landfill surface
trash fill was 16 ft thick

SETTLEMENT IN ONE YEAR: 2.1 FT, 1.4 FT, 1.25 FT AT THREE OBSERVATION POINTS NEAR CENTER OF THE LOADED AREA.

CONCLUSIONS FROM 1-4 ABOVE RE SETTLEMENT OF TRASH FILL:

1. SETTLEMENT WILL RESULT FROM SURCHARGE LOADS IMPOSED BY PLACEMENT OF RCRA CAP MATERIALS.

2. SETTLEMENT FROM SURCHARGE WILL PROBABLY OCCUR RAPIDLY WITH THE MAJORITY OF SETTLEMENT COMPLETE SOON AFTER PLACEMENT OF THE CAP.

3. SETTLEMENT FROM DECOMPOSITION MUST BE EVALUATED [illegible]

SETTLEMENT OF TRASH FILL, CONCLUSIONS (CONTINUED)

4. Magnitude of settlement difficult to determine based on available data. "Ball park" estimates of potential settlement are:

16 ft of cap thickness – 2-4 ft of settlement

6 ft of cap thickness – 1-2 ft of settlement

5. Differential settlement potential.

a) Function of cap thickness, fill thickness, and variations in existing fill conditions.

b) Potential differential settlement – 2-3 ft.

* SETTLEMENT POTENTIAL IN FINE-GRAINED SOILS BELOW TRASH FILL AND ABOVE ROCK

FACTS

- THICKNESS RANGES 60 - 120 FT.
- ALMOST ALL OCCURS BELOW EXISTING GROUNDWATER TABLE.
- DESCRIBED AS CLAY, SILTY CLAY, TRACE GRAVEL, SOME SILTY SAND AND CLAY.
- N-VALUES 39, 46, 52 WITHIN LANDFILL; GENERALLY 20's TO 50's BELOW 20 FT IN BORINGS OUTSIDE LANDFILL LIMIT. BASED ON BLOW COUNTS, CLAY & SILT WOULD BE DESCRIBED AS VERY STIFF TO HARD
- SOME DESCRIPTION OF THIS SOIL IS "GLACIAL TILL".
- POSSIBILITY OF FINES ABOVE EL. 410 PLACED AS HYDRAULIC TAILING OR BACKFILLED TAILINGS FROM RAIL TRESTLE

SURCHARGE FROM CAP: SEE PAGE 2

$\sigma_{MAX} = 2000\ \#/FT^2$; $\sigma_{min} = 750\ \#/FT^2$

ESTIMATE OF SETTLEMENT FROM CLAY

① IF MATERIAL IS GLACIAL TILL - PRECONSOLIDATION LOAD SHOULD HAVE BEEN MUCH LARGER THAN TRASH FILL PLUS SURCHARGE FROM CAP. THEREFOR NO SETTLEMENT IS ANTICIPATED FROM THIS UNIT.

② IF MATERIAL IS NOT GLACIAL TILL - PRECONSOLIDATION LOAD OF ORIGINAL MATERIAL REMOVED IN OPEN PIT MINE PROBABLY ABOUT EQUAL TO TRASH FILL PLUS SURCHARGE FROM CAP. NO SETTLEMENT ANTICIPATED.

③ CALCULATED SETTLEMENT IF 1 & 2 ABOVE IGNORED. NO DATA AVAILABLE e log p curves, etc.

④ POSSIBLE SETTLEMENT FROM SIGNIFICANT DEWATERING OF CLAYS; IGNORED FOR THIS ANALYSIS.

CONCLUSION

POTENTIAL SETTLEMENT IN CLAYS BELOW TRASH FILL MINIMAL DUE TO SURCHARGE LOAD FROM CAP MATERIALS.

* SETTLEMENT POTENTIAL FROM SOLUTION CAVITIES IN LIMESTONE BEDROCK.

FACTS:

- KARST TERRAIN & OLD COLLAPSE FEATURES RECOGNIZED IN THE AREA.
- MOST OF THE LANDFILL UNDERLAIN BY BEEKMANTOWN LIMESTONE.
- GROUNDWATER LEVELS IN LANDFILL AREA GENERALLY 50-100 FT ABOVE BEDROCK SURFACE.
- ONE BORING LOG (FW-4) INDICATED ROCK LEDGES IN A ZONE ABOUT 20 FT ABOVE TOP OF ROCK. THIS SUGGESTS A POSSIBLE CAVITY OR VERY IRREGULAR TOP OF ROCK SURFACE.

EVALUATION:

- DIFFICULT TO ASSIGN RISK OF SINKHOLE DEVELOPMENT WITHIN AREA OF THE LANDFILL.
- MOST SINKHOLE DEVELOPMENT IS RELATED TO CHANGES IN GROUNDWATER REGIMES WITHIN A KARST TERRAIN. CONCUR WITH EXISTING REPORT, RISK IS SMALL UNLESS GROUNDWATER DRAWDOWN FROM WELL PUMPING.
- IF A COLLAPSE FEATURE EXISTS BELOW THE LANDFILL AND OCCURS AS AN ARCH IN THE CLAY, THE FOLLOWING MECHANISMS ARE NEEDED TO TRIGGER COLLAPSE: (Aley, et. al., 1972, "Groundwater Contamination and Sinkhole Collapse Induced by Leaky Impoundments"

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CONT FROM Pg. 6 —
MISSOURI GEOLOGICAL SURVEY & WATER RESOURCES, ENGINEERING GEOLOGY SERIES No. 5.)

"(a) excess water entering the arch material and so causing a loss of strength. This is by far the most common trigger;

(b) earth tremors causing vertical and lateral accelerations, thus resulting in externally applied body forces to the materials of the arch,

(c) ground movements resulting from subsidences associated with mining. These movements might be irregular, resulting in differential movement which can upset the geometry of the arch,

(d) surface loading of vibratory nature, particularly where the energy of vibration is great and sustained."

CONCLUSION

POTENTIAL FOR COLLAPSE OR SUBSIDENCE FROM SINKHOLE DEVELOPMENT IS MODERATE. DIFFICULT TO EVALUATE DEGREE OF RISK. RISK CONSIDERED LOW IF NO CHANGE TO GROUNDWATER LEVELS OCCUR.

* SETTLEMENT POTENTIAL FROM MINED OPENINGS BELOW TRASH FILL.

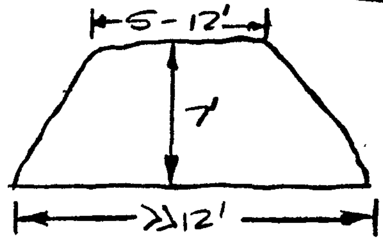
FACTS:

- MINING BEGAN AS OPEN PIT – MOVED UNDERGROUND BELOW THE PIT WHEN OVERBURDEN RATIO BECAME UNECONOMICAL.
- IRON ORE MINING BEGAN IN 1820
- WENT UNDERGROUND W/ SLOPES & SHAFTS IN 1900, ENDED IN 1915 DUE TO COMPETITION FROM MESABI RANGE.
- MAXIMUM DEPTH OF OPEN PIT WAS 90 FT AT CENTER (EL. 410)
- POSSIBILITY THAT BARRIERS WERE LEFT IN PLACE BETWEEN 3 PIT LIMITS WHICH LANDFILL OVERLIES.
- PAUL BROWN MINE (COLLECTION POND AREA) DUG TO 70 FT (EL 400 FT)
- TUNNELS & SHAFTS SUPPORTED WITH WOOD.
- MULTIPLE MINING LEVELS WERE DEVELOPED BELOW THE BOTTOM OF THE OPEN PIT, FOLLOWING ORE VEINS.
- SKETCH SHOWS A SPOIL BANK WITHIN THE OPEN PIT, THEREFOR MINE WASTE WAS DUMPED FROM A TRESTLE IN THE OPEN PIT.
- EACH TUNNEL WAS ADVANCED & TIMBER SUPPORTED, THEN SUPPORT REMOVED AND RETREAT MINING ROBBED ALL AVAILABLE ORE BACK TO THE ORE CHUTE.
- LOWEST TUNNEL WAS AT A DEPTH OF 150'; 300 FT LONG.
- FOUND EVIDENCE OF EARLIER U/G OPENINGS WHEN MINED IN 1910

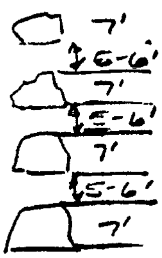
EVALUATION OF POTENTIAL SUBSIDENCE FROM ABANDONED UNDERGROUND MINES

MULTIPLE LEVELS: 5-6 FT INTERBURDEN.

MINING LEVEL OPENING DIMENSIONS:



POTENTIAL SERIES OF OPENINGS:



HOW MANY LEVELS??

WHAT MINED IN?? "CLAY"; LIMESTONE ?

POSSIBLE CONDITIONS:

1. MINED OPENINGS HAVE COLLAPSED & SURFACE SETTLEMENT HAS ALREADY OCCURRED.

2. MINED OPENINGS ARE STILL OPEN AND ARE STABLE.

3. MINED OPENINGS ARE OPEN BUT CAN COLLAPSE DUE TO INCREASED LOAD FROM SURCHARGE, DEWATERING.

4. MINED OPENINGS ARE OPEN BUT MAY COLLAPSE WHEN TIMBER SUPPORTS ROT & BECOME INEFFECTIVE.

CONCLUSIONS:

- POSSIBLE SETTLEMENT @ SURFACE FOR 3 & 4 ABOVE IS SEVERAL FEET IN ZONE ABOVE UNCOLLAPSED MINED OPENINGS.

CONCLUSIONS CONTINUED:

- AMOUNT OF POTENTIAL SETTLEMENT ≈ 0.7 * h
where h = height of mined opening.
(ref: National Coal Board _ Subsidence Engineering ~~Handbook~~)

S_{max} = (7 ft)(5 stacked drifts)(.7) = 24.5 ft.

THIS IS CONSERVATIVE AND MUST REPRESENT AN ABSOLUTE UPPER BOUND.

RATIONAL ESTIMATE OF POTENTIAL SETTLEMENT DUE TO MINED OPENINGS IS 0 – 15 FT. 0 FT IF OPENINGS HAVE COLLAPSED, 15 FT IF ALL COLLAPSE AFTER PLACEMENT OF THE CAP.

COST OF MITIGATION MEASURES — CONCEPTUAL LEVEL ESTIMATE.

1. GROUTING –

CONCEPT – INJECT WEAK CEMENT, CEMENT-BENTONITE, OR CEMENT-FLYASH GROUT FROM GROUND SURFACE THROUGH VERTICAL BOREHOLES DRILLED TO THE BOTTOM OF TRASH FILL.

PROCEDURE – DRILL 2-3 IN DIAMETER GROUT HOLES, CASE WITH REMOVABLE STEEL CASING, INJECT GROUT FROM GROUT PLANT @ GROUND SURFACE IN STAGES FROM BOTTOM OF BOREHOLE. INJECT EACH STAGE TO A "REFUSAL" CRITERIA, WITHDRAW CASING THE HEIGHT OF NEXT STAGE AND REPEAT.

TREATMENT AREA – ENTIRE AREA OF OLD OPEN PIT
ASSUMMED DIMENSIONS 1400 FT x 700 FT x 30 FT DEEP.

GROUTING (CONT)

TREATMENT VOLUME = (1400)(700)(30)(1/27 ft³/yd³) = 1,090,000 YD³

AT 20% VOID RATIO
GROUT VOLUME = (0.20)(1,090,000) = 225,000 YD³

CONSERVATIVE CONCEPTUAL LEVEL COST FOR GROUTING : $30 - $50 /YD³ IN PLACE.

COST FOR GROUTING : 225,000 YD³ @ $50/YD³ = $11,250,000.00

HELEVA LANDFILL
CALCULATIONS
T. LYMAN

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APPENDIX
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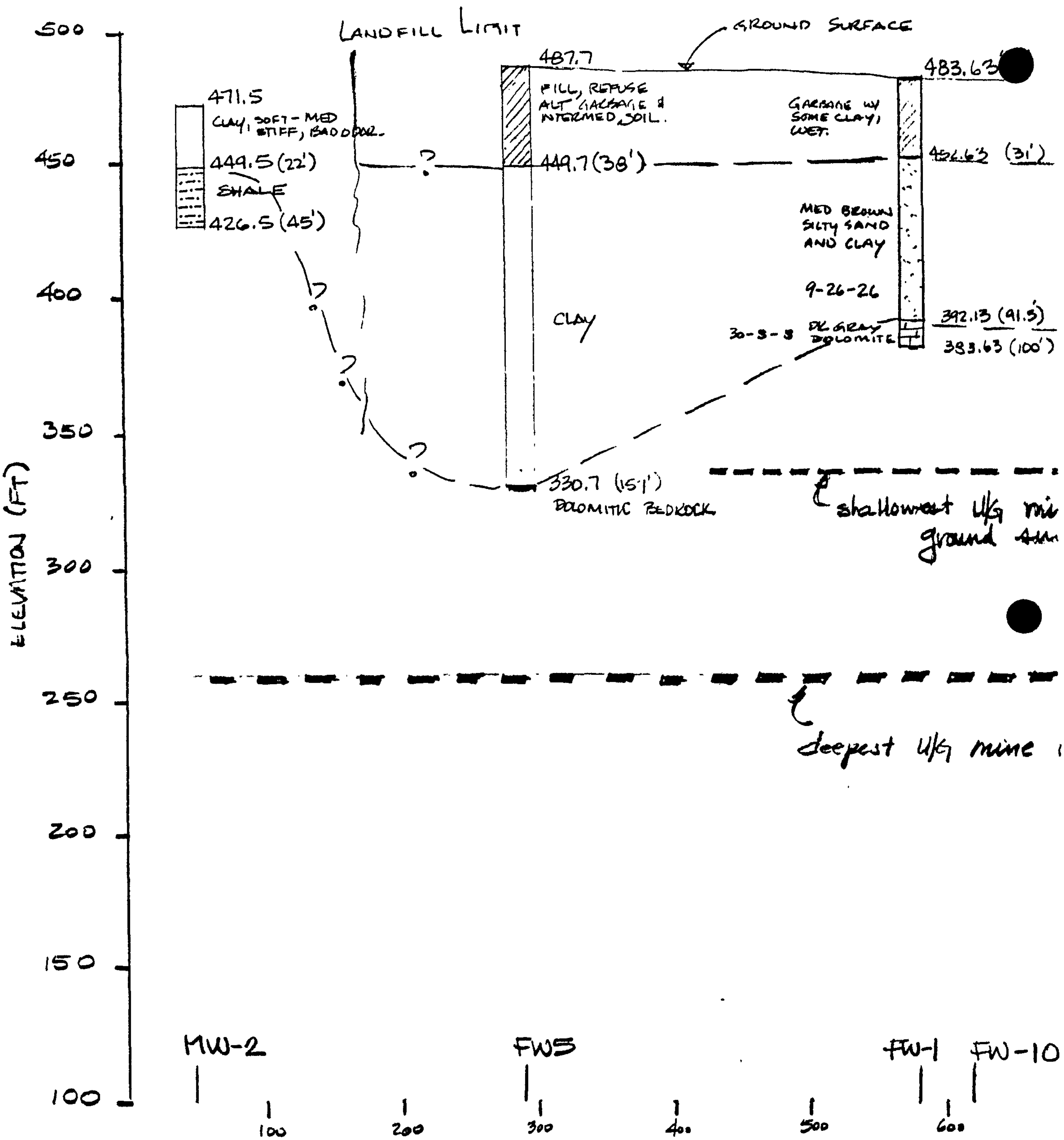
— APPENDIX —

SUPPORTING INFORMATION

GENERALIZED EAST – WEST GEOLOGIC



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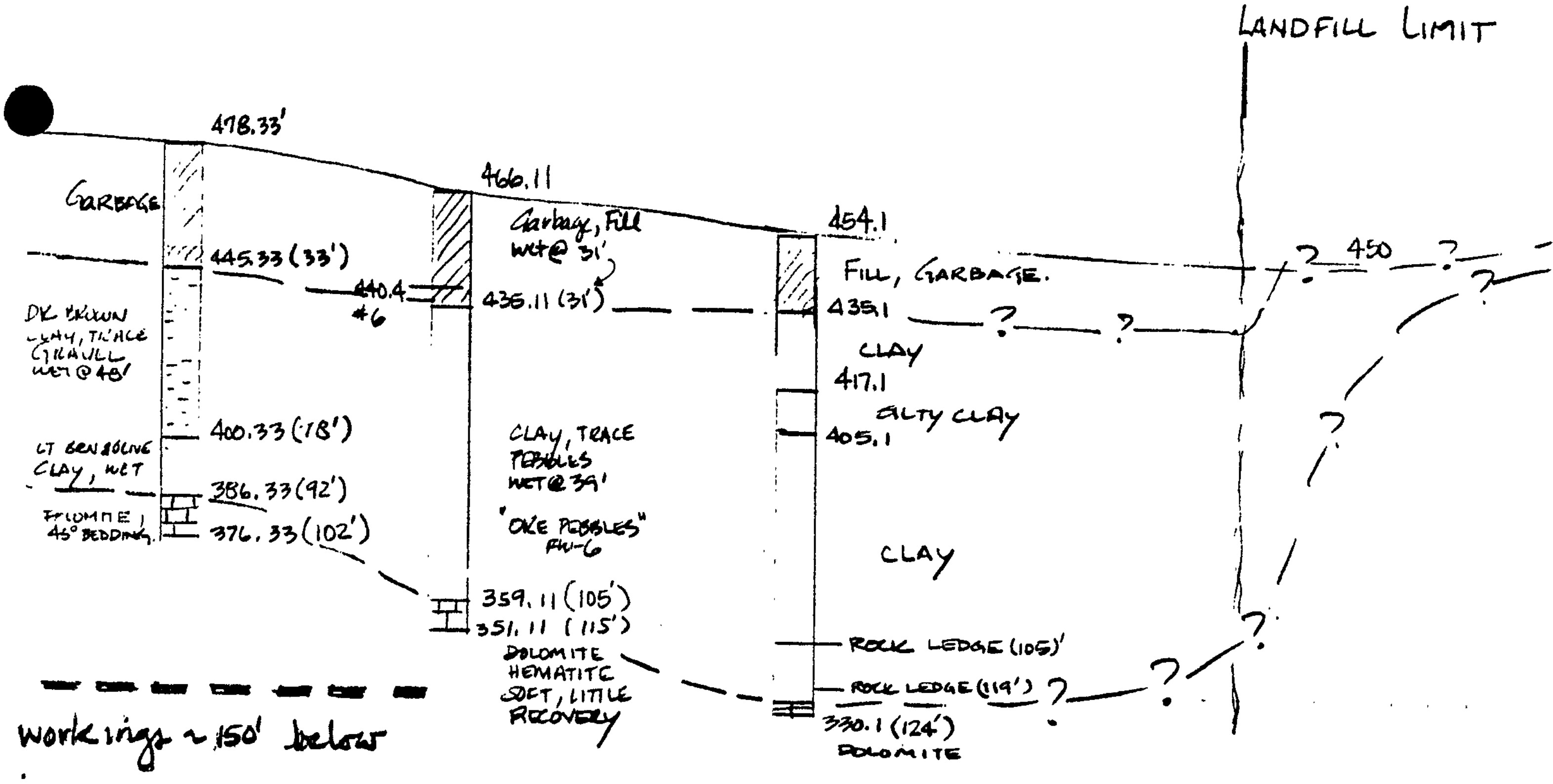
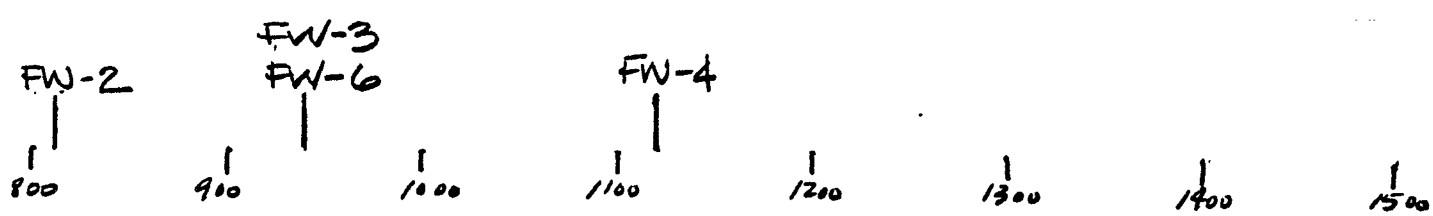
-CTION – LOOKING NORTH



-ings ~ 150' below El. 410 ft.

NOTE: VERTICAL EXAGGERATION x2



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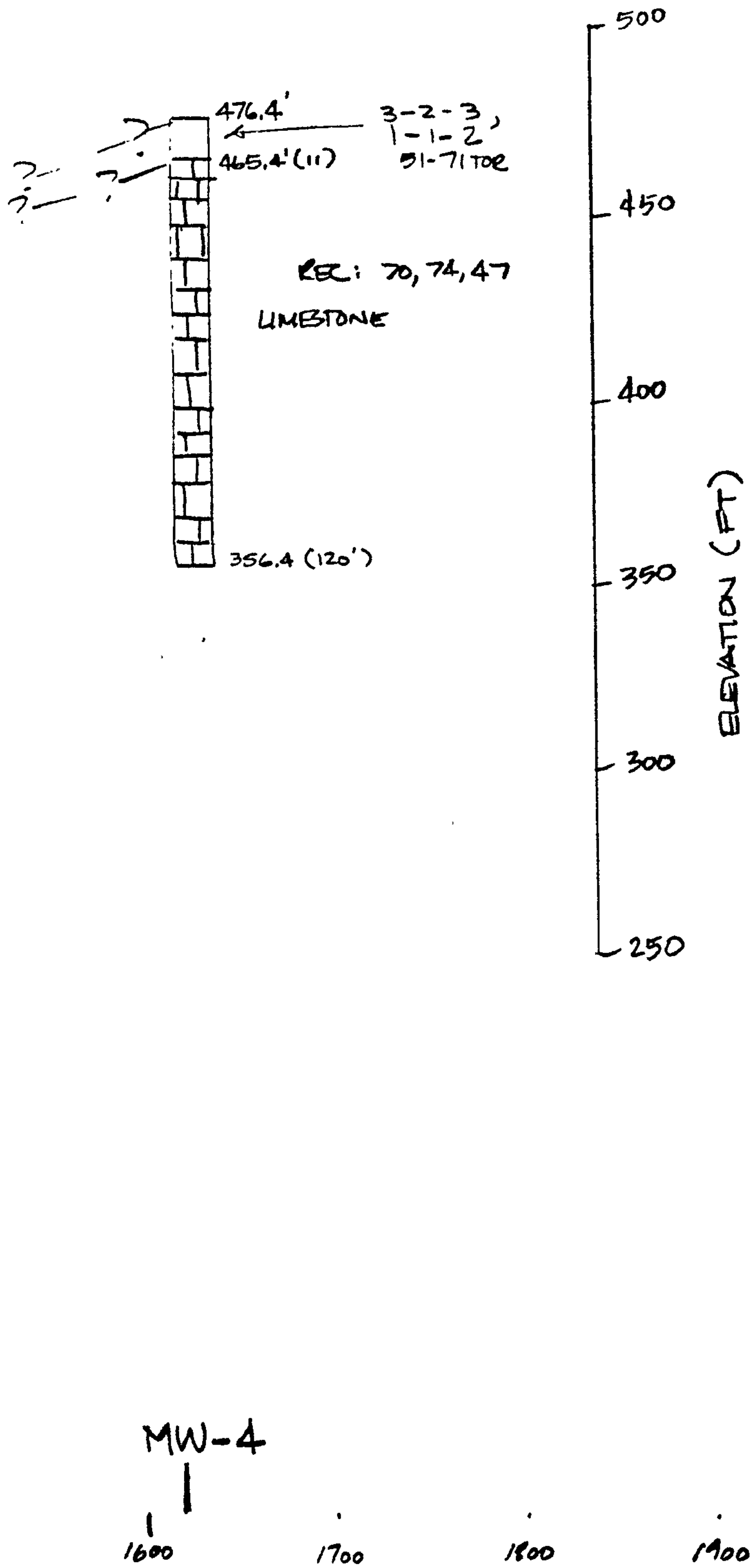

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SUMMARY OF BLOW COUNT DATA

OCT 12, 198?
TJLYMAN
PAGE 1

TRASH FILL

BLOWS	BORING LOG

CLAY, SILTY CLAY, SAND

BLOWS	N	BORING LOG	
9-26-26	52	FW-1	med. brown silty sand & clay.
30-27-19	46	FW-2	dk brown clay, trace gravel.
14-21-18	39	"	"
*3-2-3	5	M4B	clay w/ some silt, subangular hematite gravels, moist (1.5
1-1-2	3	"	" – depth (6.5')
51-71	71	"	" – depth (11'); top of rock.
2-1-3	4	M6B	silt – med stiff clayey silt (1.5)
1-1-2	3	"	" (6.5)
3-6-7	13	M6B	clayey silt, trace hematite gra (11.5)
9-9-14	23	"	(16.5)
7-9-11	20	"	clayey silt (21.5)
9-11-11	22	"	" (26.5)
12-10-14	24	"	silty clay (31.5)
16-22-20	44	"	" (36.5)
19-17-24	41	"	" (41.5)
16-27-22	49	"	" (51.5)
2-3-3	6	M7B	clay (1.5)
6-13-12	25	"	" (6.5)
11-12-14	26	"	" (11.5)
3-7-9	16	"	" (16.5)
4-7-9	16	"	" (21.5)
1-2-3	5	M9B	clay (1.5)
5-9-1	10	"	" (6.5)
6-9-11	20	"	" (11.5)
13-17-28	45	"	" (6.5)
6-7-9	16	"	" (21.5)
3-3-3	11	"	" (26.5)
5-8-9	17	"	clay & silt (31.5)
8-12-17	29	"	" (36.5)
10-16-20	36	"	clay (41.5)
3-4-7	11	M10B	silty clay (1.5)
17-21-41	68	"	(6.5)
17-18-68	86	"	(11.5)

DOLOMITE

*RQD	% REC.	BORING LOG
NR	25	FW-2 bdrk, dolomite 45° bedding, oolitic zone
0	70	M4B – limestone depth 20'
70	86	" depth (25')
74	94	" depth (35')
47	64	" depth (45')
50	100	M9B, lst, hard, no bedding (50.5)
15	80	(55.5)
0	50	(60.5)
0	50	(70.5)

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Summary of [illegible] [illegible]

TULLYMAN
PAGE 1

TRASH FILL			CLAY, SILTY CLAY, SAND			
BLOWS	BORING LOG		BLOWS	N	BORING LOG	
			9-26-26	52	FW-1	med. brown silty sand & clay.
			30-27-19	46	FW-2	dk brown clay, trace gravel
			14-21-18	39	"	"

DOLOMITE						
RQD	% REC.	BORING LOG	BLOWS	N	BORING LOG	
			*3-2-3	5	M4B	clay w/ some silt, subangular hematite gravels, moist (1.5)
			1-1-2	3	"	" - depth (6.5')
R	25	FW-2 bdrk, dolomite 45° bedding, oolitic zone	51-71	71	"	" - depth (11'); top of rock.
	70	M4B - limestone depth 20'	2-1-3	4	M6B	silt - med stiff clayey silt (1.5)
			1-1-2	3	"	" (6.5)
70	86	" depth (25')	3-6-7	13	M6B	clayey silt, trace hematite gra (11.5)
14	94	" depth (35')	9-9-14	23	"	(16.5)
			7-9-11	20	"	clayey silt (21.5)
7	64	" depth (45')	9-11-11	22	"	" (26.5)
			12-10-14	24	"	silty clay (31.5)
			16-22-20	44	"	" (36.5)
			19-17-24	41	"	" (41.5)
			16-27-22	49	"	" (51.5)

BLOWS	N	BORING LOG	
2-3-3	6	M7B	clay (1.5)
6-13-12	25	"	" (6.5)
11-12-14	26	"	" (11.5)
3-7-9	16	"	" (16.5)
4-7-9	16	"	" (21.5)

RQD	% REC.	BORING LOG	BLOWS	N	BORING LOG	
0	100	M9B, lst, hard, no bedding (50.5)	1-2-3	5	M9B	clay (1.5)
.5	80	(55.5)	5-9-1	10	"	" (6.5)
0	50	(60.5)	6-9-11	20	"	" (11.5)
1	50	(70.5)	13-17-28	45	"	" (16.5)
			6-7-9	16	"	" (21.5)
			3-3-3	11	"	" (26.5)
			5-8-9	17	"	clay & silt (31.5)
			8-12-17	29	"	" (36.5)
			10-16-20	36	"	clay (41.5)

BLOWS	N	BORING LOG	
3-4-7	11	M10B	silty clay (1.5)
17-21-41	68	"	(6.5)
17-18-68	86	"	(11.5)

ROCK DATA (CONT)

% REC	RQD	BORING / DESCRIPTION
88	50	MIIBLst, hard, thick bdd (41.6)
14	0	MIIB (44.5)
8	0	" (51.5)
50	0	" (55)
7	0	" (62)
100	0	M13B SHALE
98	10	
100	10	

WITHIN LANDFILL LIMIT →

SOIL DATA (CONT)

BLOW COUNT	N	BORING / DESCRIPTION		
1-2-2	4	M13B	clay	(1.5)
4-4-6	10	"	"	(6.5)
4-6-5	11	"	"	(11.5)
5-6-11	17	"	"	(16.5)
4-7-6	13	"	"	(21.5)
5-7-7	14	"	"	(26.5)
6-6-5	11	"	"	(31.5)
8-6-8	14	"	"	(36.5)
5-6-7	13	"	"	(41.5)
3-4-3	7	"	"	(46.5)
11-10-9-60 ?	?	"	"	(52)
10-18-25	42	B-1	trash fill	(2.0)
15-17-19	36	"	"	(7.0)
10-17-22	39	"	"	(12.0)
14-17-19	36	"	"	(17.0)
22-33-27	60	"	silty clay	(22.0)
10-11-17	28	"	"	
11-17-22	39	"	"	
10-11-12	23	"	"	
12-17-17	34	"	"	
14-14-21	35	"	"	
20-20-20	40	"	"	
3-4-4	8	B-2	silty sand	(7.0)
4-4-4	8	"	"	(12.0)
11-12-14	26	"	"	(17.0)
16-16-21	37	"	silty clay	(22.0)
10-12-12	24	"	"	(27)
15-15-15	30	"	"	(32)
14-17-17	34	"	"	(37)
19-21-23	44	"	"	(42)

TOR ⇒ 42.5.

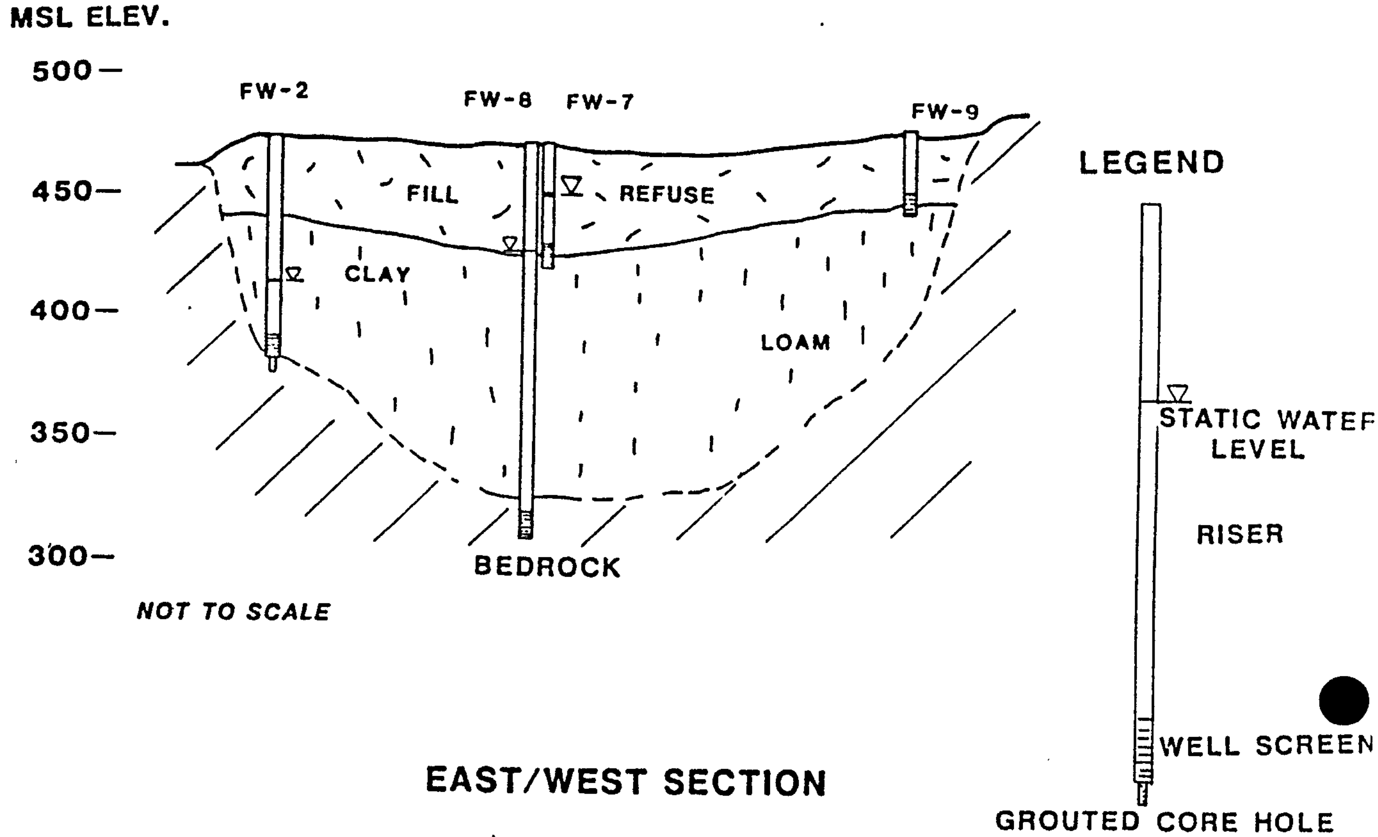
BLOW COUNT	N	BORING / DESCRIPTION		
2-3-6	9	B-4	silty clay	(7)
15-15-17	32	"	"	(12)
19-21-27	48	"	"	(17)
31-33-39	72	"	"	(22)
41-48-53	101	"	"	(27)

30' lst.

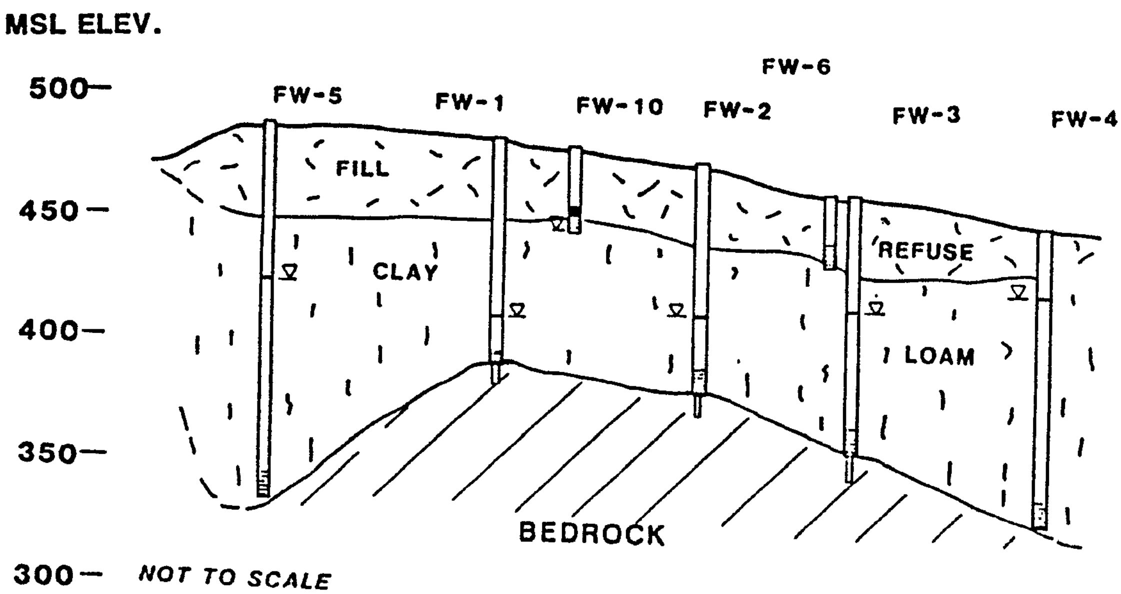
BACKGROUN DATA

FIGURE 4-12

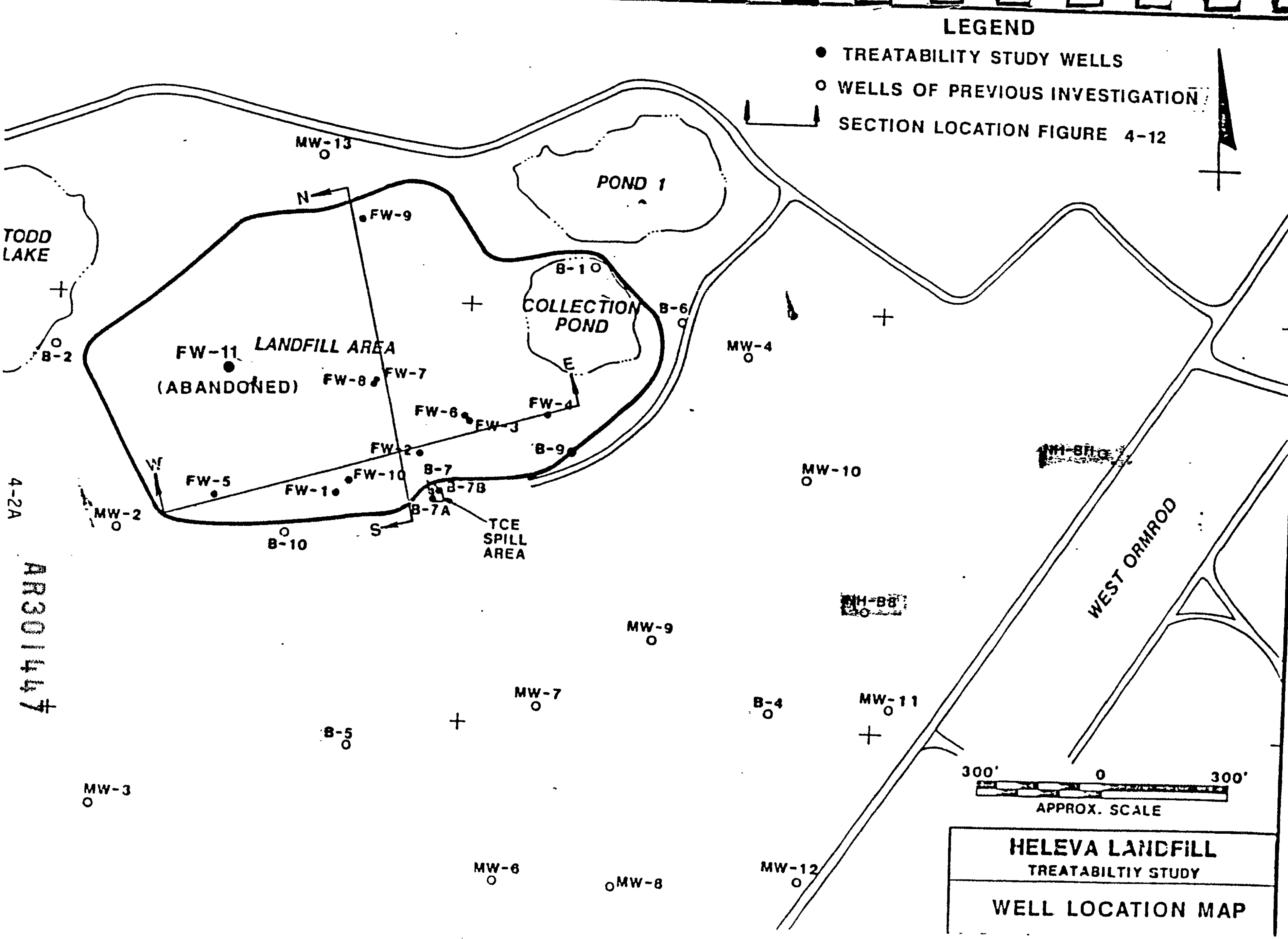
NORTH/SOUTH SECTION



EAST/WEST SECTION



Geologic cross section of the Heleva Landfill showing the refuse thickness and the underlying thick sequence of clay above a variable bedrock surface. Section locations on Figure 1.


LEGEND
TREATABILITY STUDY WELLS
WELLS OF PREVIOUS INVESTIGATION
SECTION LOCATION FIGURE 4-12
POND 1
COLLECTION POND
LANDFILL AREA
FW-11 (ABANDONED)
TODD LAKE
TCE SPILL AREA
WEST ORMROD
MW-13
MW-2
MW-3
MW-4
MW-6
MW-7
MW-8
MW-9
MW-10
MW-11
MW-12
B-1
B-2
B-4
B-5
B-6
B-7
B-7A
B-7B
B-9
B-10
FW-1
FW-2
FW-3
FW-4
FW-5
FW-6
FW-7
FW-8
FW-9
FW-10
N
S
E
W
300' 0 300'
APPROX. SCALE
HELEVA LANDFILL
TREATABILTIY STUDY
WELL LOCATION MAP

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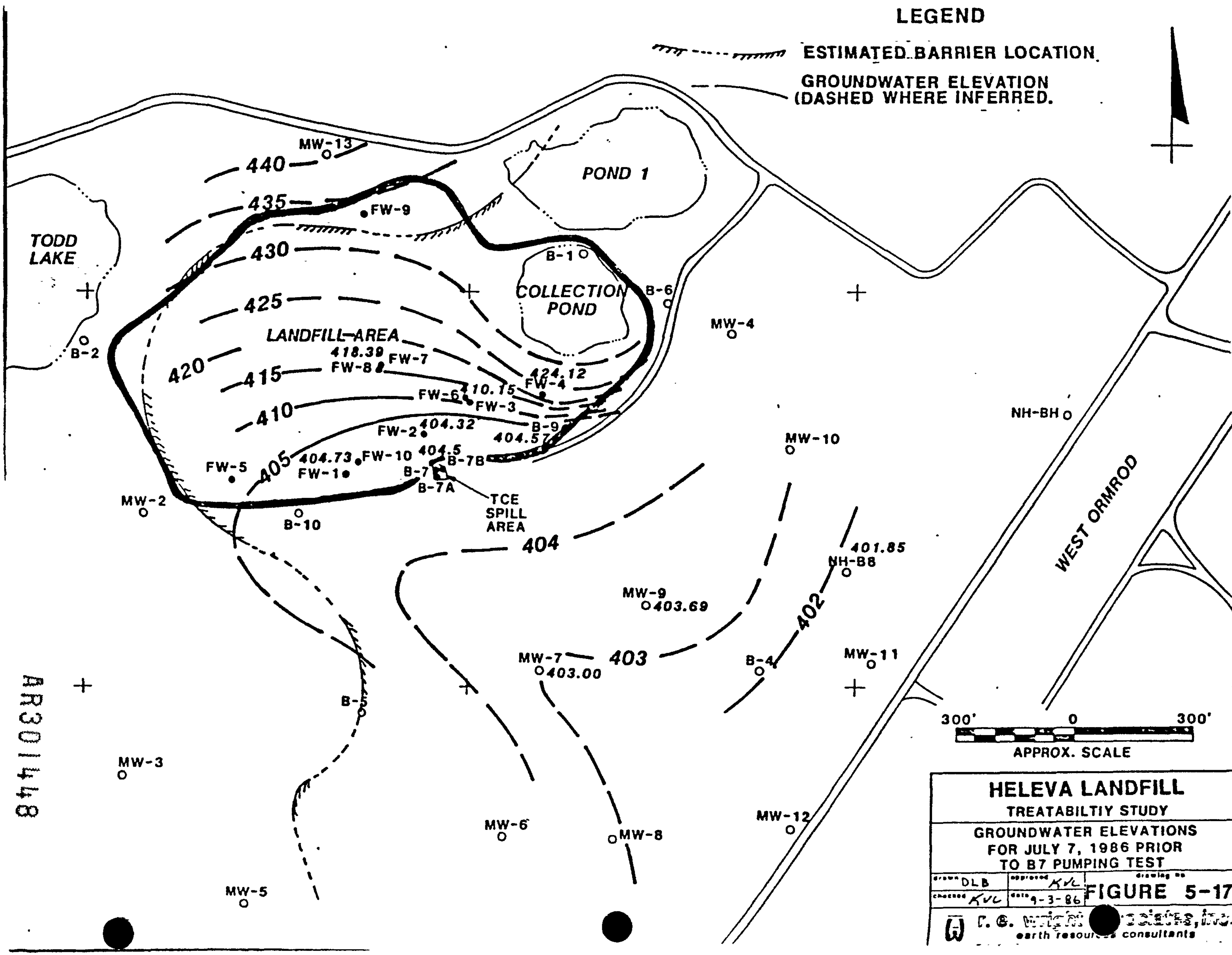

HELEVA LANDFILL	
TREATABILTIY STUDY	
GROUNDWATER ELEVATIONS FOR JULY 7, 1986 PRIOR TO B7 PUMPING TEST	
drawn DLB / approved KVL / checked KVL / date 9-3-86	drawing no. FIGURE 5-17
R. E. Wright Associates, Inc. earth resources consultants	

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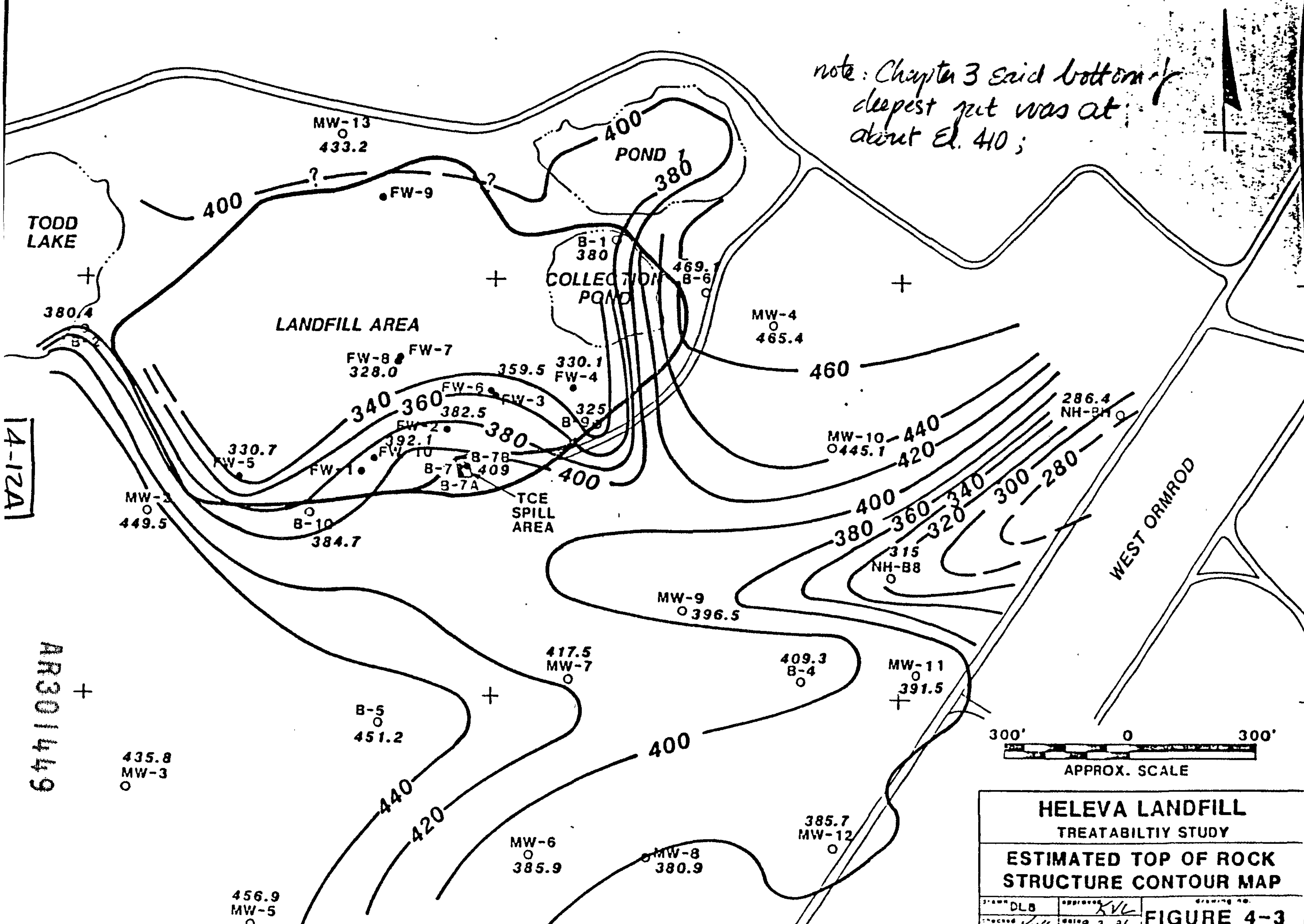

HELEVA LANDFILL

TREATABILTIY STUDY

ESTIMATED TOP OF ROCK STRUCTURE CONTOUR MAP

drawn DLB	approved KVL	FIGURE 4-3
checked KVL	date 9-3-86	

BRIERLEY
& LYMAN
INCORPORATED

NOTES OF MEETING

DATE: October 14, 1987

ATTENDEES:

Colorado Department of Highways: Mr. Brandy Gilmore
Mr. Nelson Chou

Brierley & Lyman, Inc.: Mr. Tracy Lyman

Discussion of CDOH experience with placement of a highway embankment on a closed sanitary landfill in the greater Denver area in Colorado.

Location: I-76 and Sheridan Boulevard.

Site Description:

Sanitary landfill 20 to 30 ft deep. Groundwater levels occur at or close to the bottom of the landfill.

Landfill was a sanitary landfill with municipal and industrial waste products. Drilling revealed that little decomposition of waste had occurred. Paper, rubber tires, belts and hoses, and general trash were uncovered during auger drilling through the trash.

CDOH Construction Sequence:

Placed embankment in two phases. First phase built 24 ft embankment height, waited for settlement. Second phase increased to 40 ft embankment height. Final embankment required was 30 ft, therefore second phase placed 10 ft surcharge.

Observed Settlement:

Phase 1: 32 inches maximum total settlement.

Phase 2: 40 inches maximum total settlement.

Generally the trash fill behaved like a granular soil. Most of the total settlement in Phase and Phase 2 occurred during construction of the embankment. No pore pressure increase was observed within the trash fill. Lateral spreading near the base of the embankment was a maximum of 3 inches.

Table below summarizes observed settlement and time for several points measured during embankment construction.

TABLE 1

CDOH Settlement Observations

Phase 1 Construction

Settlement Point	Total Settlement (in.)	Time	Total Settlement (in.)	Time
1	3	End emb. const.	6	Several mos. after Phase 1 const.
2	20	End emb. const.	21.5	Several mos. after Phase 1 const.
3	32.5	End emb. const.	34	Several mos. after Phase 1 const.

Phase 2

Settlement Point	Total Settlement (in.)	Time	Total Settlement (in.)	Time
1	10	End Phase 2 const.	?	4 mos. after Phase 2 const.
2	28	End Phase 2 const.	?	4 mos. after Phase 2 const.
3	39	End Phase 2 const.	42	4 mos. after Phase 2 const.

REFERENCE MATERIAL UTILIZED

SETTLEMENT OF REFUSE LANDFILLS

By Sheshagiri Kalavar Rao[1] M.ASCE, Lyle K. Moulton[2],
and Roger K. Seals[3] M.ASCE

ABSTRACT

The results of laboratory and field settlement studies of household refuse are presented and analyzed. A possible technique for stabilizing refuse landfills with the use of conventional grouting methods and a fly ash grout is discussed. Comparative results of settlement studies of both stabilized and unstabilized refuse are given. Using approaches similar to those utilized for natural soils, a settlement (rate and magnitude) prediction technique is developed for refuse landfills and used with refuse behavioral parameters (both from the laboratory and field studies) to make settlement predictions for a field loading situation. The predictions are than compared to the measured results and found to be reasonably comparable if parameters from field data are used.

INTRODUCTION

Relatively little is known about the behavior of landfills when subjected to superimposed loads (e.g., buildings, embankments, etc.). Often, when a landfill is encountered, either in the construction of building foundations or highway embankments, rules of thumb have been adopted as guides in making decisions involving the use of these landfills. As a result, there have been failures of structures and embankments built on refuse landfills, leading to the frequent practice of abandoning the landfill site or removing and replacing the unsuitable materials. Such practices are costly and should not be continued if adequate design and construction techniques can be developed. The

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question then is, is it really necessary to abandon these sites or remove and replace these materials? If it is possible to reclaim this land so that it can be used for industrial, commercial and residential development, it will be of great benefit to society. In order to accomplish this, the reclaimed land must have a substantial load bearing capacity with tolerable post-construction settlement potential and acceptable environmental conditions. Hence, an early stabilization of the landfill appears to be the most logical solution to the problem.

Studies conducted by a number of investigators have indicated that an early stabilization of the landfill can be achieved by placing the landfill material at as high an initial density as possible (compaction) (4,5,14,16) or by preloading the site with surcharge for some time prior to construction (22). However, the success of stabilization by preloading depends upon the accuracy of the prediction of the anticipated magnitude and rate of settlement of the landfill. Injection grouting, using other solid waste products like fly ash to fill the voids of sanitary landfills, has been suggested as an alternate early stabilization technique (13,14). In spite of placing the landfill material at a relatively high initial density and/or stabilizing it by grouting, significant post-construction settlements are anticipated under heavy structural loads. Thus, the design and resulting performance of any structure built on a landfill will depend, to a great extent, upon the ability to predict the rate and magnitude of the anticipated settlement.

In recognition of the need to provide early stabilization of landfill material and be able to predict the rate and magnitude of settlement of landfills, the research reported in this paper was undertaken. The experimental investigation included extensive laboratory studies on the properties and behavioral characteristics of grouted and ungrouted refuse and limited field studies of the settlement of loaded refuse (8,13,14). Because of space limitations, only those aspects of the research relative to the settlement of refuse will be presented here.

LABORATORY STUDIES

The refuse mixtures used for the laboratory experiments at WVU were prepared by using paper content as a major variable and holding the relative percentages of other components constant (14). The mixture that was used in the consolidation study was designed to resemble the average composition of typical refuse encountered in the United States and consisted of paper (40%), metal (10%), food wastes (15%), yard wastes (15%), glass (10%), rocks, ash and dust (4%), plastics (3%), cloth (2%) and wood (1%). The top particle size of the refuse was limited to two inches, except for paper, which was limited to six inches. The specimens were prepared by placing refuse in the large consolidometers (2-ft. diameter and 9-in. deep) and compacting statically to obtain a predetermined density. Two sets of specimens were prepared with initial bulk densitites of 400, 500, 600 and 700 pounds per cubic yard (pcy) at 30 percent moisture on a dry weight basis. One set of the specimens was grouted by injecting fly ash grout under pressure. The fly ash grout was mixed in a conventional laboratory mixer, poured into an agitation chamber, and injected into the compacted refuse sample under pressure (14). The maximum grouting pressure ranged from 20 to 30 psi.

Prior to the consolidation tests, both the grouted and ungrouted specimens were subjected to a sequence of initial loading and saturation. Initial loading was provided by the application of concrete disks, each of which resulted in a stress varying from 46 to 50 psf on the surface of the specimen. This stress is equivalent to about 6 in. of soil cover or about 3 ft. of loose refuse. The specimens were then brought to "field capacity" by adding water until the amount of leachate draining from the specimens was equal to the water added. The specimens were sealed by means of a rubber sleeve which connected the first concrete disk to the top of the consolidometer. This allowed commencement of anaerobic decomposition of the refuse. The specimens were then allowed to settle until the rate of settlement of the grouted samples was reduced to approximately 0.001 in. per day. The rate of settlement of the grouted specimens was chosen as the control for loading both grouted and ungrouted samples. Once this rate was established two additional concrete disks were placed on the specimens. Two more disks were placed on the refuse after the leachate was completely drained. The sequence of load increments was designed to simulate a realistic situation; where refuse in a landfill, after being in place for some time, was subjected to additional loads. The addition of water was designed to simulate the effects of rainfall and to create optimum conditions (13) to promote biological decomposition.

Following completion of the initial loading sequence, all but the first of the concrete disks were removed from each specimen and the rebound was recorded. At the end of the rebound period, the specimen was subjected to load increments similar to those adopted in conventional consolidation tests. An automatically-controlled hydraulic ram system was utilized for the load applications. Each increment of load was sustained until the rate of settlement was reduced to 0.001 in. in approximately 2 hours.

Settlement data from the initial loading and consolidation tests were used to prepare graphs showing the variation in relative specimen height as a function of the log of the applied pressure. In these graphs, the variation in the height of the specimen, H, corresponding to the particular pressure, σ, was computed by comparing the sample thickness at the end of that load increment with the initial thickness of the specimen, H_i, before any loading took place. A settlement coefficient, C_s, somewhat similar to the compression index, C_c, was determined by computing the average slope of the pressure-relative height graph between two selected pressures using the following expression:

$$C_s = \frac{\frac{H_o}{H_i} - \frac{H_1}{H_i}}{\log\left(\frac{\sigma_1}{\sigma_o}\right)} = \frac{\frac{\Delta H}{H_i}}{\log\left(\frac{\sigma_1}{\sigma_o}\right)} \quad \text{.............................} \quad (1)$$

where H_o and H_1 are the specimen heights corresponding to the selected pressures σ_o and σ_1, respectively (see Figure 9b).

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Time settlement data gathered from each load increment were used to plot percent compression versus log time graphs. Percent compression was computed on the basis of the thickness of the specimens prior to the application of each load increment. For the ungrouted samples, the coefficient of consolidation, c_v, was determined according to Taylor's square root of time fitting method, and the primary compression ratio, r, was calculated as the ratio of the theoretical primary consolidation to the total compression. The coefficients of secondary compression, C_α, were determined by computing the slope of the log time-percent compression curves in the apparent secondary compression range.

Magnitude of Settlement

The pressure-relative height relationships for various initial density ungrouted specimens are shown in Figure 1. The rebound that took place as a result of unloading prior to the laboratory consolidation tests can be seen in this figure. Although it is not shown in Figure 1, evidence of swelling was also observed when the compaction pressure exerted, to obtain a predetermined density during the sample preparation, was released. The magnitude of this swelling was proportional to the initial density of the specimen, thus indicating that, for a given initial density, there is a pressure required to prevent the sample from swelling. Although there are certain limitations, this implies that refuse in a fill will not settle under its own weight until the combined weight of the overlying material exceeds the swell pressure of the refuse. Figure 1 also shows the progressive reduction in settlement, for a given pressure intensity, with increasing initial bulk density. It is also evident that this effect is less pronounced at higher pressures.

Although the relationship between settlement and the log of pressure does not exhibit marked curvature, it is not perfectly linear. Perhaps, this effect occurred because the load increment ratio was not held constant. After unloading, the amount of settlement that took place during reloading was small until the pressure intensity was increased to a value significantly greater than the previous maximum pressure. This is similar to the behavior exhibited by preconsolidated soils (19).

Figure 1 also shows the pressure-relative height relationship from the laboratory consolidation tests on grouted samples. Like the ungrouted specimens, the grouted specimens also show a progressive reduction in settlement for a given pressure intensity with increasing initial density of the refuse. The non-linear relationship between settlement and log pressure appears to persist up to relatively large pressure intensities, thus exhibiting the effect of precompression. The increase in density, resulting from compaction of the refuse during pressure grouting, is considered to be an important factor controlling the behavior of the grouted refuse. The density of the refuse following grouting is defined as the weight of the compacted refuse divided by the difference in the original volume of the specimen and the volume of the grout injected. Grouting experiments have indicated (14) that this increase in density is inversely proportional to the paper content in the refuse, the initial density of the refuse, and the volume of the refuse being grouted. The bulk densities of the refuse

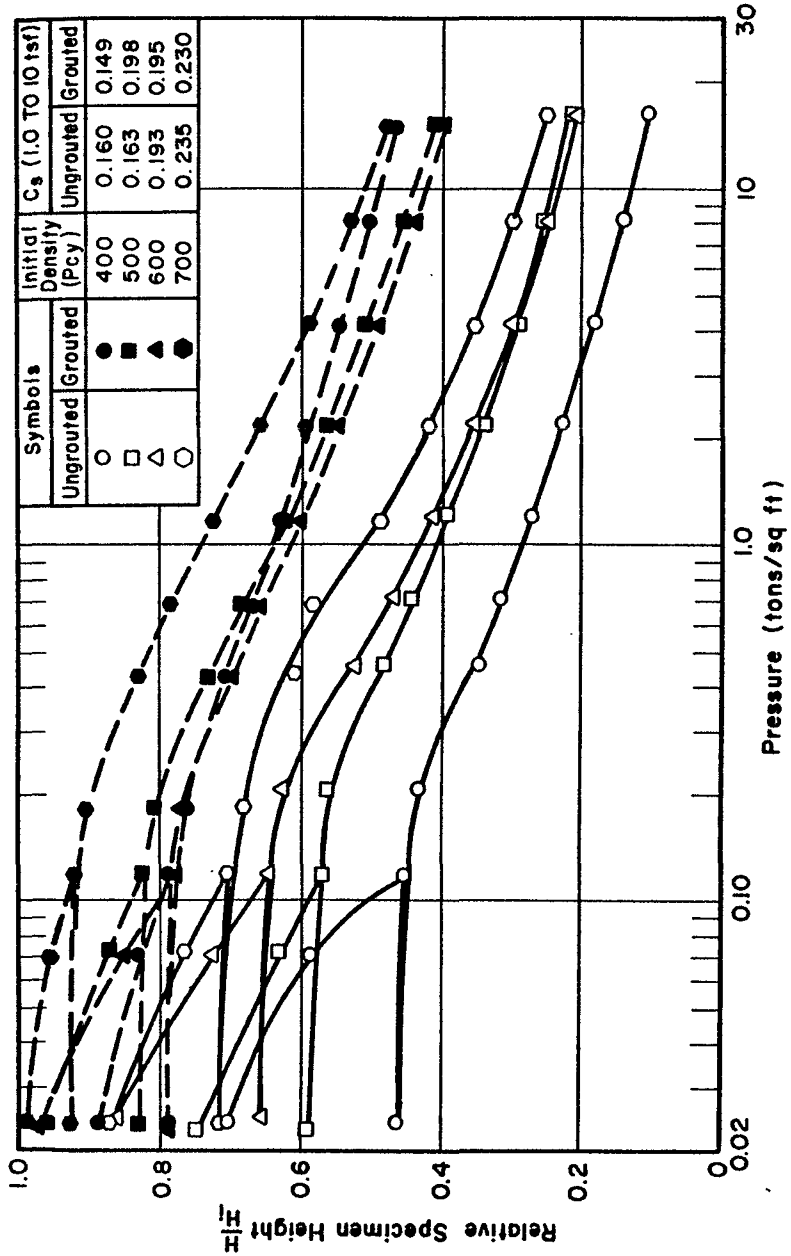

FIG. 1.—Pressure-Settlement Relationships for Ungrouted and Grouted Specimens

after grouting were found to have increased to 794, 737, 859 and 1072 pcy from initial bulk densities of 400, 500, 600 and 700 pcy, respectively.

The coefficient of settlement, C_s, for both grouted and ungrouted specimens (Figure 1) was found to increase consistently with the increase in the initial density of the sample. However, the pressure range over which this C_s value is determined appears to be significant. This is evidenced by a comparison of the magnitude of settlement between zero and 1.0 tsf and 1.0 and 10.0 tsf in Figure 1. At low pressure intensities, higher initial density specimens will experience less settlement than the lower initial density specimens. However, the higher initial density specimens experience greater settlement after the pressure intensity has exceeded a certain critical value. Perhaps, the reason for this behavior is the effect of compaction on compression. The resistance to compression is proportional to the initial density of the specimen; hence, the pressure required to overcome this resistance is also a function of the initial density. This is similar to the plastic structural resistance to compression exhibited by quasi-plastic material that was discussed by Taylor (17).

A comparison of C_s values for ungrouted and grouted specimens does not readily show the advantage of grouting. However, a study of Figure 1 clearly shows the advantage of grouting in reducing settlement. It can be seen from this figure that grouting could reduce the overall settlement by as much as 50 percent. It should be recognized, however, that this beneficial effect is tied directly to the increase in density caused by grouting. Thus, if grout injection does not result in a significant densification of the refuse, grouting may not produce such dramatic results.

Rate of Settlement

Figures 2 and 3 show typical time-compression graphs from load increments applied during the consolidation test on the 600 pcy ungrouted and grouted specimens. The rate of compression was found to be dependent upon the pressure-increment ratio, the intensity of pressure, and the duration over which the previous load was sustained on the specimen. For clarity, the time-compression curves for pressures of 8.183 and 16.183 tsf have been omitted from Figure 3, because they fall almost directly over the curve for 4.183 tsf. An almost linear relationship between log time and percent compression in the secondary compression range was observed for both grouted and ungrouted specimens when the pressure-increment ratio was close to one. It is interesting to note that the time rate of compression curves shown in Figures 2 and 3 resemble some of those described by Barden and Berry (2) for peat.

It has been pointed out (9) that, for time-compression curves shaped such as these, it is not meaningful to calculate the coefficient of consolidation using curve fitting procedures based on the Terzaghi primary consolidation theory and the log-time fitting method. This observation would lead to the belief that the Terzaghi theory alone cannot be used to predict the time rate of settlement of refuse. How-

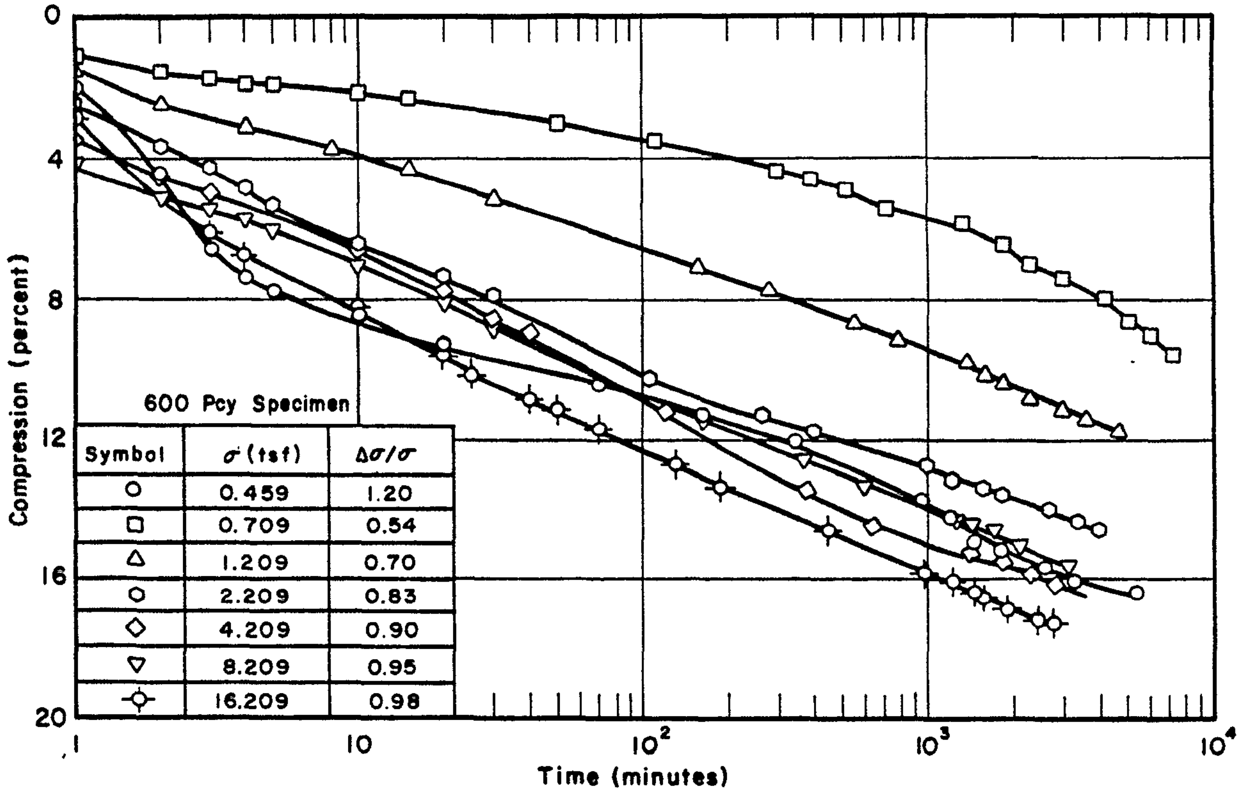

FIG. 2.—Typical Log Time – Percent Compression Curves For Ungrouted Specimen

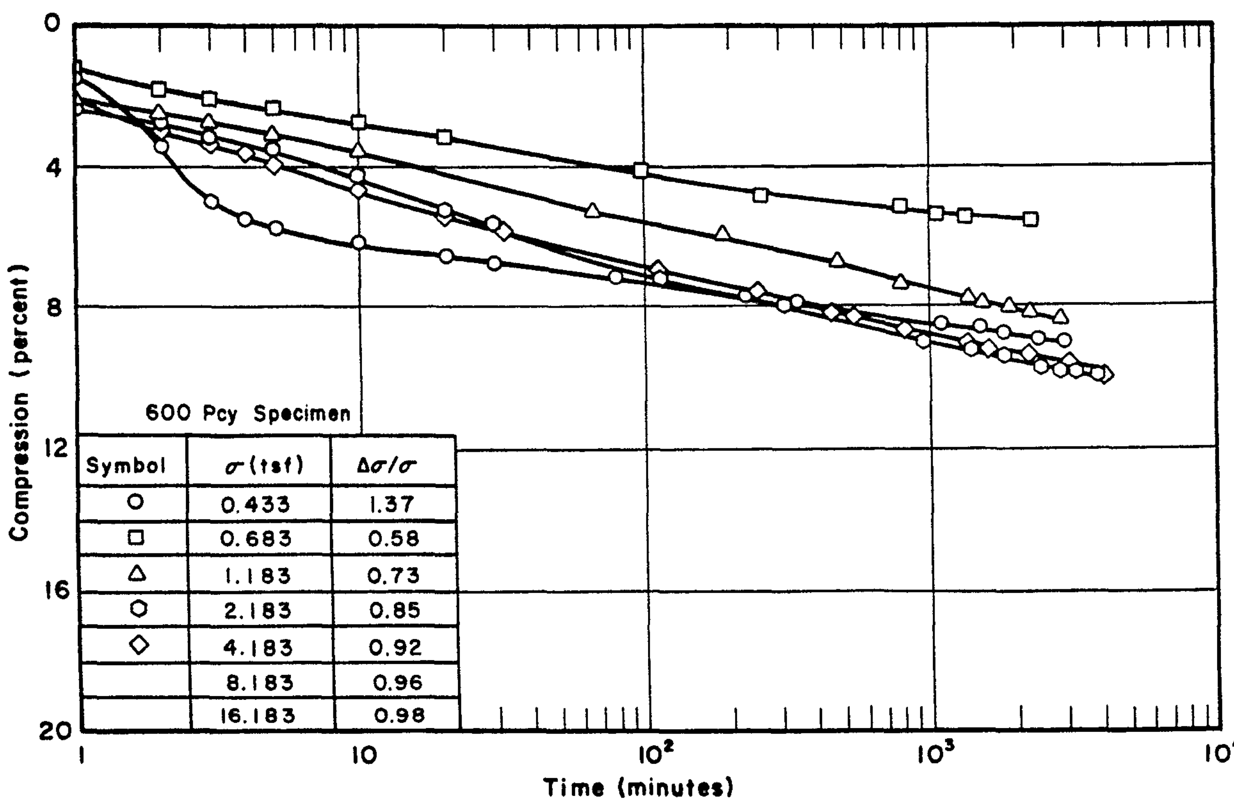

FIG. 3.—Typical Log Time – Percent Compression Curves For Grouted Specimen

ever, it is informative to compare the calculated values of c_v and r, determined by Taylor's square root of time fitting method, for the various tests on ungrouted specimens. These data are presented in Figure 4. Although the data are scattered, the values of c_v generally tend to decrease with increasing levels of stress, and there is some indication that the value of c_v tends to increase with increasing initial density. The variation in the values of r is generally less pronounced than that of c_v values at stresses over 1.0 tsf. The r values generally tend to increase somewhat with increasing levels of stress. As might have been anticipated, the application of a high load-increment ratio at relatively low stress tended to produce relatively high primary compression ratios. Although the highest density specimen produced the highest r values, there does not appear to be a consistent, well-defined variation of r with initial density.

The values of the coefficient of secondary compression, C_α, are also presented in Figure 4. It can be seen that, in general, there is remarkably little variation in C_α with pressure and initial density. However, the lowest values of C_α did correspond to the lowest load-increment ratio, and there was a general increase in C_α with pressure for the 400 pcy specimen. On the average, these C_α values indicate rates of secondary compression that are slightly higher than those reported by Sowers (16) for "conditions unfavorable to decomposition" and substantially lower than those for "conditions favorable to decomposition." It is felt that the relatively brief duration of the loading period in the laboratory was such that the effects of biological decomposition did not significantly influence the rate of secondary compression. Thus, one might be led to expect that higher values of C_α might be encountered under field conditions. However, Zoino (22) reported values of C_α for field conditions that were generally lower than those observed in the laboratory.

Although the lowest density (highest void ratio) ungrouted specimen produced the highest values of C_α, the data were not sufficiently definitive to positively confirm Sowers' (16) suggestion that higher initial void ratios result in higher rates of secondary compression. However, the rate of secondary compression was generally lower for those specimens whose density was increased by grouting (compare Figure 2 and 3).

FIELD STUDIES

The first phase of the field studies involved the construction of two experimental cells (10 ft square and 5 ft deep) and the development of suitable techniques to collect data on settlement and environmental factors. The cells were filled with household refuse and covered with approximately 21 inches of soil. The initial bulk densities of the refuse fills were 347 pcy (Cell No. 1) and 242 pcy (Cell No. 2). The cell with the lower initial density (Cell No. 2) was grouted by injecting a fly ash slurry under pressure. A total of 2150 pounds of fly ash was injected. The average water content of the grout was found to be 103 percent. Although a maximum grouting pressure of 30 psi was reached at times, a pressure of 10 psi was maintained over a large portion of the grouting operation. Data were collected pertaining to

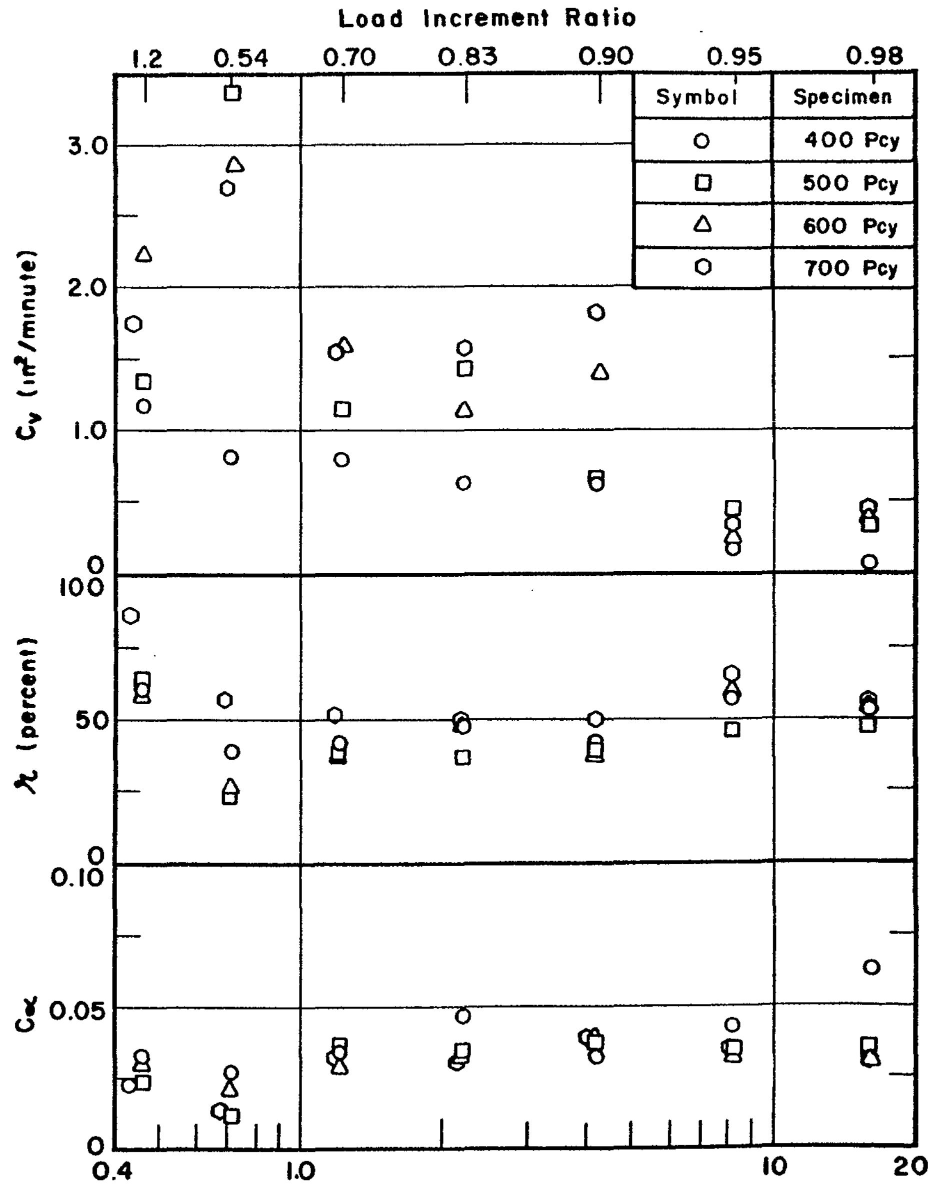

FIG. 4.—Pressure Versus C_V, r, and C_α Relationship for Ungrouted Specimen

settlements, air temperatures, temperatures within the cells, gas generation, rainfall, and leachate characteristics (8,13,14). The placement of the soil cover resulted in immediate settlements of 0.590 feet and 0.834 feet for Cells No. 1 and No. 2, respectively. Additional immediate settlement was induced in Cell No. 2 by the grouting operation, because of the increased compressibility of the paper in the refuse as its water content was increased. A graphical representation of the subsequent time settlement data is presented in Figure 5. In order to illustrate the relative effect of the grouting, the settlements plotted in Figure 5 are those in excess of the immediate settlements and that caused by grouting.

Figure 5 shows that the grouted cell settled much faster than the ungrouted cell for some time after grouting. As noted above, the process of grouting supplied additional water to the refuse, making it more compressible. However, after an initial period, the rate of settlement in the grouted cell showed a gradual decrease whereas the rate of settlement in the ungrouted cell showed an increase. The magnitude of settlement of the small grouted experimental cell, at the end of nearly 3 years, was found to be significantly less than that of the ungrouted cell. Seasonal rainfall was found to increase the rate of settlement, which is consistent with the observations made by Brunner and Keller (3). Higher summer temperatures were also found to influence the rate of settlement. The reduction in the settlement rate shown in Figure 5 between about 200 and 300 days coincided with the coldest and driest months of the year and the greatly increased settlement rate after about 350 days coincided with the hottest and wettest months of the year. These factors (i.e., high rainfall and warm temperatures) are known to provide optimal conditions for promoting bacteriological and chemical decomposition (13). Thus, these results confirm those of other investigators (6,12,16) who have found that those environmental factors which control the process of biological decomposition can play an important role in controlling the settlement of refuse landfills.

The settlement data for the ungrouted cell are shown as a function of the log of time in Figure 6. If the abberrations, resulting from variations in environmental factors, are neglected (dashed line in Figure 6), then the settlement log-time curve is concave downward. This does not agree with the results obtained in the laboratory studies, where the secondary compression curves were essentially linear. The curve is typical of what might be expected for a soil subjected to a low load-increment ratio (9,10,11,19). However, in this instance, the average load increment ratio was about 5.6.

The second phase of the field studies involved two large scale test sections (nearly 40 ft square and 18 ft deep) which were installed at the Morgantown, West Virginia, municipal landfill and instrumented to monitor settlement. One of the test sections was grouted by injecting nearly 37 tons of fly ash at approximately 100 percent water content. The grout was injected without the application of any pressure and moved freely under gravity. The size of the voids in the refuse in the two field demonstrations was much larger than in the laboratory specimens. Although this led to large grout takes, it did not result

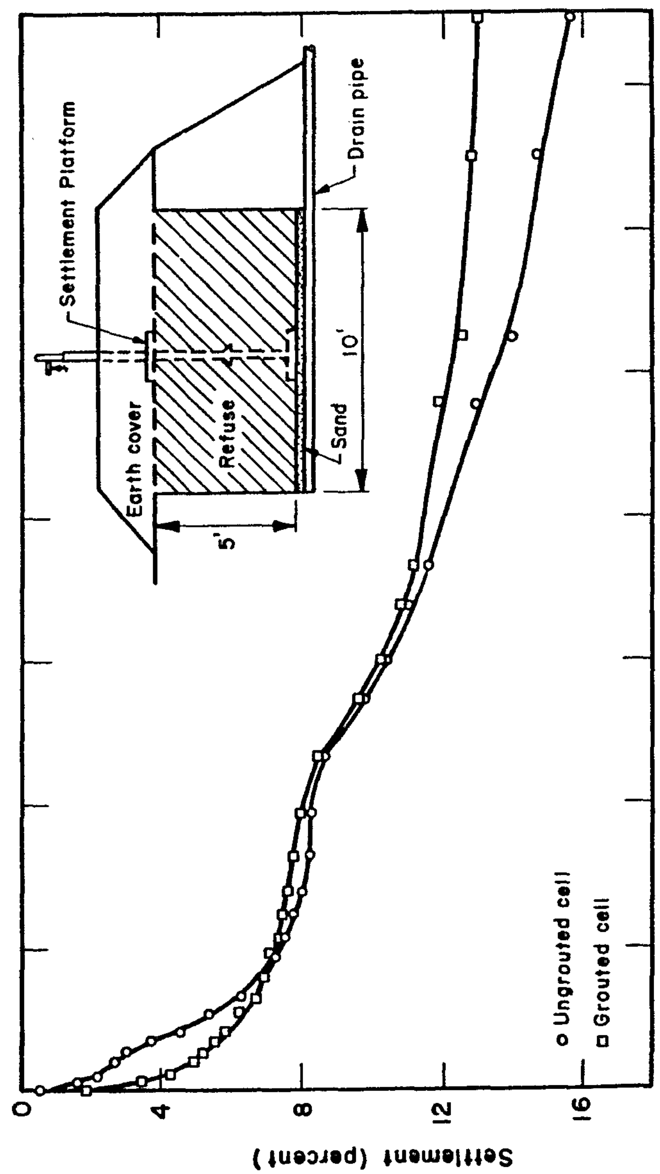

FIG. 5.—Settlement in Excess of Initial Settlement Versus Time for Experimental Cells

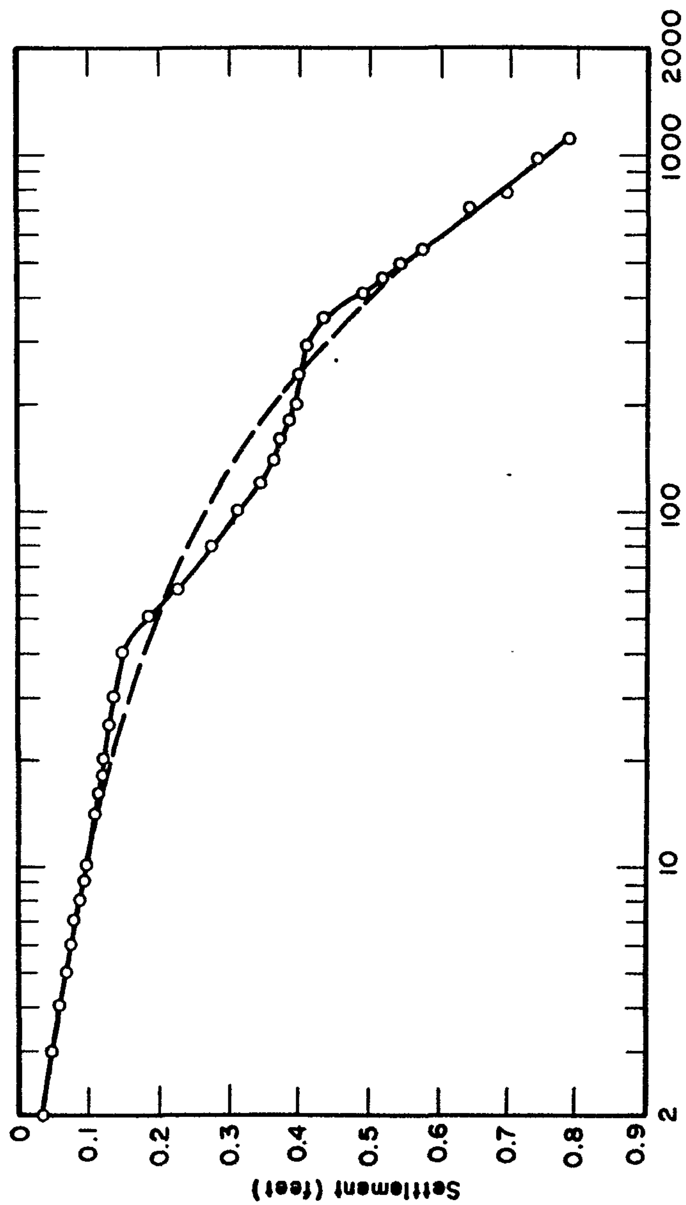

FIG. 6.–Log Time–Settlement Data for Small Ungrouted Experimental Cell

in sufficient confinement to permit the buildup of significant pressures. Failure to build up higher grouting pressures results in a loss of effectiveness in compacting the refuse during grouting.

The behavior of these test sections was similar to that of the smaller test cells, in that the rate of settlement of the grouted section decreased to one half of the rate of settlement of the ungrouted section at the end of 2 years, thus indicating faster stabilization as a result of grouting. However, both the magnitude and rate of the observed settlement were lower than might have been expected on the basis of the laboratory studies and experience with the smaller test cells.

The third phase of the field study was also carried out at the Morgantown, West Virginia, municipal landfill. A section of the landfill where the refuse had already been in place for many years was subjected to loading, and the settlement data were collected by means of suitable instrumentation. The load consisted of fly ash, spread in the form of an embankment, covering a rectangular area of approximately 50 ft by 90 ft. The intensity of the load at the surface of the refuse fill was estimated to be 1000 psf. The refuse was approximately 10 feet thick. The time-settlement data obtained from three locations beneath the fill are shown in Figure 7. The figure shows that at the midpoint of the loaded area, where the average stress in the refuse is approximately twice as much as that on either end, both the rate and magnitude of the settlement are substantially greater than that near the ends of the fill. Although it could not be determined exactly how many years the refuse had been in place prior to loading, it is reasonably certain that the amount of continuing settlement, resulting from biological decomposition, would be minor compared to that induced by the applied load. This is in contrast to the situation for the small test cells, where environmental factors might have been expected to exert a significant influence on the settlement behavior.

The settlement data shown in Figure 7 are replotted as a function of the log of time in Figure 8. Again, the resulting settlement curves are concave downward. This behavior is very much the same as that experienced in the small test cells. In this instance, the average load-increment ratio varied from about 4.0 for the fill beneath settlement platforms No. 1 and 3 to about 8.0 for the fill beneath settlement platform No. 2. There is presently no explanation for this type of log time-settlement behavior, and this suggests that much more laboratory and field research will be required before the compression characteristics of refuse can be adequately defined.

SETTLEMENT PREDICTION

The prediction of the magnitude and rate of settlement of refuse fills, either under their own weight or external loading, is presently very difficult, because of the large deformations involved and the scarcity of reliable data upon which to base settlement theories. The

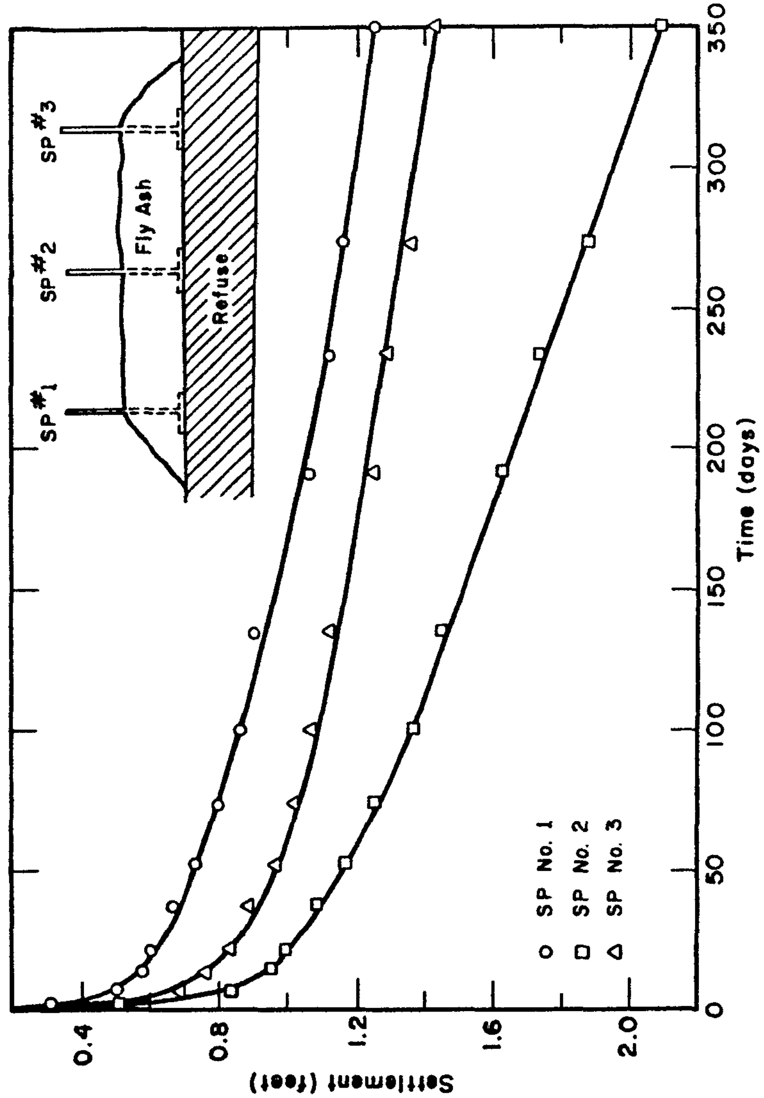

FIG. 7.– Time-Settlement Data for Loaded Test Section at Morgantown Municipal Landfill

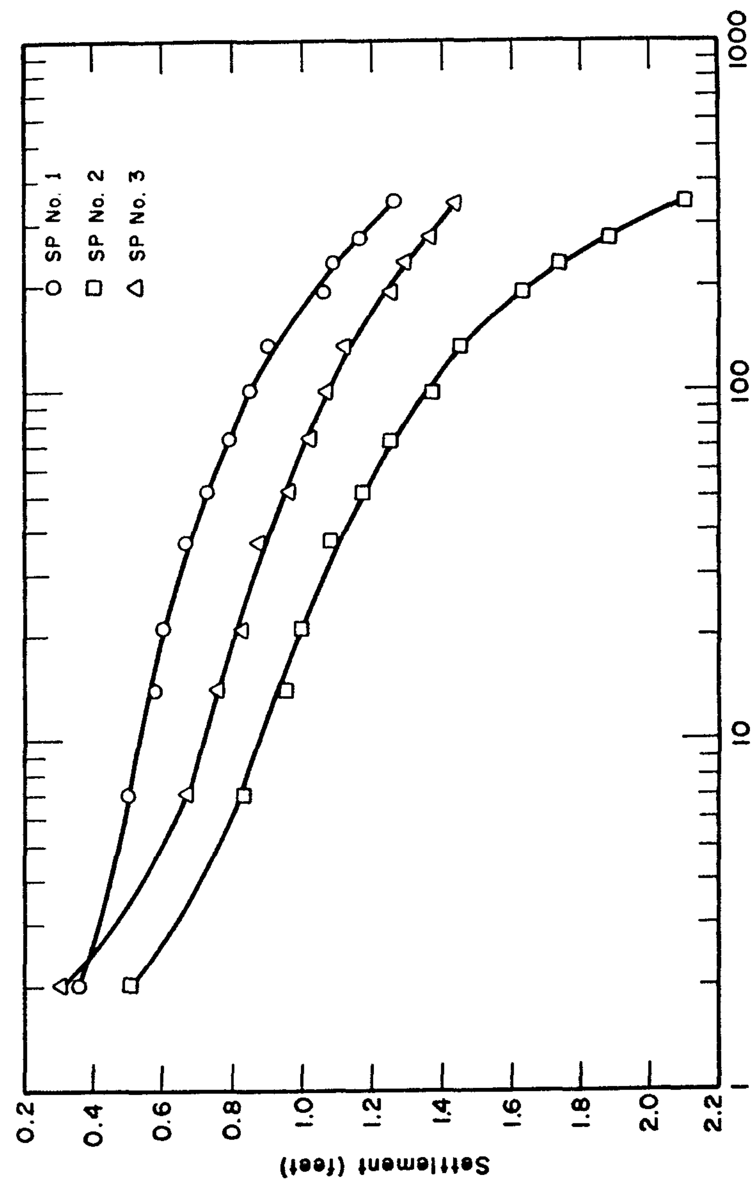

FIG. 8.– Log Time – Settlement Data for Loaded Test Section at Morgantown Municipal Landfill

former problem can be treated through appropriate consideration of the factors involved. However, the latter problem can only be overcome through continued laboratory and field research, including careful long term settlement observations. Some progress along these lines has been made in recent years (4,5,6,12,15,16,20,22), but much more needs to be done before appropriate theories can be formulated and validated.

Magnitude of Settlement

The void ratio-pressure diagram, which has been commonly used in conventional predictions of the settlement of soils, cannot be used for predicting the settlement of refuse, simply because we have no way of computing or reliably predicting the initial void ratio of the refuse. Furthermore, the large strains involved preclude the development and use of a conventional stress-strain diagram for refuse. However, plots of relative layer thickness (H/H_i) versus the applied stress, such as presented in Figure 1 and 9, can serve as useful guides for settlement prediction.

Consider the situation shown in Figure 9a. If laboratory and/or field data permit the construction of a characteristic curve of this type, then the settlement of any representative layer of refuse can be estimated using the following expression:

$$S = H_o \frac{\frac{\Delta H}{H_i}}{\frac{H_o}{H_i}} \qquad \text{.......... (2)}$$

where S is the settlement; H_o is the existing thickness of the refuse layer under consideration; H_o/H_i is the relative height, corresponding to the existing overburden pressure, σ_o; and $\Delta H/H_i$ is the change in relative height resulting from the application of an increment of stress, $\Delta\sigma$. As long as the relative height-pressure curve is valid for the particular refuse under consideration, it is not necessary to know the initial or original (compacted) height of the material, H_i. In this respect, this method is superior to that originally proposed by Råo (14).

If a reasonably representative portion of the relative height-log pressure relationship can be represented by a straight line, as shown in Figure 9b, then the settlement can be conveniently calculated using the expression:

$$S = H_o \frac{C_s}{(H_o/H_i)} \log \frac{\sigma_o + \Delta\sigma}{\sigma_o} \qquad \text{.......... (3)}$$

Obviously, the entire relative height-log pressure relationship cannot be represented by a straight line, particularly at higher pressures, where the curve must ultimately become asymptotic to the horizontal (dashed portion of the curve in Figure 9b).

In order to test this general approach, an attempt was made to empirically normalize the data of Figure 1 for the ungrouted specimens

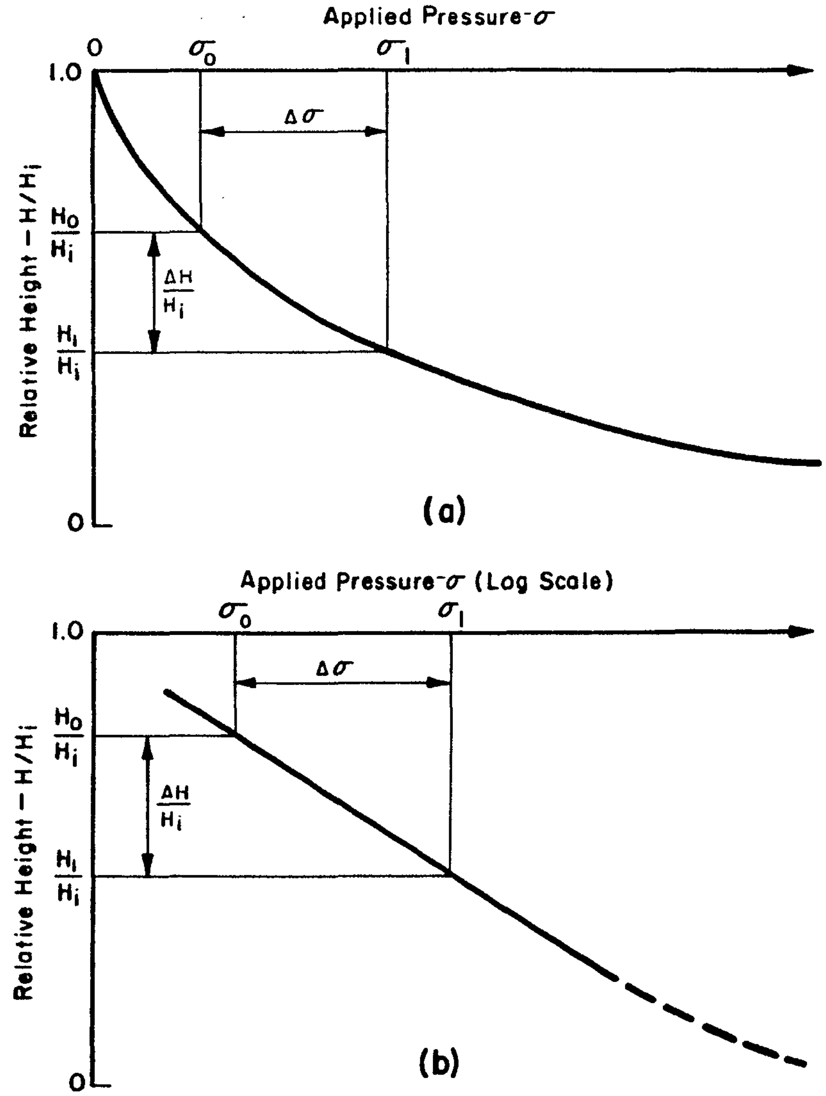

FIG. 9.— Relative Height As a Function of (a) the Applied Pressure, and (b) the Log of the applied Pressure

in terms of the initial dry density of the refuse, γ_d. The result is shown in Figure 10. It can be seen that the data can be reasonably approximated by a straight line up to a stress of about 3 tons/sq.ft.

For comparative purposes, the linear relationship shown in Figure 10 was used with Equation 3 to estimate the settlements in the small ungrouted test cell and beneath the embankment load at the Morgantown municipal landfill. The initial dry density of the refuse at the Morgantown Municipal Landfill was estimated, based on a knowledge of placement and compaction procedures. The results of these computations are shown in Table 1. It can be seen that the estimated settlements, based upon laboratory data, are not unreasonable. The most difficult part of this approach is estimating the dry density at which the refuse was initially placed and the present overburden pressure, σ_o. Hopefully, additional research will improve the reliability of such estimates.

Table 1 - Comparison of Measured and Estimated Settlements

Location	Estimated Ultimate Settlement (Feet)	Measured Settlement (Feet) Magnitude	Elapsed Time (Days)
Small Test Cell	1.38	1.32	1117
Morg. Landfill			
SP-1	1.82	1.26	350
SP-2	2.54	2.10	350
SP-3	1.96	1.43	350

<u>Rate of Settlement</u>

In order to obtain some insight into the problem of the prediction of the rate of settlement of loaded refuse, a number of prediction techniques were considered. These included Terzaghi's theory (18), an extension of Terzaghi's theory to account for secondary compression (1), Gibson and Lo's theory (7) and Zimmerman's theory (21). Except for Zimmerman's model (21), which was specifically designed to represent the time-settlement behavior of milled municipal refuse, these theories were developed for the prediction of the time-settlement behavior of soils. For comparison purposes, these theories were used to predict the time-settlement behavior of the loaded refuse at the Morgantown municipal landfill. In one case, the time settlement predictions were based on parameters derived from the laboratory studies, and in the second case the predictions were based on parameters derived from the field data. Typical results for the two cases are shown in Figures 11 and 12. Complete details of these analyses and the results were presented by Rao (14).

In general, these comparisons show that the predictions based on laboratory test results are not good. On the other hand, the time-settlement predictions, based on field data, are remarkably good for both Gibson and Lo's theory and the extension of Terzaghi's theory. This seems to imply that reliable refuse properties and behavioral

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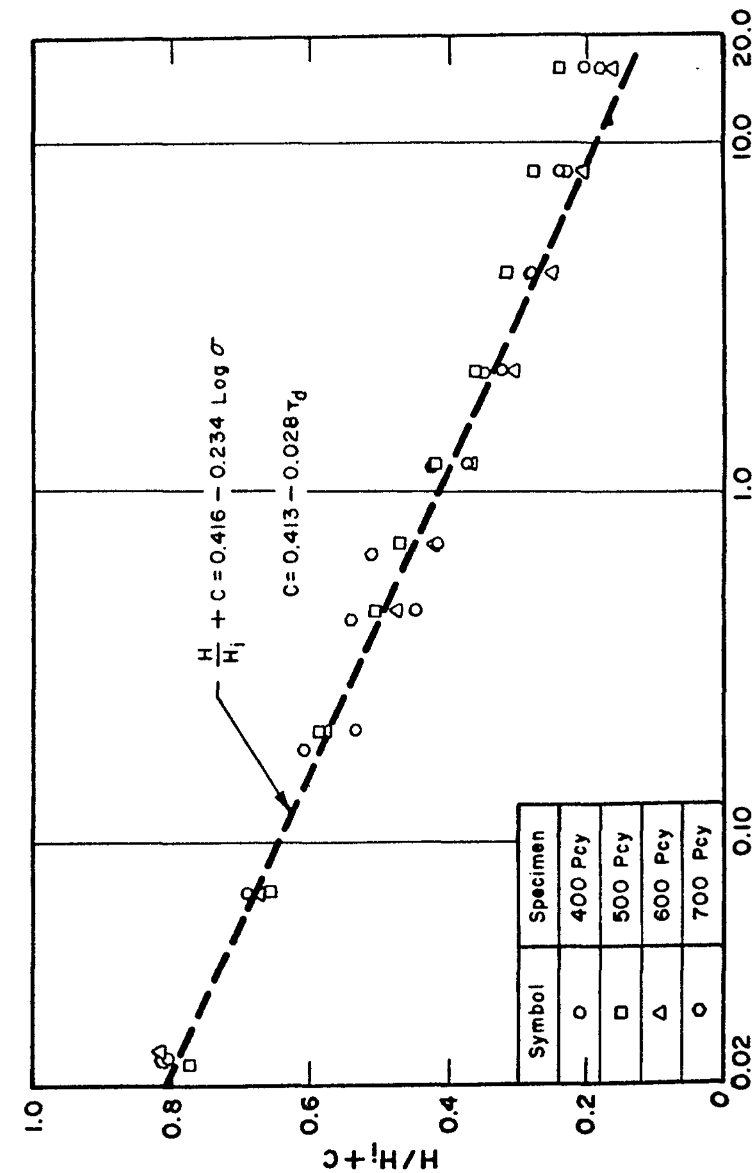

FIG. 10. — Normalized Pressure—Settlement Relationships for Ungrouted Specimens

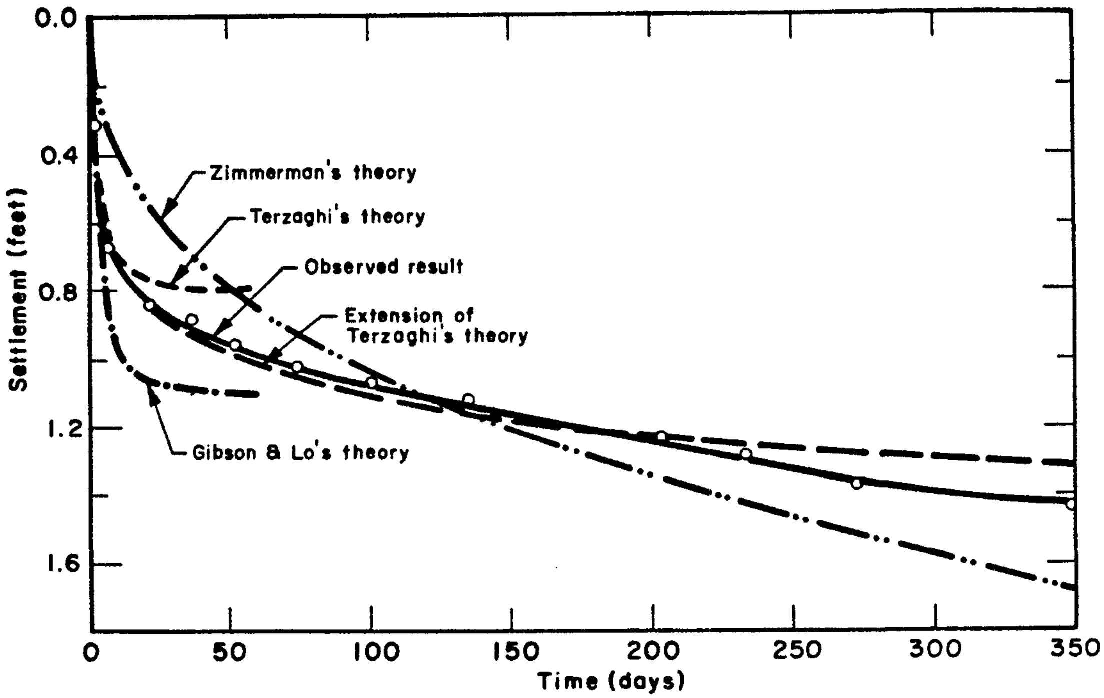

FIG. 11.—Prediction of Settlement of Loaded Test Section (SP No. 3) Based on Parameters Obtained from Laboratory Data

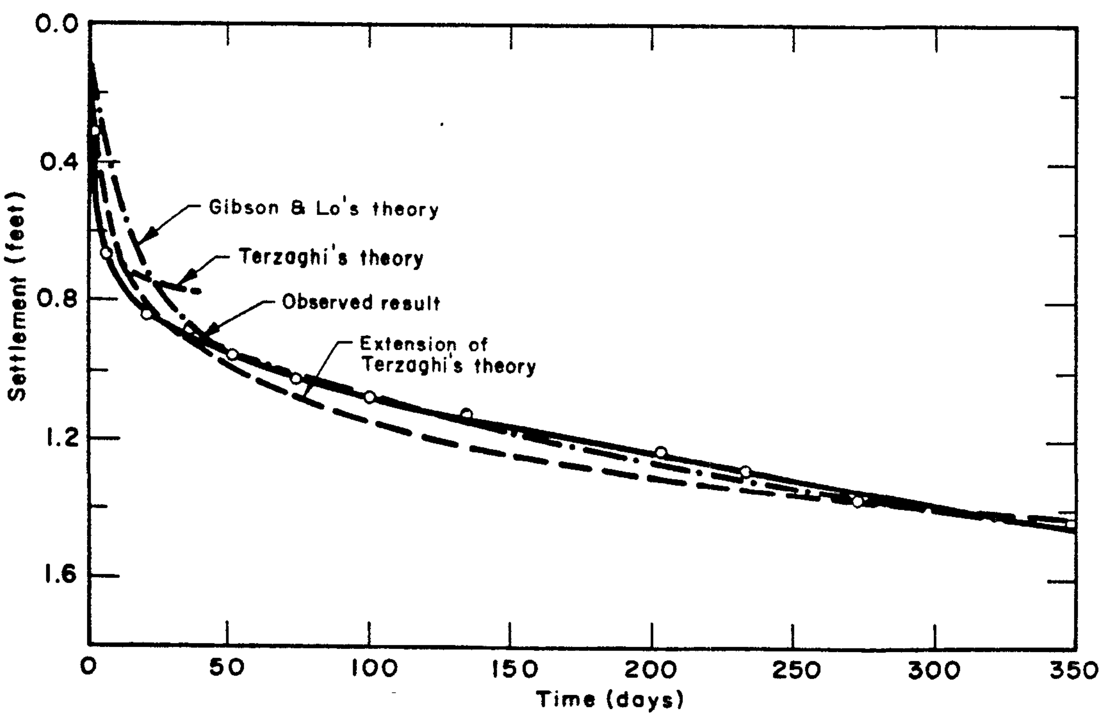

FIG. 12.—Prediction of Settlement of Loaded Test Section (SP No. 3) Based on Parameters Obtained from Field Data

characteristics are more important than the prediction method as long as the method properly accounts for primary and secondary compression. Again, this indicates the need for additional research that is specifically designed to evaluate time settlement behavior.

CONCLUSIONS

Laboratory studies have indicated that the settlement characteristics of household refuse are dependent upon such factors as stress history, initial density, load increment ratio, and magnitude of pressure. Field studies indicated the importance of environmental factors (rainfall and temperature), which effect biological decomposition, on the rate and magnitude of settlement.

Both laboratory and field studies of grout stabilization of refuse suggest that favorable results can be obtained if adequate confinement is present so that compaction of the refuse will occur during grouting. However, development of the beneficial effects of grouting requires time. Additional field studies are necessary to develop grouting techniques that will produce favorable conditions for compaction.

Reasonable predictions of the magnitude and rate of settlement of refuse landfills can be made using the methods and data presented in the paper. However, the settlement parameters should be obtained from field rather than laboratory data. To develop better prediction methods, as well as establish more reliable refuse settlement parameters, further field and laboratory studies are warranted.

ACKNOWLEDGEMENTS

The authors are grateful to the many organizations and individuals who have given technical, financial, and/or moral support to the work described herein. The continued encouragement and support of Allan Babcock, Monongahela Power Company; Ronald Morrison, American Electric Power Service Corporation; Donald Gilmore, Morgantown Energy Research Center, ERDA; John Faber, National Ash Association; William Morton, Highway Materials, Inc.; the U.S. Environmental Protection Agency; the City of Morgantown, WV; and the Regional Research Institute and the Department of Civil Engineering of West Virginia University, are particularly appreciated.

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SETTLEMENT OF WASTE DISPOSAL FILLS

TASSEMENT DES REMBLAIS DES TERRES
ОСАДКИ НАСЫПЕЙ ИЗ ХЛАМОВ

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SYNOPSIS. Waste disposal fills are becoming the major mechanism for disposing of materials unsuitable for other purposes, including garbage, household refuse, construction debris and industrial wastes. Settlement of such organic-mineral complexes occurs through four mechanisms: (1) consolidation or void ratio reduction, (2) biochemical decomposition, (3) physico-chemical, and (4) ravelling of soil into large voids. The author's studies show that settlement is similar to that of peats: large initial consolidation, little or no hydrodynamic and substantial secondary compression. The compression index C_c is approximately proportional to the initial void ratio and increases with the organic content of the fill.

Decomposition and disintegration are reflected in the rate of secondary compression. For aerobic moist conditions above the water table the secondary is three times as great as for anerobic below a stagnant water table. The rate of ravelling cannot be expressed analytically at present. Settlement can be reduced by compaction, preloading, and controlling the environmental factors favorable to decomposition.

INTRODUCTION

Land filling has become the major method for disposing of solid wastes in the USA. Two purposes are served: (1) rid the community of waste that cannot be economically recycled or consumed, and (2) fill in low areas of land to provide usable space. In the past such waste disposal fills have been considered suitable only for green areas or parks. The increasing scarcity of land in urban areas is making it necessary to build structures above such fills. Data on the engineering properties of such fills is lacking. The engineering problems involved have been summarized by Sowers (1968). These include bearing capacity, settlement, gas production, leachate production, corrosion of buried materials, and difficult construction. The present paper presents quantitative data on settlement that the author has accumulated.

IMPORTANCE OF SETTLEMENT

Settlement is the key to the use of waste disposal fills. Because potential settlements are large, they control the design of roads, parking lots, and lighter structures supported on shallow foundations. Moreover, when deep foundations are employed, the continuing fill settlement is critical because explosive gas can collect in the enlarging gap between the fill surface and the supported floor. If the ground floor is fill-supported, the differential settlement between the pile and ground-supported components can be damaging. For example, both problems are developing simultaneously at a large restaurant whose site is underlain by an old sanitary land fill. The ground floor and the partitions resting on it sag downward from the pile-supported exterior wall and methane is accumulating below the floor adjacent to the wall. Disaster could occur from either structural collapse or explosion.

THE NATURE OF WASTE DISPOSAL FILLS

Waste is as heterogeneous as the modern industrial-urban complex that produces it. It consists of anything that cannot be further used or recycled economically; thus, its composition varies from community to community, and from nation to nation. The principal ingredients are given in Table 1.

The density varies greatly from 200 lb. per cu. yd. (120 kg per cu. m) to 500 lb. per cu. yd. (300 kg per cu. m) as delivered to the fill, depending on the amount of metal and debris. After compaction the densities may be more than 1000 lb. per cu. yd. (600 kg per cu. m). Moisture contents range from 10 to 50 per cent and average specific gravity of solids from 1.7 to 2.5. Typical void ratios are between 15 uncompacted and 2 well-compacted.

Two extreme forms of decomposition are utilized: the open dump and the encapsulated "sanitary land fill", Fig. 1. The former is heterogeneous, accumulating at random as dumped, possibly allowed to burn, and finally covered with soil to control odors, rats, and flies. The true sanitary land fill is spread in layers, compacted, and then covered with soil after each days filling. Each cell may be 10 to 25 ft. (3 to 8 m) thick, 50 ft. (16 m) wide, and 100 to 200 ft. (30 m to 60 m) long, covered with 1 m of soil.

Table I

MUNICIPAL WASTE MATERIALS INCORPORATED IN FILLS

Material	Typical Percentage	Characteristics As Fill
Garbage: Food Waste	10-20	Wet. Ferments and decays readily; Compressible, weak.
Paper, Cloth	10-40	Dry to damp, decays and burns, compressible.
Lawn and Garden Refuse: Grass, Brush, Stumps	10-20	Damp. Ferments, decays, and burns.
Plastic	1-2	Dry: Compressible, decay resistant but may burn.
Hollow Metal: Cans, Drums, Refrigerators, Auto Bodies, Bed Springs	5-15	Dry. Corrodable and crushable.
Massive Metal: Castings, Kettle Bottoms, Auto Batteries	1	Dry. Slightly corrodable, rigid.
Rubber: Tires, Trimmings	5-10	Dry. Resilient, burnable, compressible but uncrushable, decay resistant.
Glass	5-15	Dry. Crushable and compressible, decay resistant.
Lumber from Demolition	0-5	Dry. Crushable, compressible, decays and burns, some interlocking strength.
Rubble: Brick, Concrete, Stone, Soil from Demolitions	0-10	Damp. Crushable, erodable, decay resistant.
Ashes, Cinders, Chemical Wastes*	0-5	Damp. Soil-like: Compressible, active chemically and partially soluble.

* Does not include separate industrial waste-disposal fills.

MECHANISMS OF SETTLEMENT

A number of mechanisms are responsible for the settlement:

1. Mechanical: Distortion, bending, crushing and reorientation of the materials, similar to the consolidation of organic soils.

2. Ravelling: The erosion or sifting of fine materials into the voids between larger particles.

3. Physico-Chemical Change: Corrosion, oxidation and combustion.

4. Bio-Chemical Decay: Fermentation and decay, both aerobic and anerobic.

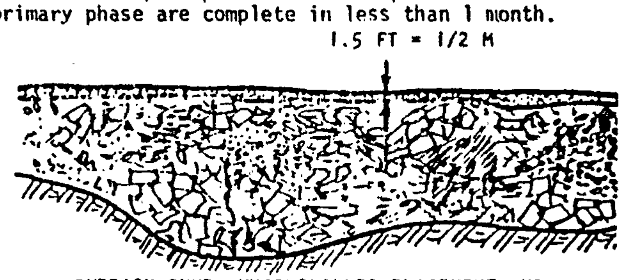
5. Interaction: Methane from bio-chemical decay may support combustion, ignited spontaneously from the heat of decay. Organic acids from decay may produce corrosion; volume changes from consolidation may trigger ravelling.

Of these mechanisms, only the first is load related and can be analyzed in terms of the stresses involved. The other mechanisms are related to the environment: air, moisture, and temperature. A waste fill is dynamic, changing with the environment and partially creating its own environment. For example, temperatures 60° F (33C) above ambient are common during biochemical decay. Decay utilizes moisture and the oxygen in the air voids to form carbon dioxide; when the oxygen is depleted, methane is produced which is poisonous and inflammable. Saturation of the fill inhibits decay, because the bacteria are eventually destroyed by the products of their own growth.

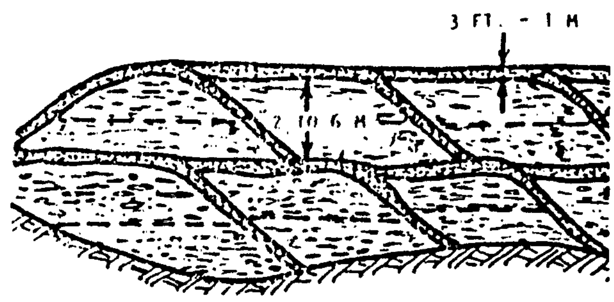
AMOUNT OF SETTLEMENT

The usual laboratory tests for consolidation are meaningless with such heterogeneous materials of such varied particle sizes. Instead, large scale pilot cells, 3 to 6 ft. (1 to 2 m) in diameter and the behavior of actual fills must be analyzed for meaningful data. These are limited (Stoll, 1971) (Merz and Stone, 1962) (Law, Various Dates). However, tentative conclusions can be drawn which are useful in predicting settlements.

1. The mechanical settlement occurs rapidly with little or no pore pressure build-up. The initial and primary phase are complete in less than 1 month.



a. RUBBISH DUMP: UNCONTROLLED PLACEMENT, NO COMPACTION



b. SANITARY LANDFILL: SPREAD AND COMPACTED IN LAYERS 6 TO 10 FT OR 2 TO 3 M THICK, ENCAPSULATED WITH SOIL IN CELLS 6 TO 20 FT OR 2 TO 6 M THICK DAILY

FIG. 1 CONSTRUCTION OF WASTE DISPOSAL FILLS

2. The relation of stress to settlement during the first month can be expressed by the well-known equation:

$$\Delta e = -C_c \log \frac{\sigma_o' + \Delta\sigma}{\sigma_o'} \qquad (1)$$

3. The compression index, C_c is related to the initial void ratio, as shown in Fig. 2. There is a considerable variation in C_c for any value of e. The higher values are for fills containing large amounts of garbage, wood, brush, and tin cans; the lower values are for the less resilient materials. The upper limit for peat soils is also shown; the maximum C_c for peat is about one-third greater than the maximum observed for waste fills.

4. The amount of ravelling or combustion settlement cannot be predicted.

RATE OF SETTLEMENT

Settlement of the waste fills continues at substantial rates as can be seen from Fig. 3. This is the combination of mechanical secondary compression, physico-chemical action, and bio-chemical decay. When there has been no drastic change in the environment the settlement-log time relationship is more or less linear, similar to secondary compression of soils. The settlement can be expressed by:

$$\Delta e = -\alpha \log (t_2/t_1) \qquad (2)$$

where α is a coefficient analogous to C_c. The limited data available indicate that α is a function of the void ratio, Fig. 4. For any given void ratio there is a large range in α, related to the potential for physico-chemical and bio-chemical decay. The value is high if the organic content subject to decay is large and the environment is favorable: (warm, moist, with fluctuating water table that pumps fresh air into the fill). The value is low for more inert materials and in unfavorable environments. More research and data are necessary before the relationship can be defined more closely.

The rate of settlement produced by ravelling and combustion is erratic. Movement generally occurs in sudden episodes of varying magnitude following progressive deterioration. Deterioration is related to environmental changes. These include rapid changes in ground water, flooding due to torrential rainfall or

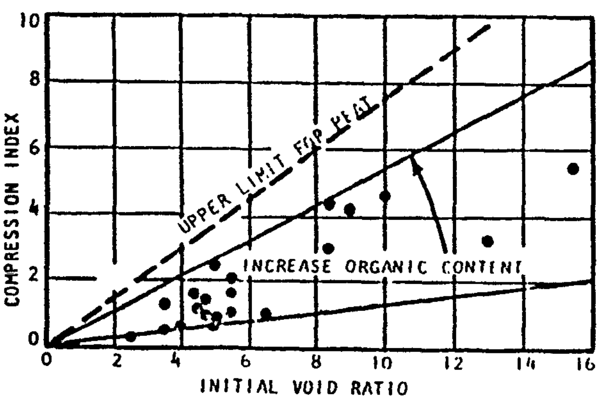


FIG. 2 COMPRESSIBILITY OF WASTE DISPOSAL FILLS

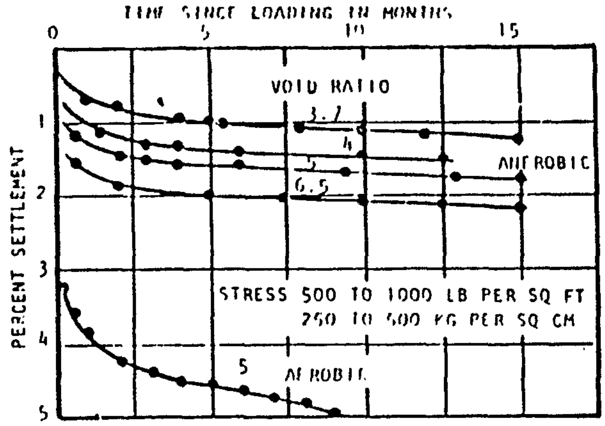


FIG. 3 TIME-SETTLEMENT FOR WASTE OF GARBAGE, REFUSE AND BUILDING DEBRIS

broken water pipes, and drying and exposure to air from making excavations in the soil cover or the fill.

MINIMIZING SETTLEMENT

The ultimate settlement is related to the initial void ratio and the environmental conditions favorable to deterioration, decay, ravelling and combustion. Because void ratio or initial density is related to the initial-primary settlement as well as secondary compression, densification offers an element of control over potential settlement.

Some form of compaction is employed with the controlled, encapsulated fills. The tracked tractor with a bulldozer blade both spreads and crushes the looser materials. Special trash compactors weighing about 30 tons with lugs similar to the sheepsfoot roller but larger are very effective in compacting fill in lifts 6 to 8 ft. (2 to 2.5 m) thick, Fig. 5. The 40 to 50 ton rubber tired roller is effective in layers that are 10 ft. (3 m) thick initially.

Examples of the surface settlement or densification produced are shown in Fig. 6. The data include rollers of from 12 to 50 tons; these have been normalized considering the effective depth of compaction based on the author's experience. They show considerable variations in effectiveness of compaction: a maximum compaction of 15 per cent and a minimum of 2 per cent. The higher degrees of compaction may include some lateral displacement of the fill. The greatest effect is in the first 12 to 15 roller passes; there are some benefits with as many as 25 passes. Resilient materials such as old tires do not densify under any amounts of rolling.

If the roller is too heavy a bearing capacity failure will result. If a very wet fill is compacted, a temporary pore pressure build-up reduces the strength and bearing capacity sufficiently that shear failure, lateral displacement and loosening will occur. Only field tests can show the optimum roller weight and rate of rolling, for any given situation.

Preloading with fill can reduce potential settlement

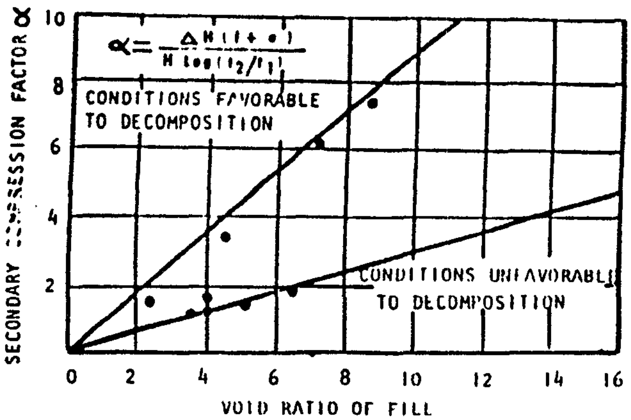


FIG. 4 SECONDARY COMPRESSION OF WASTE FILLS

in the same way as it is effective with organic clays and peats. Because of high permeability and partial saturation, the initial-primary settlement is virtually complete in a month or two. The secondary is so great, however, that it determines the preload periods.

Environmental control offers intriguing possibilities for minimizing continuing settlement from ravelling and bio-chemical action. Flooding the fill, with no opportunity for water circulation, may bring decomposition to a halt when the products of decomposition inhibit further bio-chemical action. Keeping the fill dry can have a similar effect. Both have been achieved in test fills encapsulated in plastic. Chemical control of decomposition is a possible future development.

CONCLUSIONS

Waste fills are being used increasingly for structural support. Settlements can be so great that they generally control structural design. Techniques for predicting settlement and methods for minimizing settlement have been compiled from scattered large-scale pilot tests and full size instrumented fills.

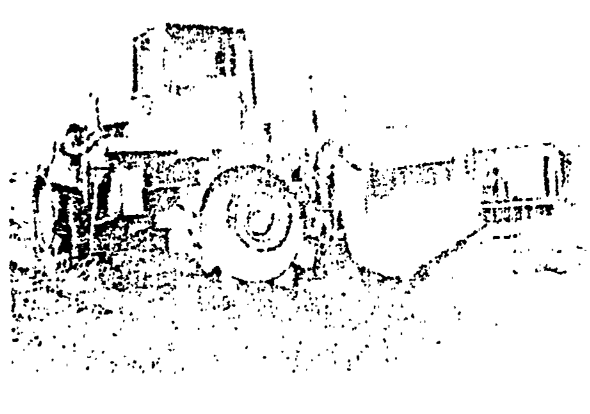


FIG. 5 COMPACTOR FOR SOLID WASTES

1. The total settlement for the first month can be found from a compression index that is related to the void ratio: $C_c = 0.15\ e_0$ for fills low in organic matter to $C_c = 0.55\ e_0$ for fills high in organic matter.

2. Continuing settlement is analogous to secondary compression and is also related to the environment for bio-chemical decay. The rate can be expressed by $\alpha = 0.03\ e_0$ for conditions unfavorable to decay to $\alpha = 0.09\ e_0$ for conditions favorable to decay.

3. Settlement can be minimized by fill compaction, preloading and possibly by environment control.

4. Compaction is most effective during the first 8 to 12 passes.

ACKNOWLEDGMENTS

The data in this paper have been accumulated from many sources. Mr. Donald York, Engineer of Soils, The Port of New York Authority and Mr. C. M. Kennedy,

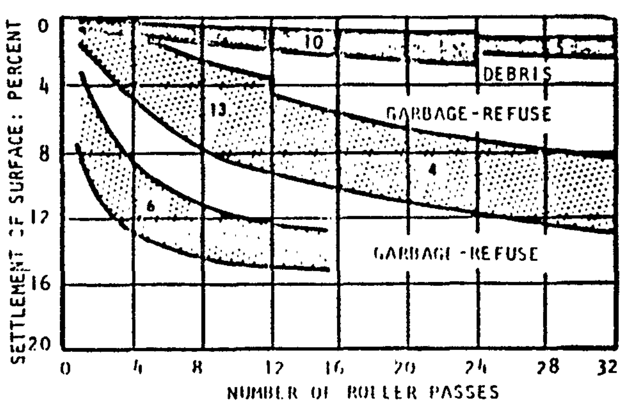


FIG. 6 COMPACTION OF WASTE FILLS BY 12 TON ROLLERS IN 5 FT OR 1.5 M LIFTS AND 30-50 TON ROLLERS IN 8-10 FT OR 2.5-3 M LIFTS (NUMBER OF TEST AREAS SHOWN IN SHADED ZONES)

Vice President of Engineering, Law Engineering Testing Company deserve special thanks for making data available.

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SETTLEMENT OF WASTE DISPOSAL FILLS

TASSEMENT DES REMBLAIS DES TERRES

ОСАДКИ НАСЫПЕЙ ИЗ ХЛАМОВ

GEORGE F. SOWERS, Consultant, Law Engineering Testing Company, Atlanta (U.S.A.)

SYNOPSIS. Waste disposal fills are becoming the major mechanism for disposing of materials unsuitable for other purposes, including garbage, household refuse, construction debris and industrial wastes. Settlement of such organic-mineral complexes occurs through four mechanisms: (1) consolidation or void ratio reduction, (2) biochemical decomposition, (3) physico-chemical, and (4) ravelling of soil into large voids. The author's studies show that settlement is similar to that of peats: large initial consolidation, little or no hydrodynamic and substantial secondary compression. The compression index C_c is approximately proportional to the initial void ratio and increases with the organic content of the fill.

Decomposition and disintegration are reflected in the rate of secondary compression. For aerobic moist conditions above the water table the secondary is three times as great as for anerobic below a stagnant water table. The rate of ravelling cannot be expressed analytically at present. Settlement can be reduced by compaction, preloading, and controlling the environmental factors favorable to decomposition.

INTRODUCTION

Land filling has become the major method for disposing of solid wastes in the USA. Two purposes are served: (1) rid the community of waste that cannot be economically recycled or consumed, and (2) fill in low areas of land to provide usable space. In the past such waste disposal fills have been considered suitable only for green areas or parks. The increasing scarcity of land in urban areas is making it necessary to build structures above such fills. Data on the engineering properties of such fills is lacking. The engineering problems involved have been summarized by Sowers (1968). These include bearing capacity, settlement, gas production, leachate production, corrosion of buried materials, and difficult construction. The present paper presents quantitative data on settlement that the author has accumulated.

IMPORTANCE OF SETTLEMENT

Settlement is the key to the use of waste disposal fills. Because potential settlements are large, they control the design of roads, parking lots, and lighter structures supported on shallow foundations. Moreover, when deep foundations are employed, the continuing fill settlement is critical because explosive gas can collect in the enlarging gap between the fill surface and the supported floor. If the ground floor is fill-supported, the differential settlement between the pile and ground-supported components can be damaging. For example, both problems are developing simultaneously at a large restaurant whose site is underlain by an old sanitary land fill. The ground floor and the partitions resting on it sag downward from the pile-supported exterior wall and methane is accumulating below the floor adjacent to the wall. Disaster could occur from either structural collapse or explosion.

THE NATURE OF WASTE DISPOSAL FILLS

Waste is as heterogeneous as the modern industrial-urban complex that produces it. It consists of anything that cannot be further used or recycled economically; thus, its composition varies from community to community, and from nation to nation. The principal ingredients are given in Table I.

The density varies greatly from 200 lb. per cu. yd. (120 kg per cu. m) to 500 lb. per cu. yd. (300 kg per cu. m) as delivered to the fill, depending on the amount of metal and debris. After compaction the densities may be more than 1000 lb. per cu. yd. (600 kg per cu. m). Moisture contents range from 10 to 50 per cent and average specific gravity of solids from 1.7 to 2.5. Typical void ratios are between 15 uncompacted and 2 well-compacted.

Two extreme forms of decomposition are utilized: the open dump and the encapsulated "sanitary land fill", Fig. 1. The former is heterogeneous, accumulating at random as dumped, possibly allowed to burn, and finally covered with soil to control odors, rats, and flies. The true sanitary land fill is spread in layers, compacted, and then covered with soil after each days filling. Each cell may be 10 to 25 ft. (3 to 8 m) thick, 50 ft. (16 m) wide, and 100 to 200 ft. (30 m to 60 m) long, covered with 1 m of soil.

Table I

MUNICIPAL WASTE MATERIALS INCORPORATED IN FILLS

Material	Typical Percentage	Characteristics As Fill
Garbage: Food Waste	10-20	Wet. Ferments and decays readily; Compressible, weak.
Paper, Cloth	10-40	Dry to damp, decays and burns, compressible.
Lawn and Garden Refuse: Grass, Brush, Stumps	10-20	Damp. Ferments, decays, and burns.
Plastic	1-2	Dry: Compressible, decay resistant but may burn.
Hollow Metal: Cans, Drums, Refrigerators, Auto Bodies, Bed Springs	5-15	Dry. Corrodable and crushable.
Massive Metal: Castings, Kettle Bottoms, Auto Batteries	1	Dry. Slightly corrodable, rigid.
Rubber: Tires, Trimmings	5-10	Dry. Resilient, burnable, compressible but uncrushable, decay resistant.
Glass	5-15	Dry. Crushable and compressible, decay resistant.
Lumber from Demolition	0-5	Dry. Crushable, compressible, decays and burns, some interlocking strength.
Rubble: Brick, Concrete, Stone, Soil from Demolitions	0-10	Damp. Crushable, erodable, decay resistant.
Ashes, Cinders, Chemical Wastes*	0-5	Damp. Soil-like: Compressible, active chemically and partially soluble.

* Does not include separate industrial waste-disposal fills.

MECHANISMS OF SETTLEMENT

A number of mechanisms are responsible for the settlement:

1. Mechanical: Distortion, bending, crushing and reorientation of the materials, similar to the consolidation of organic soils.

2. Ravelling: The erosion or sifting of fine materials into the voids between larger particles.

3. Physico-Chemical Change: Corrosion, oxidation and combustion.

4. Bio-Chemical Decay: Fermentation and decay, both aerobic and anerobic.

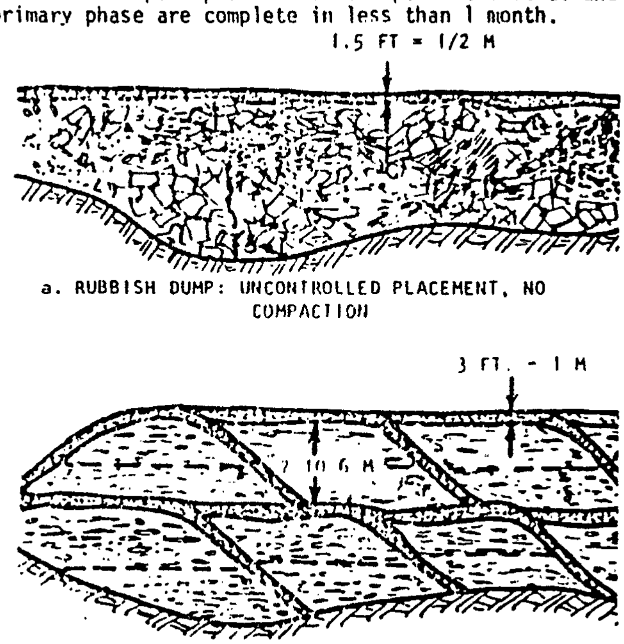
5. Interaction: Methane from bio-chemical decay may support combustion, ignited spontaneously from the heat of decay. Organic acids from decay may produce corrosion; volume changes from consolidation may trigger ravelling.

Of these mechanisms, only the first is load related and can be analyzed in terms of the stresses involved. The other mechanisms are related to the environment: air, moisture, and temperature. A waste fill is dynamic, changing with the environment and partially creating its own environment. For example, temperatures 60° F (33C) above ambient are common during biochemical decay. Decay utilizes moisture and the oxygen in the air voids to form carbon dioxide; when the oxygen is depleted, methane is produced which is poisonous and inflammable. Saturation of the fill inhibits decay, because the bacteria are eventually destroyed by the products of their own growth.

AMOUNT OF SETTLEMENT

The usual laboratory tests for consolidation are meaningless with such heterogeneous materials of such varied particle sizes. Instead, large scale pilot cells, 3 to 6 ft. (1 to 2 m) in diameter and the behavior of actual fills must be analyzed for meaningful data. These are limited (Stoll, 1971) (Merz and Stone, 1962) (Law, Various Dates). However, tentative conclusions can be drawn which are useful in predicting settlements.

1. The mechanical settlement occurs rapidly with little or no pore pressure build-up. The initial and primary phase are complete in less than 1 month.



a. RUBBISH DUMP: UNCONTROLLED PLACEMENT, NO COMPACTION

b. SANITARY LANDFILL: SPREAD AND COMPACTED IN LAYERS 6 TO 10 FT OR 2 TO 3 M THICK, ENCAPSULATED WITH SOIL IN CELLS 6 TO 20 FT OR 2 TO 6 M THICK DAILY

FIG. 1 CONSTRUCTION OF WASTE DISPOSAL FILLS

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2. The relation of stress to settlement during the first month can be expressed by the well-known equation:

$$\Delta e = -C_c \log \frac{\sigma_o' + \Delta\sigma}{\sigma_o'} \qquad (1)$$

3. The compression index, C_c is related to the initial void ratio, as shown in Fig. 2. There is a considerable variation in C_c for any value of e. The higher values are for fills containing large amounts of garbage, wood, brush, and tin cans; the lower values are for the less resilient materials. The upper limit for peat soils is also shown; the maximum C_c for peat is about one-third greater than the maximum observed for waste fills.

4. The amount of ravelling or combustion settlement cannot be predicted.

RATE OF SETTLEMENT

Settlement of the waste fills continues at substantial rates as can be seen from Fig. 3. This is the combination of mechanical secondary compression, physico-chemical action, and bio-chemical decay. When there has been no drastic change in the environment the settlement-log time relationship is more or less linear, similar to secondary compression of soils. The settlement can be expressed by:

$$\Delta e = -\alpha \log (t_2/t_1) \qquad (2)$$

where α is a coefficient analogous to C_c. The limited data available indicate that α is a function of the void ratio, Fig. 4. For any given void ratio there is a large range in α, related to the potential for physico-chemical and bio-chemical decay. The value is high if the organic content subject to decay is large and the environment is favorable: (warm, moist, with fluctuating water table that pumps fresh air into the fill). The value is low for more inert materials and in unfavorable environments. More research and data are necessary before the relationship can be defined more closely.

The rate of settlement produced by ravelling and combustion is erratic. Movement generally occurs in sudden episodes of varying magnitude following progressive deterioration. Deterioration is related to environmental changes. These include rapid changes in ground water, flooding due to torrential rainfall or

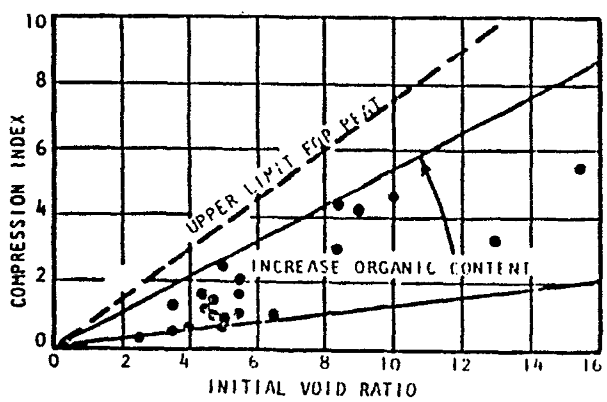

FIG. 2 COMPRESSIBILITY OF WASTE DISPOSAL FILLS

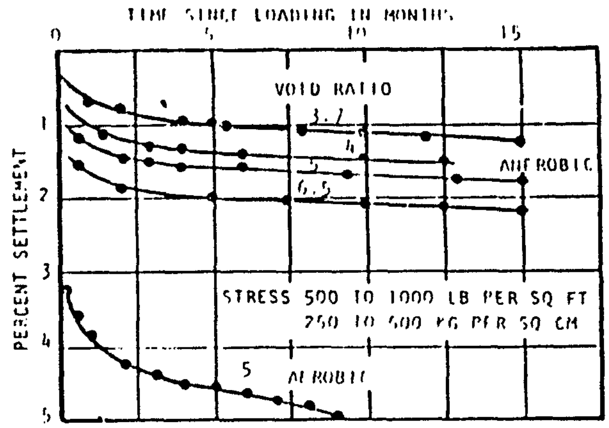

FIG. 3 TIME-SETTLEMENT FOR WASTE OF GARBAGE, REFUSE AND BUILDING DEBRIS

broken water pipes, and drying and exposure to air from making excavations in the soil cover or the fill.

MINIMIZING SETTLEMENT

The ultimate settlement is related to the initial void ratio and the environmental conditions favorable to deterioration, decay, ravelling and combustion. Because void ratio or initial density is related to the initial-primary settlement as well as secondary compression, densification offers an element of control over potential settlement.

Some form of compaction is employed with the controlled, encapsulated fills. The tracked tractor with a bulldozer blade both spreads and crushes the looser materials. Special trash compactors weighing about 30 tons with lugs similar to the sheepsfoot roller but larger are very effective in compacting fill in lifts 6 to 8 ft. (2 to 2.5 m) thick, Fig. 5. The 40 to 50 ton rubber tired roller is effective in layers that are 10 ft. (3 m) thick initially.

Examples of the surface settlement or densification produced are shown in Fig. 6. The data include rollers of from 12 to 50 tons; these have been normalized considering the effective depth of compaction based on the author's experience. They show considerable variations in effectiveness of compaction: a maximum compaction of 15 per cent and a minimum of 2 per cent. The higher degrees of compaction may include some lateral displacement of the fill. The greatest effect is in the first 12 to 15 roller passes; there are some benefits with as many as 25 passes. Resilient materials such as old tires do not densify under any amounts of rolling.

If the roller is too heavy a bearing capacity failure will result. If a very wet fill is compacted, a temporary pore pressure build-up reduces the strength and bearing capacity sufficiently that shear failure, lateral displacement and loosening will occur. Only field tests can show the optimum roller weight and rate of rolling, for any given situation.

Preloading with fill can reduce potential settlement

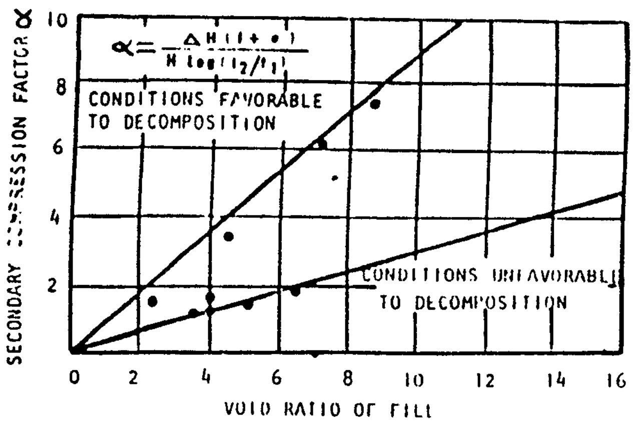

FIG. 4 SECONDARY COMPRESSION OF WASTE FILLS

in the same way as it is effective with organic clays and peats. Because of high permeability and partial saturation, the initial-primary settlement is virtually complete in a month or two. The secondary is so great, however, that it determines the preload periods.

Environmental control offers intriguing possibilities for minimizing continuing settlement from ravelling and bio-chemical action. Flooding the fill, with no opportunity for water circulation, may bring decomposition to a halt when the products of decomposition inhibit further bio-chemical action. Keeping the fill dry can have a similar effect. Both have been achieved in test fills encapsulated in plastic. Chemical control of decomposition is a possible future development.

CONCLUSIONS

Waste fills are being used increasingly for structural support. Settlements can be so great that they generally control structural design. Techniques for predicting settlement and methods for minimizing settlement have been compiled from scattered large-scale pilot tests and full size instrumented fills.

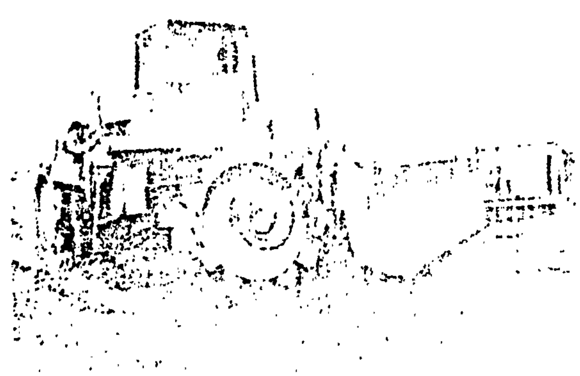

FIG. 5 COMPACTOR FOR SOLID WASTES

1. The total settlement for the first month can be found from a compression index that is related to the void ratio: C_c 0.15 e_0 for fills low in organic matter to C_c ~ 0.55 e_0 for fills high in organic matter.

2. Continuing settlement is analogous to secondary compression and is also related to the environment for bio-chemical decay. The rate can be expressed by $\alpha = 0.03\ e_0$ for conditions unfavorable to decay to $\alpha = 0.09\ e_0$ for conditions favorable to decay.

3. Settlement can be minimized by fill compaction, preloading and possibly by environment control.

4. Compaction is most effective during the first 8 to 12 passes.

ACKNOWLEDGEMENTS

The data in this paper have been accumulated from many sources. Mr. Donald York, Engineer of Soils, The Port of New York Authority and Mr. C. M. Kennedy,

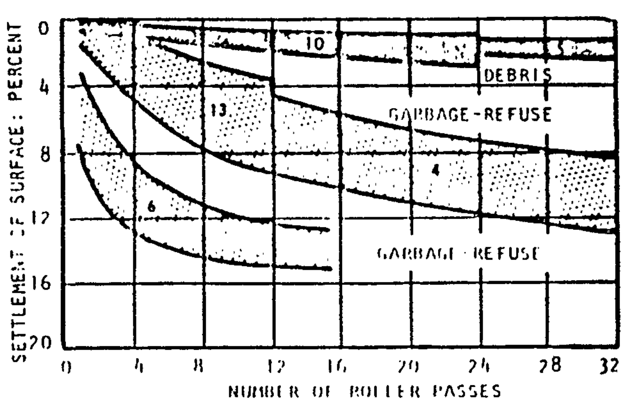

FIG. 6 COMPACTION OF WASTE FILLS BY 12 TON ROLLERS IN 5 FT OR 1.5 M LIFTS AND 30-50 TON ROLLERS IN 8-10 FT OR 2.5-3 M LIFTS (NUMBER OF TEST AREAS SHOWN IN SHADED ZONES)

Vice President of Engineering, Law Engineering Testing Company deserve special thanks for making data available.

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Principles of Foundation Engineering

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Part b: Reinforcement

The reinforcement should be provided for the total uplift load—that is, 1252 kN (assuming that dead load and live load are zero). So, the area of steel

$$A_s = \frac{U}{\left(\dfrac{\text{yield point of steel}}{\text{factor of safety}}\right)}$$

The preceding factor of safety may be taken as 1.25. The yield point of steel ≈ 275 MN/m^2 (≈40,000 lb/in.^{2}). Hence, the area of steel

$$A_s = \frac{1252}{\left(\dfrac{275 \times 10^3}{1.25}\right)} = 5.69 \times 10^{-3}\ \text{m}^2 = 5.69 \times 10^3\ \text{mm}^2\ (8.82\ \text{in.}^2)$$

Part c: Check for Bearing Capacity

Assume $U = 0$.

$$\text{Dead load} + \text{live load} = 600 + 300 = 900\ \text{kN}$$

$$\text{Downward load per unit area} = \frac{900}{\left(\dfrac{\pi}{4}\right)(D_b^2)} = \frac{900}{\left(\dfrac{\pi}{4}\right)(1.25)^2} = 733.4\ \text{kN/m}^2$$

Net bearing capacity of the soil under the bell = q_u =

$$c_u N_c = 450(6.14) = 2763\ \text{kN/m}^2$$

Hence, factor of safety against bearing capacity failure

$$= \frac{2763}{733.4} = \underline{3.77 > 3\text{—O.K.}}$$

Sanitary Landfill

10.12 Sanitary Landfills—General

Sanitary landfills provide a way to dispose of refuse on land without causing danger to public health. Almost all countries use sanitary landfills with varying degrees of success. The refuse disposed in sanitary landfills can contain materials like wood, paper, and fibrous wastes or demolition wastes like bricks and stones. The refuse is dumped and compacted at frequent intervals and then covered with a layer of soil (Figure 10.14). In the compacted state, the average unit weight of the refuse may vary between 5–10 kN/m^3. A typical city in the United States, with a population of one million, can generate about 3.8×10^6 m^3 of compacted landfill material per year.

As property value continues to increase in densely populated areas, it becomes more and more tempting to construct structures over sanitary landfills. In some instances, a visual site inspection may not be enough to detect an old sanitary landfill. However, construction of foundations over sanitary landfills is

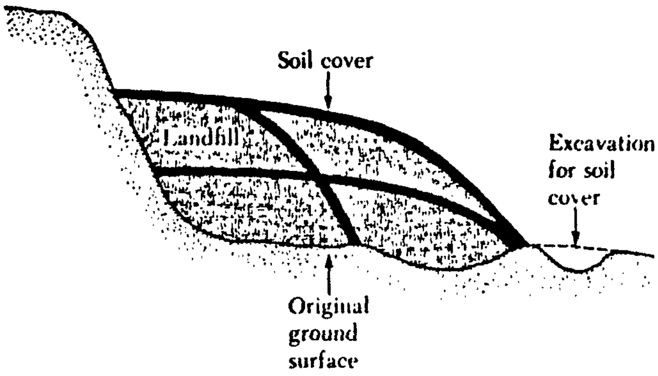


Figure 10.14 Schematic diagram of sanitary landfill in progress

generally problematic because of poisonous gases such as methane, excessive settlement, and low inherent bearing capacity. Few studies are available on this topic. Based on the information available, the next two sections will discuss settlement and bearing capacity problems associated with sanitary landfills.

10.13 Settlement of Sanitary Landfills

Sanitary landfills undergo large continuous settlements over a long period of time. Yen and Scanlon (1975) have documented the settlement of several landfill sites in California. Based on their analysis, the settlement rate after the completion of the landfill (Figure 10.15) can be expressed as

$$m = \frac{\Delta H_f}{\Delta t} \quad (10.17)$$

where m = settlement rate
H_f = maximum height of the sanitary landfill

Based on several field observations, the following empirical correlations for the settlement rate have been determined (Yen and Scanlon, 1975).

$$m = 0.0268 - 0.0116 \log t_1 \quad \text{(for fill heights ranging from 12–24 m)} \quad (10.18)$$

$$m = 0.038 - 0.0155 \log t_1 \quad \text{(for fill heights ranging from 24–30m)} \quad (10.19)$$

$$m = 0.0433 - 0.0183 \log t_1 \quad \text{(for fill heights greater than 30 m)} \quad (10.20)$$

where m is in m/month and t_1 is the median fill age, in months. The medium fill age can be defined as (Figure 10.15)

$$t_1 = t - \frac{t_c}{2} \quad (10.21)$$

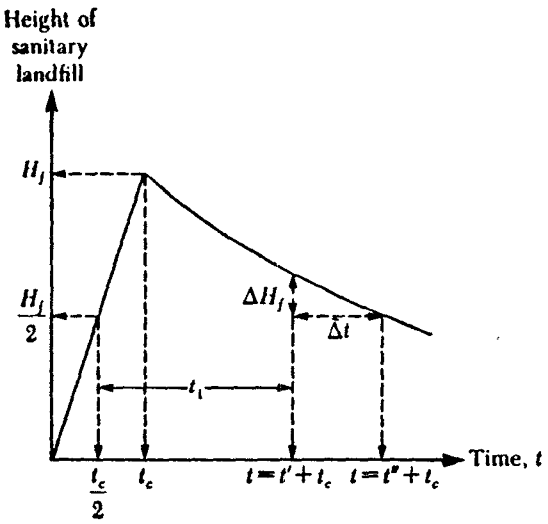


Figure 10.15 Settlement of sanitary landfills

where t = time from the beginning of landfill
t_c = time for completion of the landfill

Equations (10.18), (10.19), and (10.20) were based on field data from landfills for which the value of t_c varied from 70 to 82 months. To get an idea of the approximate length of time required for a sanitary landfill to undergo complete settlement, consider Eq. (10.18). For a fill of height of 12 m and t_c = 72 months

$$m = 0.0268 - 0.0116 \log t_1$$

or

$$\log t_1 = \frac{0.0268 - m}{0.0116}$$

If $m = 0$ (that is, for zero settlement rate), the $\log t_1 = 2.31$, or $t_1 \approx 200$ months. Thus, the settlement of the fill will continue for a period of $t_1 - t_c/2 = 200 - 36 = 164$ months ($\approx$14 years) after its completion. This is a fairly long time. This calculation shows that one must pay close attention to the settlement of foundations constructed on sanitary landfills.

A comparison of Eqs. (10.18) to (10.20) for rates of settlement shows that the value of m increases with the increase of the height of the fill. However, for fill heights greater than about 30 m, the rate of settlement should not be much different than that from Eq. (10.20). This is because decomposition of the organic matter close to the surface is mainly the result of anaerobic environment. For deeper fills, the decomposition is slower. Hence, for fill heights greater than about 30 m, the rate of settlement does not accelerate any faster than those that are about 30 m in height.

16. Sowers, G. F., "Settlement of Waste Disposal Fills," Proceedings, The Eighth International Conference of Soil Mechanics and Foundation Engineering, Moscow, 1973, pp. 207-210.

Sowers (1973) has also proposed a relation for calculation of the settlement of a sanitary landfill:

$$\Delta H = \frac{\alpha H_f}{1 + e} \log \left(\frac{t''}{t'}\right)$$

where H_f = height of the fill
e = void ratio
α = a coefficient for settlement
t'', t' = times (see Figure 10.15)
ΔH = settlement between times t' and t''

The coefficients α are between the following limits

$$\alpha = 0.09e \text{ (for conditions favorable to decomposition)} \quad (10.23)$$

and

$$\alpha = 0.03e \text{ (for conditions unfavorable to decomposition)} \quad (10.24)$$

Equation (10.22) is similar to the equation for secondary consolidation settlement.

10.14 Bearing Capacity of Foundations on Sanitary Landfills

Shallow foundations constructed on sanitary landfills with a compacted soil cover may fail in two ways (Sowers, 1968): by punching shear, or by rotational shear, as shown in Figure 10.16. Punching shear failure (Figure 10.16a) occurs when the width of the foundation, B, is relatively small compared to the thickness of the soil cover, D_C. However, when the thickness of the soil cover is relatively small compared to the foundation width and where the strength of the soil cover is low, rotational shear failure may occur (Figure 10.16b). The allowable bearing capacity of shallow foundations for light residential or office buildings over sanitary landfills should not be greater than about 20–40 kN/m^2.

Sometimes the allowable bearing capacity of shallow foundations can be increased by increasing the thickness of the compacted soil cover such that $D_C \geq 1.5$–$2B$. Note, however, that this excess weight of the fill and the compaction process may eventually increase the ultimate settlement of the structure.

When the fill is relatively homogeneous and light structures are constructed over it, the settlement pattern will be somewhat like that in Figure 10.16c. However, when the fill is nonhomogeneous in nature with irregular hard zones, such as boulders, the settlement is nonuniform, as shown in Figure 10.16d. Serious damage to structures is usually caused by this type of settlement.

In several instances, the use of continuous foundations, such as that shown in Figure 10.5, may help reduce the differential settlement problem. If the estimated settlement of a structure is not tolerable, or heavier structures are to be built, pile or drilled-pier foundations are alternatives. In this case, it will be

III. CAP SELECTION BACKUP

The eventual capping option will depend on the grading option selected and if the closure will be handled on a phased approach. Regardless of the final selection, the capping options proposed must meet basic regulatory criteria.

The final cover should be designed and constructed to provide long-term minimization of migration of liquids through the closed waste site.

The effort at this site should comply with applicable and relevant standards of other statutes besides CERCLA. For capping options, this means that at a minimum, RCRA technical guidance contained in 40 CFR 264.310 should be met. To conform with this guidance the following objectives should be met by the final cover design:

° Provide long-term minimization of migration of liquids through the closed waste site,

° Function with minimum maintenance,

° Promote drainage and minimize erosion or abrasion of the cover,

° Accommodate settling and subsidence so that the cover's integrity is maintained, and

° Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

- o Vegetated top cover
- o Middle drainage layer
- o Low permeability bottom layer
  - $\geq$20 mil synthetic - upper component (may be optional)
  - $\geq$2 foot clay layer - lower component

The following guidance elements provided by EPA will be applied to this option:

- o <u>Vegetated Top Cover</u>
  - o minimum 24 in. thick
  - o should support vegetation that minimizes erosion without continued maintenance
  - o planted with persistent species - no roots that will penetrate beyond the vegetative and drainage layers
  - o top slope, after settling and subsidence, of between 3-5%- if > 5% use USDA Universal Soil Loss Equation to demonstrate a soil loss of <2.0 tons/acre/yr.
  - o surface drainage system capable of conducting runoff across cap with no problems
- o <u>Middle Drainage Layer</u>
  - o minimum 12 in. thick if granular material
  - o saturated conductivity not less than $1x10^{-3}$ cm/sec
  - o bottom slope of at least 2 percent
  - o designed to prevent clogging - overlain by a graded granular or synthetic fabric filter
  - o discharge flows freely

- Low Permeability Bottom Layer

  - upper component:

    - at least 20 mil synthetic (may be optional)
    - bedding layer at least 6-feet thick - no coarser than unified soil classification system sand (sp)
    - final upper slope at least 2%
    - be located wholly below the average depth of frost penetration in the area of interest

  - lower component:

    - at least 2 feet of soil compacted to a saturated conductivity of not more than $1x10^{-7}$ cm/sec
    - soil emplaced in lifts not exceeding 6 inches before compaction

This is the basis for the standard type cap and it will be viewed as an option into final design in its typical form. It is presently anticipated that the upper layer would consist of a 2-foot thick layer of topsoil placed above the drainage layer. The entire cover area would then be revegetated for erosion control. Fertilizer will be added to the topsoil at the rate of 700 pounds per acre and the area would be seeded with appropriate grass seed.

The middle drainage layer can consist of a basic gravel layer. Internal transport collectors are not anticipated at this time. This is partially due to the potential settlement problems. Beyond the standard gravel drainage blanket, the use of a synthetic drainage net product or composite system will be evaluated. For the final bottom layer, the options presently being carried into final design are two feet of compacted clay, 3 feet of compacted clay, or a properly bedded synthetic liner. At a minimum, High Density Polyethylene (HDPE) is being maintained as a synthetic material. Other materials are being considered but preference at this stage of the project is for use of HDPE. As a final option, a composite system of clay and synthetics is being retained for evaluation prior to final design.

Due to the nature of the settlement problems at the site, consideration must be given to options beyond the standard cap. These will be discussed further at the review meeting to be conducted in November. The guidance does allow for "alternative designs" capable of meeting the five regulatory requirements. It appears that if initial compaction cannot achieve an acceptable base then a phased type program will be required. In this system, an initial cap would be placed to meet the basic requirement of reducing infiltration through the landfill. Since some damage to this initial system through settlement would be anticipated, it is assumed that a cap of a more temporary nature than the standard RCRA cap would be used.

Three options are presently being considered for this type of cap. These include a "repairable" clay capping system, the use of a HDPE liner with expansion folds designed in, and finally a reinforced type asphalt material. Initially a self-supporting fabric structure type cover was also considered but the costs support system and anchoring at such an irregular sit precludes it from additional considerations. Some type of stabilized soil is also being considered as a temporary cover for the liner option.

The reinforced asphalt material under consideration consists of asphalt and a nonwoven polypropylene fabric. The nonwoven polypropylene fabric to be used is "Petromat," which is manufactured by the Phillips Fibers Corporation. This layer of asphalt and Petromat can be installed to follow the shape, contour, slope, etc. of the base material to provide for a final surface slope of 2% in all direction across the landfill site. This material has traditionally been used to repair cracked roadbeds. For closure projects the system generally consists of a base course followed by a ¼-inch asphalt cement course serving as a stabilizing and support layer. An asphalt emulsion sealant is then applied to the asphalt cement course and the fabric rolled onto this surface. A second asphalt emulsion layer is then applied to the top surface at the same rate. A chip seal (small grave) will then be placed on this emulsion layer at a rate of 25 pounds per square yard. Because of the durability of the chip seal surface, very little maintenance is required, and erosion of the surface can be eliminated.

These options will be presented in greater detail at the review meeting and the eventual selection may be tied to the grading option selected.

COMMUNICATION REPORTS
ON CAP SELECTION

COMMUNICATION REPORT

Name Susan Hogle	Project No. F-1536
Company National Seal	Date 2/10/88 Time
Address	[X] Telephone Conversation
	[ ] Office Conversation
Telephone No. 800/323-3820	Re: Heleva Landfill
Recorded By Bill Cannon	HDPE Liners

Ms. Hogle said a 1-foot minimum of soil or sand is required before equipment can be driven on the membrane. The recommended dozers for earth work over the membrane is a John Deere 350 or Caterpillar D-3.

COMMUNICATION REPORT

Name: Jackie Boostrom	Project No. F-1536
Company: National Seal	Date 3/7/88 Time 9:00
Address: Galesburg, Illinois	[X] Telephone Conversation
	[ ] Office Conversation
Telephone No. 800/323-3820	Re: HDPE Verification of 60 mil Thickness
Recorded By: Jon Caime	

40 mil - Too thin, can go through when welding
60 mil - Modules of elasticity 80K psi
80 mil - Modules of elasticity 80K psi

* Tensile at yield and tensile strength equal

Puncture Resistance

60 mil 90 pounds
80 mil 110 pounds

Hydrostatic Resistance

60 mil 450#/sq.inches
80 mil 650#/sq.inches

"Generally caps are 40 mil, but suggests 60 mil due to welding problem."

AR301486

COMMUNICATION REPORT

Name Elon Thompson, Jr.

Company Gundle Lining

Address Houston, Texas

Telephone No. 800/435-2008

Recorded By Bill Cannon

Project No. F-1536

Date 2/12/88 Time

[X] Telephone Conversation

[ ] Office Conversation

Re: Heleva Landfill

HDPE Liners

Mr. Thompson said that a 1-foot minimum layer of sand over the membrane would be required before a small, wide-tracked dozer could be driven over the membrane.

If drainage net is used, then still a 1-foot layer of fill dirt or top soil is required before the fill can be worked, and they recommend that 18-inch final thickness be called for, for the total thickness of soil above the membrane.

COMMUNICATION REPORT

Name Don Hildebrant

Project No. F-1536

Company Gundle Lining

Date 3/11/88 Time 10:00

Address Houston, Texas

[X] Telephone Conversation

[ ] Office Conversation

Telephone No. 800/435-2008

Re: HDPE Trenching

Recorded By Jon Caime

4 feet - 5 feet minimum distance from edge of landfill for:

V trench - liner system can move through trench
⊔ trench - would not allow movement of liner

------------------------COMMUNICATION REPORT------------------------

Name Jackie Boostrom

Company National Seal

Address Galesburg, Illinois

Telephone No. 800/323-3820

Recorded By Jon Caime

Project No. F-1536

Date 3/7/88 Time 9:00

[X] Telephone Conversation

[ ] Office Conversation

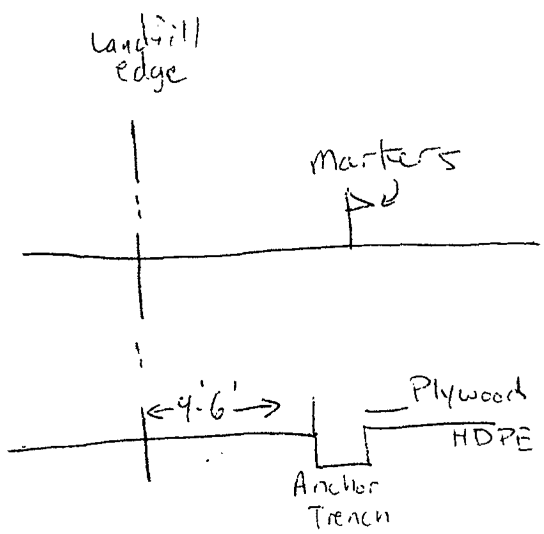
Re: HDPE Capping TCE Area at a Later Date

° Leave overlap to come back with; leave 4 feet - 6 feet

° Anchor trench

° Lay plywood on top of liner (treated)

° 1 foot of material



------------------------COMMUNICATION REPORT------------------------

Name Bob Trexler	Project No. F-1536
Company Gundle Lining	Date 3/29/88 Time 9:45
Address Houston, TX	[X] Telephone Conversation
	[ ] Office Conversation
Telephone No. 800-435-2008	Re: Soil Vent Cap TCE Area
Recorded By W. Jon Caime	and Redrill Later

Can come back and drill through HDPE to put in soil vents. Must clean existing HDPE before welding new HDPE or boots on or around soil vents.

---------------------COMMUNICATION REPORT---------------------

Name Elon Tompson, Jr.	Project No. F-1536
Company Gundle Lining	Date 3/7/88 Time 11:00
Address Houston, TX	[X] Telephone Conversation
	[ ] Office Conversation
Telephone No. 800-435-2008	Re: Confirmation of 60 mil HDPE
Recorded By Jon Caime	

* Don Hildebrant *

20 mil	-	May have problem welding
40 mil	-	No problem when welding
60 mil	-	Gives additional strength as gets thicker mil HDPE
	-	Same elongation
	-	Same tensile yield and tensile strength

Thickness Difference:

- puncture resistance, tear resistance, and added seam strength as thicker mil HDPE

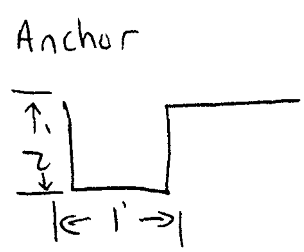
- 60 mil is as easy as 80 mil to install and costs about the same

COMMUNICATION REPORT

Name: Elon Tompson, Jr.	Project No. F-1536
Company: Gundle Lining	Date 3/7/88 Time 11:30
Address: Houston, TX	[X] Telephone Conversation
	[ ] Office Conversation
Telephone No. 800-435-2008	Re: HDPE Capping TCE Area at a Later Date
Recorded By Jon Caime	

Can always weld later on.

- o Geotextile - keeps liner clean 3 feet - 4 feet
- o 4 feet X 8 feet plywood protects when digging later on



- o Can anchor with plywood and dirt

AR301492

----------------------COMMUNICATION REPORT----------------------

Name Tom Liebert	Project No. F-1536
Company Schlegel Lining Systems	Date 2/24/88 Time 4:00
Address	[X] Telephone Conversation
	[ ] Office Conversation
Telephone No. 409-273-3066	Re: Expansion of Cap Membrane
Recorded By Ed Harris	Heleva Landfill

Mr. Liebert has studied the problems associated with the landfill cap and the possible subsidence due to various factors. He recommends that the membrane not be folded. Folds would cause localized stress cracking when the material unfolds. He recommends that the integrity of the material be depended upon to allow for as much as 15 percent elongation without overstressing the material (HDPE). Mr. Liebert has determined that 7 feet of subsidence could occur over a 1 acre area without overstressing the HDPE membrane.

-----------------------COMMUNICATION REPORT------------------------

Name: Elon Tompson, Jr.	Project No. F-1536
Company: Gundle Lining	Date 3/7/88 Time 11:00
Address: Houston, TX	[X] Telephone Conversation
	[ ] Office Conversation
Telephone No. 800-435-2008	Re: Folding HDPE - Also Had Comments on Specs
Recorded By: Jon Caime	

* Don Hildebrant will be handling the project *

Folding is a bad idea; it creates stress points. Minimum 700 percent expansion.

Comments on Spec of HDPE

13450-2

Part 3.0

Based on National Sanitation Foundation Standard 54:

Nominal Gauge 60 ± 10%
Sp. Gravity 0.94 min.

Minimum Tensile Prop.	
Min. Tensile Yield	2,400 psi
Break	4,000
Elon at Break	700
Mod. Elasticity	80,000
* Tear Resistance	45 pounds min.
Low Temp. Brittleness	112°F
Environmental Stress Crack	2,000
	Better Worst
Carbon Disp.	A-1, A-2 or A-3
Melt Index	0.3 - 0.5
Puncture Resistance *FTMS101B*	270#
Bonded Seam Strength	90% of Sheet Strength
Peel	50% of Sheet Strength

* IMPORTANT-WE HAVE 700

AR301494

Preliminary Cost Comparison

Cap Alternatives

DESCRIPTION OF SYNTHETIC CAP ALTERNATIVE

Prior to beginning cap construction the landfill must be prepared in four respects. First, the onsite pond must be pumped dry to permit the placement of common fill. It has been assumed that this surface water is uncontaminated and can be pumped to the existing pond at the northeast corner of the landfill site. Also, the existing monitoring wells within the area of work must be removed and filled per State guidelines. Third, an existing power line must be relocated to not interfere with the construction operation. Lastly, erosion control measures must be in place before earthwork construction begins. It is estimated that a system of silt fences will be installed perpendicular to surface flow paths that direct stormwater offsite to serve as erosion protection. Following this preparation the area to receive the cap will be rough graded as shown on the drawings. Common fill will be used at this stage for fill material.

The cap will be constructed in layers beginning with a select fill layer placed and compacted over the rough graded fill and existing landfill surfaces. This layer will provide a cushion for the synthetic membrane and will be devoid of large stones and other material that would damage the membrane. A heavy geotextile fabric will be placed on top of the select fill course to further protect the membrane. Next the membrane will be placed over the landfill surface. This high density polyethylene material and the geotextile below will be lapped or folded 3 feet every 100 feet of landfill face in the east - west direction. These folds will provide slack in the two sheets to allow them to adjust to future settlement as it may occur. A clean sand drainage layer will be placed over the membrane. This sand layer will be 6 inches thick and have a light weight geotextile fabric placed on top. This geotextile will separate the drainage layer from the one foot layer of overburden and topsoil. A six inch layer of common fill will be placed on top of the geotextile and followed by a six inch layer of topsoil. For these estimates topsoil is estimated as being a mixture of select fill and compost from a nearby sanitary treatment facility. The constructed landfill surface will then be seeded by hydro-seeder.

Gas vents are provided over most of the cap surface to collect methane gas from under the membrane and dissipate it into the air. These vents are spaced at 50 feet
center-to-center over the landfill.

The drawings detail the method of constructing ditches on the landfill. The ditches will be lined with rip rap. A gravel roadway and truck turnaround area are provided for use during the construction operation. An equipment washdown area is included in the roadway. This area consists of a drained wash area that directs flow to an underground tank. A pipe and valve system prevents stormwater from entering the tank. This system will be removed by the contractor at the end of the capping operation. All of the facilities will be contained inside a chain link fence. The estimate includes a 7 foot high fence topped by three strands of barbed wire.

IN PROGRESS ESTIMATE
30 % DESIGN STAGE
HELEVA LANDFILL
LEHIGH COUNTY, PENNSYLVANIA
SYNTHETIC MEMBRANE CAP ALTERNATIVE

Exc. - Cut to Fill	$64,100
Common fill	$1,032,000
Select fill	$306,600
Sand drainage layer	$409,000
Geotextile sep.	$374,600
Synthetic Membrane	$814,300
Topsoil	$204,600
Fine Grading	$182,800
Seeding	$33,700
Fencing	$70,400
Rip Rap	$15,900
Gravel Paving	$35,300
Equip. Wash Station	$5,900
Settlement Markers	$300
Gas Vents	$153,300
Pump Onsite Pond	$1,400
Erosion Control	$8,200
Remove Monitor Wells	$14,800
Reloc. Ohd. Power line	$7,500
Estimated Current Contract Costs	$3,735,000
Contingencies - 25%	$933,800
Subtotal	$4,669,000
S & A - 5.5%	$256,800
TOTAL ESTIMATED PROJECT COST	$4,926,000

--CWE--

AR301499

UNIT COST SUMMARY - SYNTHETIC CAP ALTERNATIVE

DESCRIPTION	Direct Cost	Indirect Cost 11.7%	Total Cost	No. Units	Unit Meas.	Unit Cost
Exc. - Cut to Fill	$52,159	$6,097	$58,256	19,390	cy	$3.00
Common fill	$839,819	$98,164	$937,984	92,900	cy	$10.10
Select fill	$249,550	$29,169	$278,719	16,505	cy	$16.89
Sand drainage layer	$332,898	$38,912	$371,810	16,505	cy	$22.53
Geotextile sep.	$304,928	$35,642	$340,570	1	LS	$340,570
Synthetic Membrane	$662,789	$77,472	$740,261	835,800	sf	$0.89
Topsoil	$166,532	$19,465	$185,997	16,505	cy	$11.27
Fine Grading	$148,800	$17,393	$166,193	310,000	sy	$0.54
Seeding	$27,444	$3,208	$30,652	930	msf	$32.96
Fencing	$57,284	$6,696	$63,980	1	LS	$63,980
Rip Rap	$12,929	$1,511	$14,440	700	cy	$20.63
Gravel Paving	$28,706	$3,355	$32,061	4,828	sy	$6.64
Equip. Wash Station	$4,800	$561	$5,361	1	ea	$5,361
Settlement Markers	$233	$27	$260	3	ea	$86.56
Gas Vents	$124,748	$14,582	$139,330	221	ea	$630
Pump Onsite Pond	$1,140	$133	$1,273	1	LS	$1,273
Erosion Control	$6,640	$776	$7,416	1	LS	$7,416
Remove Monitor Wells	$12,016	$1,405	$13,421	1	LS	$13,421
Reloc. Ohd. Power Line	$6,100	$713	$6,813	1	LS	$6,813

FILE: CEA1
COST ESTIMATE ANALYSIS
PROJECT: Heleva Landfill
LOCATION: Lehigh County, Pennsylvania

Invitation/Contractor

CODE: B

Effective Pricing Date

Estimator: J. Impens

Sht. of Shts.
Date Prepared 12/87

Checked: E. Harris

SYNTHETIC MEMBRANE CAP ESTIMATE*

DESCRIPTION	QUANT. No. Units	Unit Meas.	MH/ Unit	Total Hours	LABOR Unit Price	LABOR Cost	EQUIPMENT Unit Price	EQUIPMENT Cost	MATERIAL Unit Price	MATERIAL Cost	TOTAL
DIRECT COSTS TO PRIME CONTRACTOR											
SITE WORK											
Exc. - Cut to Fill	19,390	cy			0.34	$6,593	1.52	$29,473			$36,065
Compaction	19,390	cy			0.37	$7,174	0.46	$8,919			$16,094
Common fill											
Exc. - borrow	92,900	cy			0.30	$27,870	0.57	$52,953	3.00	$278,701	$359,524
Haul (2 mi. rnd trip)	92,900	cy			1.08	$100,332	1.74	$161,647			$261,979
Spread	92,900	cy			0.38	$35,302	1.00	$92,900			$128,202
Compaction	92,900	cy			0.43	$39,947	0.54	$50,166			$90,113
Select fill											
Exc. - borrow	16,505	cy			0.30	$4,951	0.57	$9,408	3.00	$49,514	$63,873
Haul (10 mi. rnd trip	16,505	cy			2.90	$47,863	6.00	$99,028			$146,891
Spread	16,505	cy			0.38	$6,272	1.00	$16,505			$22,776
Compaction	16,505	cy			0.43	$7,097	0.54	$8,913			$16,009
Sand drainage layer											
Exc. - borrow	16,505	cy			0.30	$4,951	0.57	$9,408	8.00	$132,037	$146,396
Haul (2 mi. rnd trip)	16,505	cy			2.90	$47,863	6	$99,028			$146,891
Spread	16,505	cy			0.38	$6,272	1.00	$16,505			$22,776
Compaction	16,505	cy			0.46	$7,592	0.56	$9,243			$16,835
Geotextile sep.											
Cushion layer	835,800	sf			0.05	$41,790			0.17	$151,141	$192,931
Filter layer	835,800	sf			0.05	$41,790			0.08	$70,207	$111,997
Synthetic Membrane											
80 mil HDPE	835,800	sf			0.1	$83,580			0.66	$579,209	$662,789
Topsoil (6 inch layer)											
Exc. - borrow	16,505	cy			0.30	$4,951	0.57	$9,408	4.00	$66,019	$80,378
Haul (2 mi. rnd trip)	16,505	cy			1.08	$17,825	1.74	$28,718			$46,543
Spread	16,505	cy			0.38	$6,272	1.00	$16,505			$22,776
Compaction	16,505	cy			0.46	$7,592	0.56	$9,243			$16,835
Fine Grading (3 passes/layer)	310,000	sy			0.18	$55,800	0.30	$93,000			$148,800
Seeding											
Turf mix - hydro spread incl fert. & mulch	930	msf			3.77	$3,506	4.74	$4,408	20.00	$19,530	$27,444

FILE: CEA1
COST ESTIMATE ANALYSIS
PROJECT: Heleva Landfill
LOCATION: Lehigh County, Pennsylvania

Invitation/Contractor

CODE: B

Effective Pricing Date

Estimator: J. Impens

Sht. of Shts.
Date Prepared 12/87

Checked: E. Harris

SYNTHETIC MEMBRANE CAP ESTIMATE*

DESCRIPTION	QUANT. No. Units	Unit Meas.	MH/ Unit	Total Hours	LABOR Unit Price	LABOR Cost	EQUIPMENT Unit Price	EQUIPMENT Cost	MATERIAL Unit Price	MATERIAL Cost	TOTAL
Fencing											
7 ft. w/ 3 strands	4,550	lf			2.50	$11,375			9.5	$45,386	$56,761
20 ft. gate	1	ea			50.00	$50			450	$473	$523
Rip Rap	700	cy			5.00	$3,500	4.97	$3,479	8.5	$5,950	$12,929
Gravel Paving											
Geotextile	43,450	sf			0.05	$2,173			0.08	$3,650	$5,822
Gravel Surf. 6 in.	4,828	sy			0.24	$1,159	0.30	$1,448	4.00	$20,277	$22,884
Equip. Wash Station											
Drainage Pipe 6" DIP	30	lf			3.65	$110			7.00	$221	$330
Valve	1	ea			100	$100			488.00	$512	$612
Holding Tank (2000 gal)	1	ea			400.00	$400	400.00	$400	2150.00	$2,258	$3,058
Tank Removal	1	ea			400.00	$400	400.00	$400			$800
Settlement Markers	3	ea			25.00	$75			50.00	$158	$233
Gas Vents											
Borings	5746	lf			4.50	$25,857	5.30	$30,454			$56,311
Vents	221	ea			109.05	$24,100	12.00	$2,652	179.64	$41,685	$68,438
Pump Onsite Pond (assume non-contamin.)	1	LS			650.00	$650	490.00	$490			$1,140
Erosion Control											
Silt Fence	2270	lf			0.30	$681			2.5	$5,959	$6,640
Remove Monitor Wells	1600	lf			4.14	$6,624	3.37	$5,392			$12,016
Reloc. Ohd. Power Line	1	LS			2000	$2,000	2000	$2,000	2000	$2,100	$6,100
**TOTAL DIRECT COSTS TO PRIME CONTRACTOR						$692,440		$872,090		$1,474,985	$3,039,515

CURRENT CONTRACT COST LESS PROFIT	$3,394,797
Contractor profit at 10%	$339,480
TOTAL CURRENT CONTRACT COST	$3,734,276

AR301502

FILE: CEA1
COST ESTIMATE ANALYSIS
PROJECT: Heleva Landfill
LOCATION: Lehigh County, Pennsylvania

Invitation/Contractor
CODE: B

Effective Pricing Date
Estimator: J. Impens

Sht. of Shts.
Date Prepared 12/87
Checked: E. Harris

SYNTHETIC MEMBRANE CAP ESTIMATE*

DESCRIPTION	QUANT. No. Units	Unit Meas.	MH/ Unit	Total Hours	LABOR Unit Price	LABOR Cost	EQUIPMENT Unit Price	EQUIPMENT Cost	MATERIAL Unit Price	MATERIAL Cost	TOTAL
OVERHEAD TO PRIME CONTRACTOR											
Superintendent	4	mth			3700	$14,800					$14,800
Time Keeper	4	mth			2300	$9,200					$9,200
Office Trailer & Suppli	4	mth					280	$1,120			$1,120
Telephone	4	mth					110	$440			$440
Surveying	15	day			450	$6,750					$6,750
Mobilization - Demobil.	1	LS					2070	$2,070			$2,070
Temp. Power	1	LS					1000	$1,000			$1,000
Temp Water	1	LS					120	$120			$120
Soils Testing	1	LS					15655	$15,655			$15,655
Pickup	4	mth					530	$2,120			$2,120
Toilet	4	mth					73	$292			$292
Project Sign	1	ea					350	$350			$350
Small Tools	1	LS									$22,796
Cleanup	1	LS									$7,599
Home Office Expense	1	LS									$60,790
Workman Comp., misc., and unemploy. ins.(14.3% labor)											$99,019
FICA (7.25% labor)											$50,202
Bond											$30,563
Insurance (1% direct cost)											$30,395
** TOTAL PRIME CONTR. OVERHEAD **											$355,282

TOTAL INDIRECT % = 11.7%

== Construct. to begin 4/88 and end 7/88
4 month duration

AR301503

FILE: CEA1
COST ESTIMATE ANALYSIS
PROJECT: Heleva Landfill
LOCATION: Lehigh County, Pennsylvania

Invitation/Contractor

CODE: B

Effective Pricing Date

Estimator: J. Impens

Sht. of Shts.
Date Prepared 12/87

Checked: E. Harris

SYNTHETIC MEMBRANE CAP ESTIMATE*

DESCRIPTION	QUANT. No. Units	Unit Meas.	MH/ Unit	Total Hours	LABOR Unit Price	LABOR Cost	EQUIPMENT Unit Price	EQUIPMENT Cost	MATERIAL Unit Price	MATERIAL Cost	TOTAL
BOND											
based on total directs plus ovhd less bond amount											
Total contract amount less bond	$3,364,233										
14.4/1000 first 500,000	7200										
8.7/1000 next 2 mill	17400										
6.9/1000 next 2.5 mill	5963										
TOTAL BOND EXPENSE	$30,563										

AR301504

DESCRIPTION OF THE RCRA CAP ALTERNATIVE

The difference between the RCRA Cap and the Synthetic Cap is the cap construction itself. The estimated item takeoffs are identical in all other respects. For the RCRA Cap, the site will be rough graded and filled with common fill to the same elevations as the Synthetic Cap. Clay will be brought in from a borrow source and placed in a two foot thick layer over the landfill subgrade. The clay will be placed in lifts and compacted to achieve a low permeability. A synthetic membrane will be placed on top of the clay cap. This membrane will not be lapped as with the Synthetic Cap. A one foot thick layer of clean sand will be placed over the high density polyethylene sheet. The sand drainage layer will be topped with a light weight geotextile to separate the sand from the topsoil and overburden above. An eighteen inch layer of common fill will be place over the geotextile fabric. Lastly, a six inch layer of topsoil will be placed over the common fill. Again it is estimated that the topsoil is a mixture of select fill and compost from a sanitary treatment facility nearby. The site will be seeded using a hydro-seeder.

All other components of the RCRA Cap alternative are the same as the Synthetic Cap alternative.. The site requires the same preparation and will be provided with the same fencing and erosion control.

IN PROGRESS ESTIMATE
30 % DESIGN STAGE
HELEVA LANDFILL
LEHIGH COUNTY, PENNSYLVANIA
RCRA CAP ALTERNATIVE

Exc. - Cut to Fill	$63,800
Common fill	$1,415,000
Clay cap 2′ thick	$1,415,000
Sand drainage layer 1′	$814,000
Geotextile sep.	$127,300
Synthetic Membrane	$753,500
Topsoil	$203,700
Fine Grading	$182,000
Seeding	$33,600
Fencing	$70,100
Rip Rap	$15,800
Gravel Paving	$35,100
Equip. Wash Station	$5,900
Settlement Markers	$300
Gas Vents	$141,300
Pump Onsite Pond	$1,400
Erosion Control	$8,100
Remove Monitor Wells	$14,700
Relo. ohd. power line	$7,500
Estimated Current Contract Costs	$5,308,000
Contingencies - 25%	$1,327,000
Subtotal	$6,635,000
S & A - 5.5%	$364,900
TOTAL ESTIMATED PROJECT COST --CWE--	$7,000,000

AR301506

UNIT COST SUMMARY - RCRA CAP ALTERNATIVE

DESCRIPTION	Direct Cost	Indirect Cost 11.2%	Total Cost	No. Units	Unit Meas.	Unit Cost
Exc. - Cut to Fill	$52,159	$5,827	$57,986	19,390	cy	$2.99
Common fill	$1,157,124	$129,274	$1,286,397	128,000	cy	$10.05
Clay cap 2' thick	$1,156,775	$129,235	$1,286,010	71,760	cy	$17.92
Sand drainage layer 1'	$665,615	$74,362	$739,978	33,000	cy	$22.42
Geotextile sep.	$104,118	$11,632	$115,750	1	LS	$115,750
Synthetic Membrane	$616,161	$68,837	$684,998	777,000	sf	$0.88
Topsoil	$166,532	$18,605	$185,137	16,505	cy	$11.22
Fine Grading	$148,800	$16,624	$165,424	310,000	sy	$0.53
Seeding	$27,444	$3,066	$30,510	930	msf	$32.81
Fencing	$57,284	$6,400	$63,683	1	LS	$63,683
Rip Rap	$12,929	$1,444	$14,373	700	cy	$20.53
Gravel Paving	$28,706	$3,207	$31,913	4,828	sy	$6.61
Equip. Wash Station	$4,800	$536	$5,336	1	ea	$5,336
Settlement Markers	$233	$26	$258	3	ea	$86.16
Gas Vents	$115,527	$12,907	$128,433	221	ea	$581
Pump Onsite Pond	$1,140	$127	$1,267	1	LS	$1,267
Erosion Control	$6,640	$742	$7,382	1	LS	$7,382
Remove Monitor Wells	$12,016	$1,342	$13,358	1	LS	$13,358
Relo. ohd. power line	$6,100	$681	$6,781	1	LS	$6,781

LE: CEA2
COST ESTIMATE ANALYSIS
)JECT: Heleva Landfill
:ATION: Lehigh County, Pennsylvania

Invitation/Contractor

CODE: B

Effective Pricing Date

Estimator: J. Impens

Sht. of Shts.
Date Prepared 12/87

Checked: E. Harris

*RCRA CAP ESTIMATE****

DESCRIPTION	QUANT. No. Units	Unit Meas.	MH/ Unit	Total Hours	LABOR Unit Price	LABOR Cost	EQUIPMENT Unit Price	EQUIPMENT Cost	MATERIAL Unit Price	MATERIAL Cost	TOTAL
IRECT COSTS TO PRIME CONTRACTOR											
:TE WORK											
:c. - Cut to Fill	19,390	cy			0.34	$6,593	1.52	$29,473			$36,065
Compaction	19,390	cy			0.37	$7,174	0.46	$8,919			$16,094
mmon fill											
Exc. - borrow	128,000	cy			0.30	$38,400	0.57	$72,960	3.00	$384,001	$495,362
Haul (2 mi. rnd trip)	128,000	cy			1.08	$138,240	1.74	$222,721			$360,961
Spread	128,000	cy			0.38	$48,640	1.00	$128,000			$176,641
Compaction	128,000	cy			0.43	$55,040	0.54	$69,120			$124,160
ay cap 2' thick											
Exc. - borrow	71,760	cy			0.30	$21,528	0.57	$40,903	4.00	$287,041	$349,472
Haul (10 mi. rnd trip	71,760	cy			2.90	$208,105	6.00	$430,562			$638,666
Spread	71,760	cy			0.38	$27,269	1.00	$71,760			$99,029
Compaction	71,760	cy			0.43	$30,857	0.54	$38,751			$69,607
nd drainage layer 1'											
Exc. - borrow	33,000	cy			0.30	$9,900	0.57	$18,810	8.00	$264,002	$292,712
Haul (10 mi. rnd trip	33,000	cy			2.90	$95,701	6.00	$198,002			$293,702
Spread	33,000	cy			0.38	$12,540	1.00	$33,000			$45,540
Compaction	33,000	cy			0.46	$15,180	0.56	$18,480			$33,660
otextile sep. Filter layer	777,000	sf			0.05	$38,850			0.08	$65,268	$104,118
nthetic Membrane 80 mil HDPE	777,000	sf			0.1	$77,700	-		0.66	$538,461	$616,161
psoil (6 inch layer)											
Exc. - borrow	16,505	cy			0.30	$4,951	0.57	$9,408	4.00	$66,019	$80,378
Haul (2 mi. rnd trip)	16,505	cy			1.08	$17,825	1.74	$28,718			$46,543
Spread	16,505	cy			0.38	$6,272	1.00	$16,505			$22,776
Compaction	16,505	cy			0.46	$7,592	0.56	$9,243			$16,835
ne Grading (3 passes/layer)	310,000	sy			0.18	$55,800	0.30	$93,000			$148,800
eding											
Turf mix - hydro spread incl fert. & mulch	930	msf			3.77	$3,506	4.74	$4,408	20.00	$19,530	$27,444

ILE: CEA2
COST ESTIMATE ANALYSIS
ROJECT: Heleva Landfill
CATION: Lehigh County, Pennsylvania

Invitation/Contractor

CODE: B

Effective Pricing Date

Estimator: J. Impens

Sht. of Shts.
Date Prepared 12/87

Checked: E. Harris

RCRA CAP ESTIMATE**

DESCRIPTION	QUANT. No. Units	Unit Meas.	MH/ Unit	Total Hours	LABOR Unit Price	LABOR Cost	EQUIPMENT Unit Price	EQUIPMENT Cost	MATERIAL Unit Price	MATERIAL Cost	TOTAL
'encing											
7 ft. w/ 3 strands	4,550	lf			2.50	$11,375			9.5	$45,386	$56,761
20 ft. gate	1	ea			50.00	$50			450	$473	$523
ip Rap	700	cy			5.00	$3,500	4.97	$3,479	8.5	$5,950	$12,929
ravel Paving											
Geotextile	43,450	sf			0.05	$2,173			0.08	$3,650	$5,822
Gravel Surf. 6 in.	4,828	sy			0.24	$1,159	0.30	$1,448	4.00	$20,277	$22,884
quip. Wash Station											
Drainage Pipe 6" DIP	30	lf			3.65	$110			7.00	$221	$330
Valve	1	ea			100	$100			488.00	$512	$612
Holding Tank (2000 gal)	1	ea			400.00	$400	400.00	$400	2150.00	$2,258	$3,058
Tank Removal	1	ea			400.00	$400	400.00	$400			$800
ettlement Markers	3	ea			25.00	$75			50.00	$158	$233
as Vents											
Borings	5746	lf			4.50	$25,857	5.30	$30,454			$56,311
Vents	221	ea			109.05	$24,100	12.00	$2,652	139.90	$32,464	$59,216
mp Onsite Pond (assume non-contamin.)	1	LS			650.00	$650	490.00	$490			$1,140
osion Control											
Silt Fence	2270	lf			0.30	$681			2.50	$5,959	$6,640
move Monitor Wells	1600	lf			4.14	$6,624	3.37	$5,392			$12,016
lo. ohd. power line	1	LS			2000	$2,000	2000	$2,000	2000	$2,100	$6,100
						===========		===========		===========	===========
TAL DIRECT COSTS TO PRIME CONTRACTOR						$1,006,917		$1,589,458		$1,743,727	$4,340,102

CURRENT CONTRACT COST LESS PROFIT	$4,824,977
Contractor profit at 10%	$482,498
	===========
TOTAL CURRENT CONTRACT COST	$5,307,475

AR301509

FILE: CEA2
COST ESTIMATE ANALYSIS
PROJECT: Heleva Landfill
LOCATION: Lehigh County, Pennsylvania

Invitation/Contractor

CODE: B

Effective Pricing Date

Estimator: J. Impens

Sht. of Shts.
Date Prepared 12/87

Checked: E. Harris

RCRA CAP ESTIMATE*

DESCRIPTION	QUANT. No. Units	Unit Meas.	MH/ Unit	Total Hours	LABOR Unit Price	LABOR Cost	EQUIPMENT Unit Price	EQUIPMENT Cost	MATERIAL Unit Price	MATERIAL Cost	TOTAL
OVERHEAD TO PRIME CONTRACTOR											
Superintendent	4	mth			3700	$14,800					$14,800
Time Keeper	4	mth			2300	$9,200					$9,200
Office Trailer & Suppli	4	mth					280	$1,120			$1,120
Telephone	4	mth					110	$440			$440
Surveying	15	day			450	$6,750					$6,750
Mobilization - Demobil.	1	LS					2070	$2,070			$2,070
Temp. Power	1	LS					1000	$1,000			$1,000
Temp Water	1	LS					120	$120			$120
Soils Testing	1	LS					15655	$15,655			$15,655
Pickup	4	mth					530	$2,120			$2,120
Toilet	4	mth					73	$292			$292
Project Sign	1	ea					350	$350			$350
Small Tools	1	LS									$32,551
Cleanup	1	LS									$10,850
Home Office Expense	1	LS									$86,802
Workman Comp., misc., and unemploy. ins.(14.3% labor)											$143,989
FICA (7.25% labor)											$73,001
Bond											$40,364
Insurance (1% direct cost)											$43,401
											===========
** TOTAL PRIME CONTR. OVERHEAD **											$484,875

TOTAL INDIRECT % = 11.2%

** Construct. to begin 4/88 and end 7/88
4 month duration

==

AR301510

FILE: CEA2
COST ESTIMATE ANALYSIS
PROJECT: Heleva Landfill
LOCATION: Lehigh County, Pennsylvania

Invitation/Contractor

CODE: B

Effective Pricing Date

Estimator: J. Impens

Sht. of Shts.
Date Prepared 12/87

Checked: E. Harris

RCRA CAP ESTIMATE*

DESCRIPTION	QUANT. No. Units	Unit Meas.	MH/ Unit	Total Hours	LABOR Unit Price	LABOR Cost	EQUIPMENT Unit Price	EQUIPMENT Cost	MATERIAL Unit Price	MATERIAL Cost	TOTAL
BOND											
based on total directs plus ovhd less bond amount											
Total contract amount less bond	$4,784,613										
14.4/1000 first 500,000	7200										
8.7/1000 next 2 mill	17400										
6.9/1000 next 2.5 mill	15764										
TOTAL BOND EXPENSE	$40,364										

AR301511

IV. GRADING EVALUATION AND DRAINAGE DESIGN

The following information presents a summary of the general grading options evaluated and the recommended option. Although four options were considered, Option 4 was rejected early in the process and consequently a final concept layout drawing was not produced. For informational purposes, a layout drawing for the other three options and some general sections have been included with this design memo.

A. OPTION NO. 1

Option No. 1 involves filling the landfill site to form a dome allowing rainfall to run across the cap to either Todd Lake or the northeast pond. A ridge will be made at the high point of the landfill near Todd Lake. This ridge will essentially divide the runoff flow into two directions. The majority of the runoff will collect in Todd Lake and in the northeast pond with minor amounts reaching other areas. The effect of Option No. 1 is to shed water off of the landfill cap.

A great deal of fill will be required to elevate this area to an allowable slope. It is estimated that 128,700 cubic yards of fill will be required to implement this option. The ridge between the landfill and the northeast Pond will have to be removed and some of the landfill near Todd Lake will have to be leveled to create a sheet flow. This cut is approximately 5200 cubic yards and if this material proves suitable, it can be used for make-up fill material.

This option should not require any engineered ditches within the landfill. Should it be selected for final design, some ditches outside the limits of the cap may be required. In addition to the large amount of fill, this option has the disadvantage that runoff is allowed to run across the cap for long distances. The runoff has a greater chance to percolate through the cap and into the landfill underneath.

4.2 OPTION NO. 2

This option consists of creating a ridge in the center of the landfill so that the runoff will flow away from the centers of the landfill and towards the sides of the cap. Engineered trenches will be provided at the sides of the cap to collect the runoff and channel it towards the northeast pond.

The creation of a ridge together with the fill required to bring the collection pond and other low areas up to the designed elevation will require an estimated 220,592 cubic yards of fill. The ridge that divides the landfill and the northeast pond will have to be removed in this option. This ridge will amount to about 8120 cubic yards of cut material. If this material proves suitable, it can be used in the fill operation.

Approximately 2,000 linear feet of engineered trenching will be required for this option. In addition to the expense of providing trenches, another disadvantage to this option is that a large amount of fill is required. An advantage to this option is the fact that the runoff will be directed away from the center of the cap which will minimize the amount of time runoff will be on the cap. This reduction of time that the runoff will be on the cap will result in less possibility for runoff to seep through the cap into the landfill below.

4.3 OPTION NO. 3

In this option limited changes will be made to the existing contour layout. A north-south ridge will be graded to direct runoff toward either Todd Lake or to the northeast pond. The flow that will be directed towards the northeast pond will be channeled into engineered ditches that will be lined with rip rap and tied into the landfill cap by an impermeable liner. The ditches will discharge the runoff to the northeast pond.

The approximate fill quantity for this option is estimated at 25,000 cubic yards. This fill is required to form the ridge and for filling the collection pond and general low spots. The existing ridge that divides the landfill and the northeast pond will have to be removed. It is assumed that some high spots can be lowered and that some cutting into the existing landfill material can occur. This cut amounts to 8037 cubic yards and can be used as fill if it proves suitable.

The primary advantage to this option is that less change is required in the existing topography resulting in a smaller amount of fill required than the other three options. Also, runoff will exit from the cap quickly and enter the ditches which will minimize the chance of runoff getting through the cap and into the landfill below.

This option has the disadvantage that runoff is directed towards the center of the cap instead of away from the center. Engineered ditches will also have to be designed and constructed which add some cost but should control any infiltration associated with the center ditch.

4.4 OPTION NO. 4

In this option, a large amount of fill will need to be placed so that a dome will be created to shed runoff to the nearest cap edge. Any runoff will flow off the cap relatively rapidly. The area of the landfill near Todd Lake will be sloped so that runoff will flow towards Todd Lake in that area. The runoff near the northeast pond will flow towards the northeast pond. Therefore, the ridge between the northeast pond and the landfill will have to be removed. Runoff near the center of the landfill will flow north towards Hill Street or south to the opposite side of the landfill. This option will require 505,555 cubic yards of fill to create the dome. The cut is very minimal. No engineered ditches should be required for this option on the cap.

Runoff will flow off the landfill rapidly and have less of a chance to percolate through the landfill cap. The primary disadvantage to this option is the fact that the large amount of fill will require a great deal of time and money to place and increase the anticipated settlement.

Although the dome construction of Option No. 4 meets all the requirements for a RCRA landfill closure, the expense involved with providing such a large quantity of fill is prohibitive. For this reason Option No. 4 is not included in the conceptual drawing package and is removed from further consideration.

4.5 CONCLUSION

All four of the options described above provide a technically acceptable landfill closure and capping system. The severe relief on the Heleva site makes the more normal dome closures prohibitively expensive and difficult to construct. Large quantities of fill would be required for this type of closure and this fill material is does not appear to be available either on-site or nearby the site. The two major cost items that differ in the options are the fill and the engineered ditches on the cap. These are summarized in Table 2. A comparison of the alternative options shows that Option No. 3 involves the least amount of fill and should be the easiest to construct and least expensive. It also will limit the additional loading on the base.

This option does have the negative aspect that storm runoff is directed toward the center of the cap instead of shedding the runoff to the sides. This negative aspect can be overcome by constructing a high quality cap along with well planned and designed ditches to carry the flow on the cap interior. For these reasons Option No. 3 is recommended for selection as the subgrade grading option.

TABLE 2

HELEVA LANDFILL SUPERFUND SITE

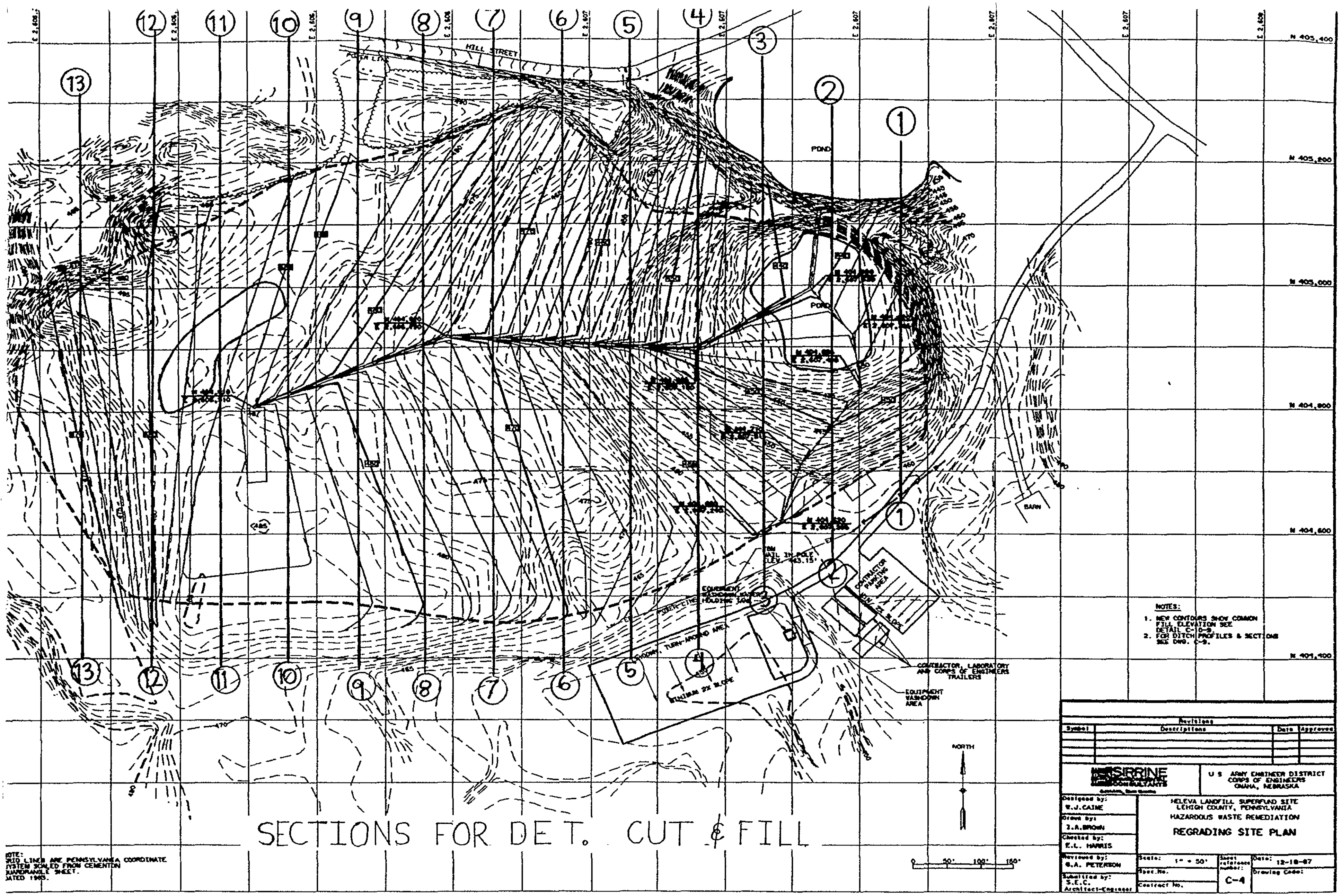
OPTION NO.	FILL (CY)	CUT (CY)	FILL COST ($)	ENGINEERED DITCH ($)
1	128,700	5,200	1,512,225	0
2	220,592	8,120	2,600,749	20,000
3	25,000	8,037	302,590	20,000
4	505,555	Minimal	5,940,271	0

GRADING CALCULATIONS

SIRRINE ENVIRONMENTAL CONSULTANTS

HELEVA LANDFILL SUPERFUND SITE - Cut & Fill

Section #	Cut (ft²)	Fill (ft²)	Avg. (ft²) x 100 ft ÷ 27 ft³/cy =	c.y. cut	c.y. fi
1	0	3290			
2	265	5625		490	16510
3	160	4350		790	1847[illegible]
4	460	2448		1150	12590
5	600	1500		1960	7310
6	650	1150		2315	4910
7	250	850		1670	3705
8	0	1500		460	4350
9	0	2000		0	6480
10	0	1550		0	6575
11	1150	700		2130	416[illegible]
12	1150	200		4260	1665
13	1100	300		4165	9[illegible]5
				19390	87660



NOTES:
1. NEW CONTOURS SHOW COMMON FILL ELEVATION SEE DETAIL C-9.
2. FOR DITCH PROFILES & SECTIONS SEE DWG. C-9.

NOTE:
GRID LINES ARE PENNSYLVANIA COORDINATE SYSTEM SCALED FROM CEMENTON QUADRANGLE SHEET. DATED 1965.

Revisions			
Symbol	Descriptions	Date	Approved

SIRRINE CONSULTANTS

U S ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
OMAHA, NEBRASKA

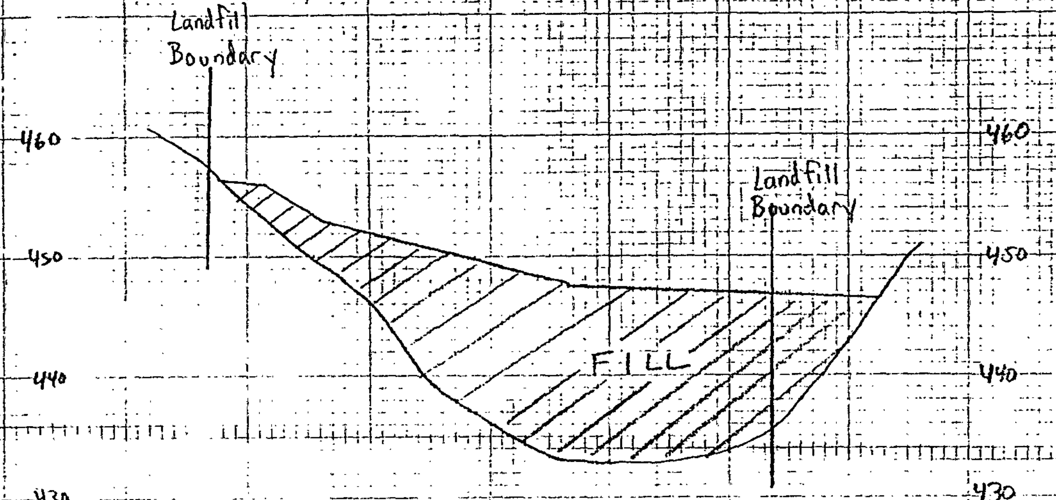
HELEVA LANDFILL SUPERFUND SITE
LEHIGH COUNTY, PENNSYLVANIA
HAZARDOUS WASTE REMEDIATION

REGRADING SITE PLAN

Designed by: W.J.CAINE
Drawn by: J.A.BROWN
Checked by: E.L. HARRIS
Reviewed by: G.A. PETERSON
Submitted by: S.E.C. Architect-Engineer
Scale: 1" = 50'
Spec.No.
Contract No.
Sheet reference number: C-4
Date: 12-18-87
Drawing Code:

AR301519

HELEVA LANDFILL SUPERFUND SITE



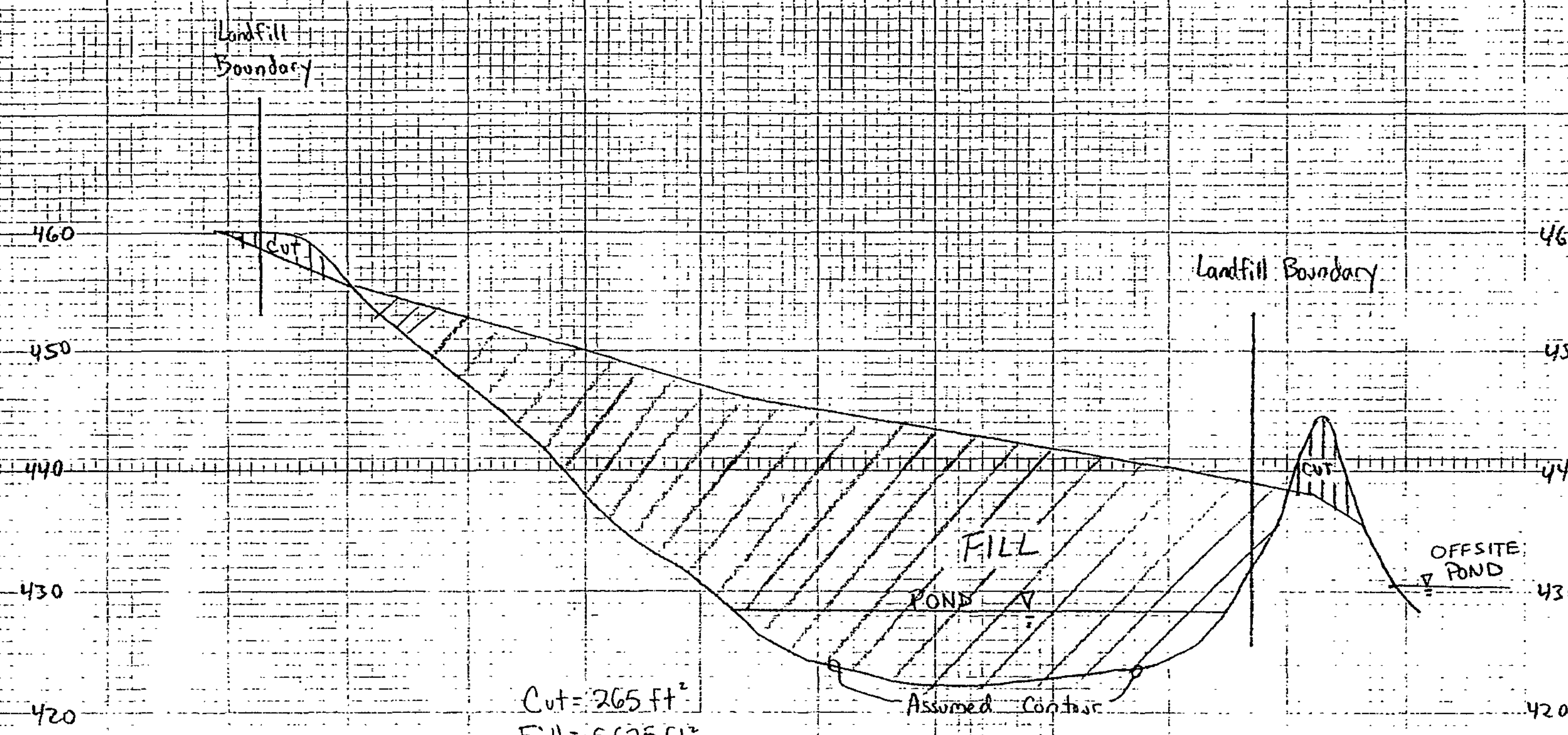
Fill = 3290 ft²

Section #1

Horizontal Scale 1" = 50'
Vertical Scale 1" = 10'

1/28/85

HELEVA LANDFILL SUPERFUND SITE

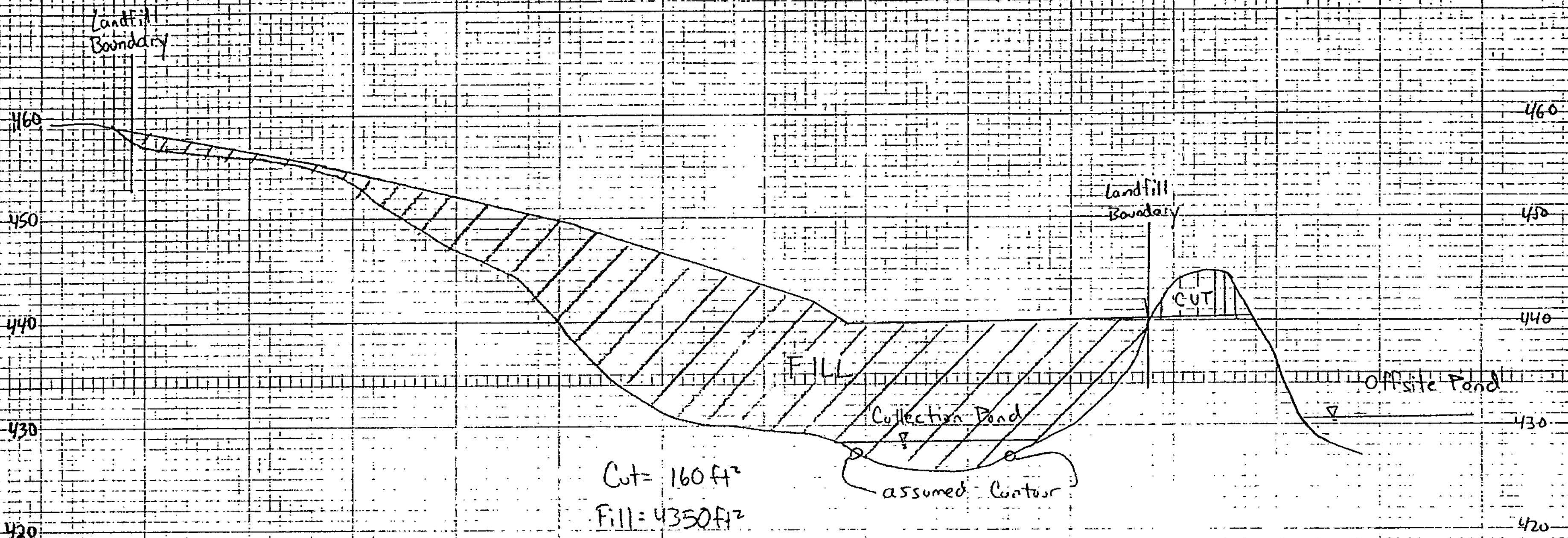


Cut = 265 ft^2
Fill = 5625 ft^2

Section # 2
Horizontal Scale 1" = 50'
Vertical Scale 1" = 10'

Jon [signature]
1/28/88

HELEVA LANDFILL SUPERFUND SITE

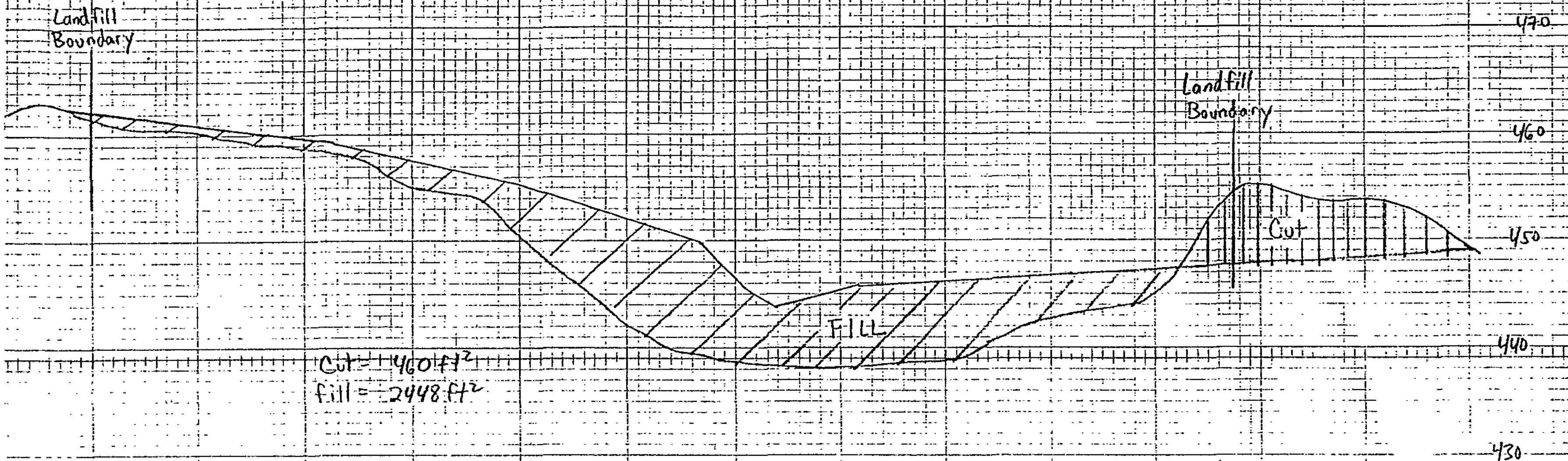


Cut = 160 ft^2
Fill = 4350 ft^2

Section #3
Horizontal Scale 1" = 50'
Vertical Scale 1" = 10'

[signature] 1/28/88

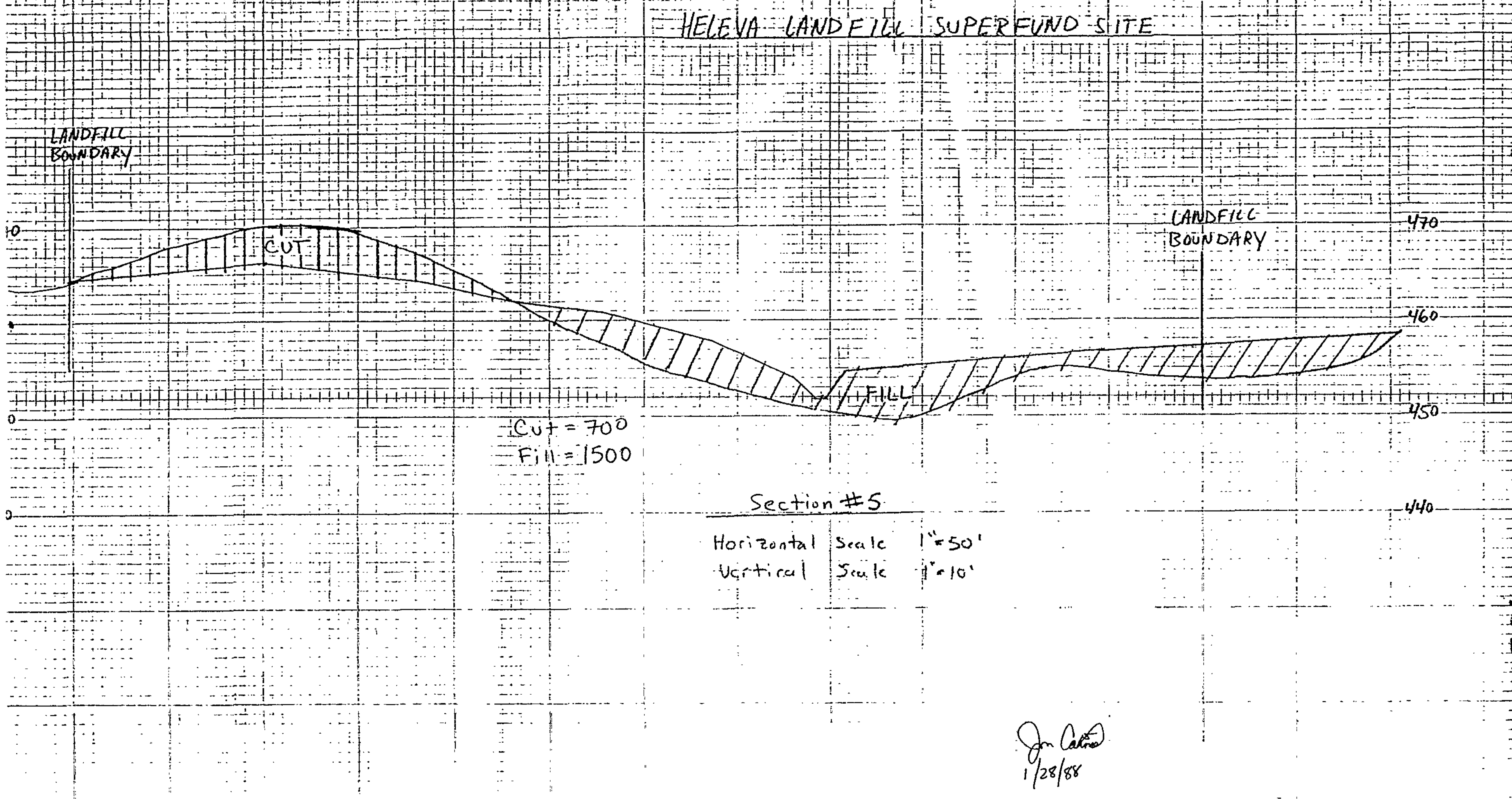
HEUEVA LANDFILL SUPERFUND SITE



Section #4

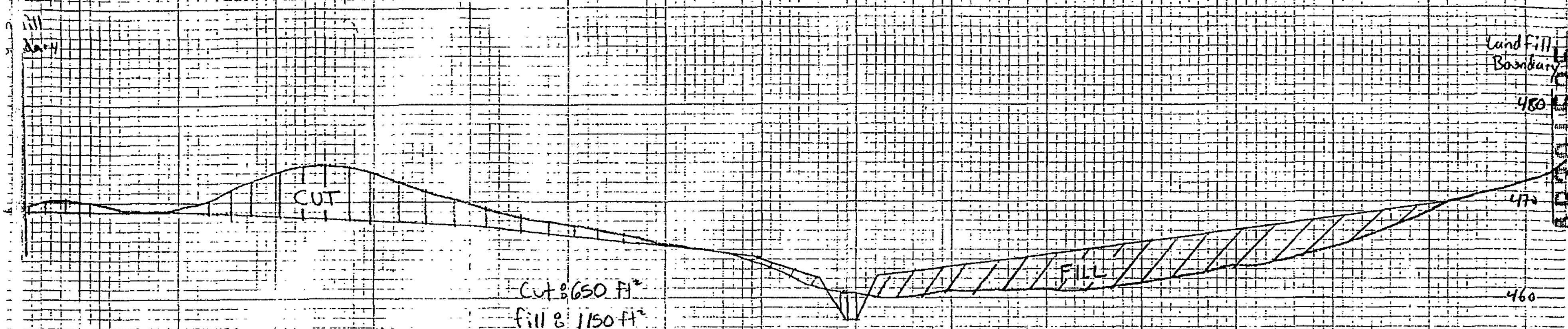
Horizontal Scale: 1" = 50'
Vertical Scale 1" = 10'

1/28/88


HELEVA LANDFILL SUPERFUND SITE
LANDFILL BOUNDARY
CUT
FILL
LANDFILL BOUNDARY
470
460
450
440
Cut = 700
Fill = 1500
Section #5
Horizontal Scale 1" = 50'
Vertical Scale 1" = 10'
1/28/88

AR301524

HELEVA LANDFILL SUPERFUND SITE



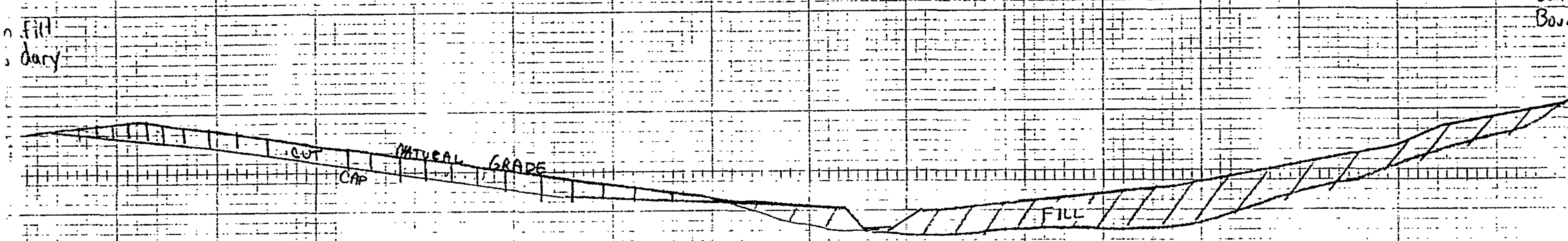
Section #6

Horizontal Scale 1" = 50'

Vertical Scale 1" = 10'

1/28/88

HELEVA LANDFILL SUPERFUND SITE



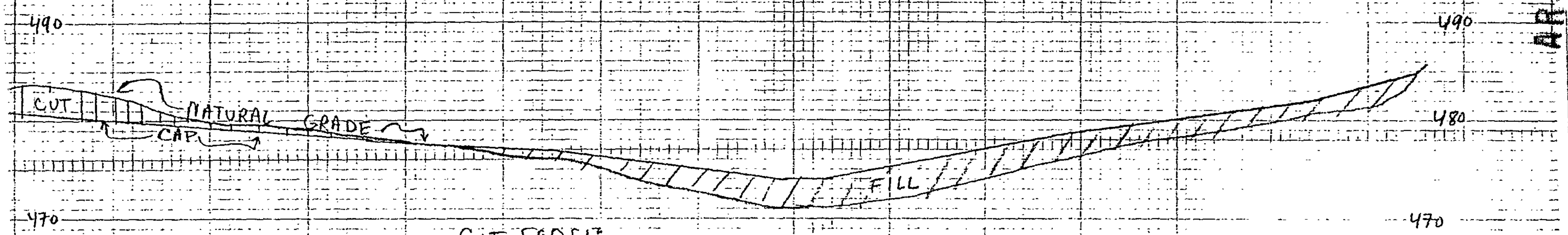
Cut = 1450 ft²
Fill = 850 ft²

Section #7

Horizontal Scale 1" = 50'
Vertical Scale 1" = 10'

Jim [signature]
4/28/88

HELEVA LANDFILL SUPERFUND SITE



CUT = 500 ft²

FILL = 1250

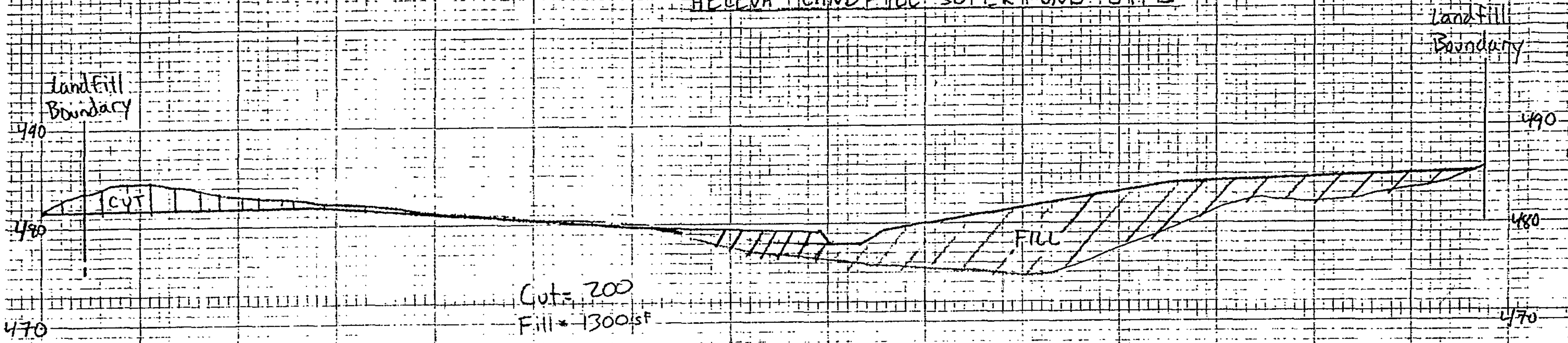
Section #8

Horizontal Scale 1" = 50'

Vertical Scale 1" = 10'

[signature] 1/28/88

HELEVA LANDFILL SUPERFUND SITE

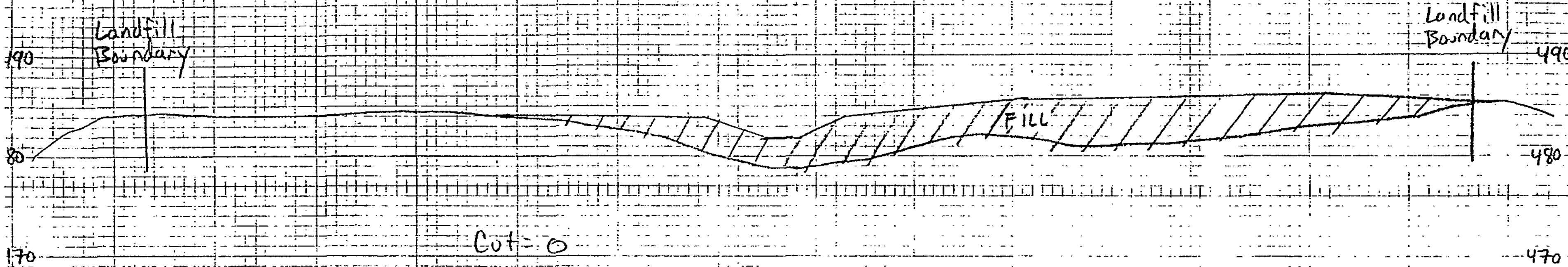


Section #9

Horizontal Scale 1" = 50'
Vertical Scale 1" = 10'

1/28/88

HELEVA LANDFILL SUPERFUND SITE



Cut = 0

Fill = 1550 sf

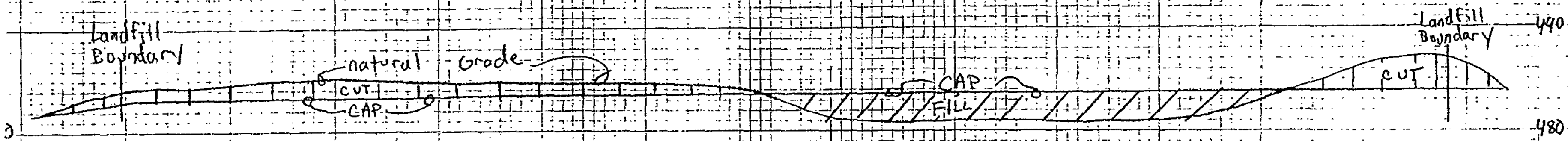
Section # 10

Horizontal Scale 1" = 50'

Vertical Scale 1" = 10'

Jon Castro
1/28/88

HELEVA LANDFILL SUPERFUND SITE

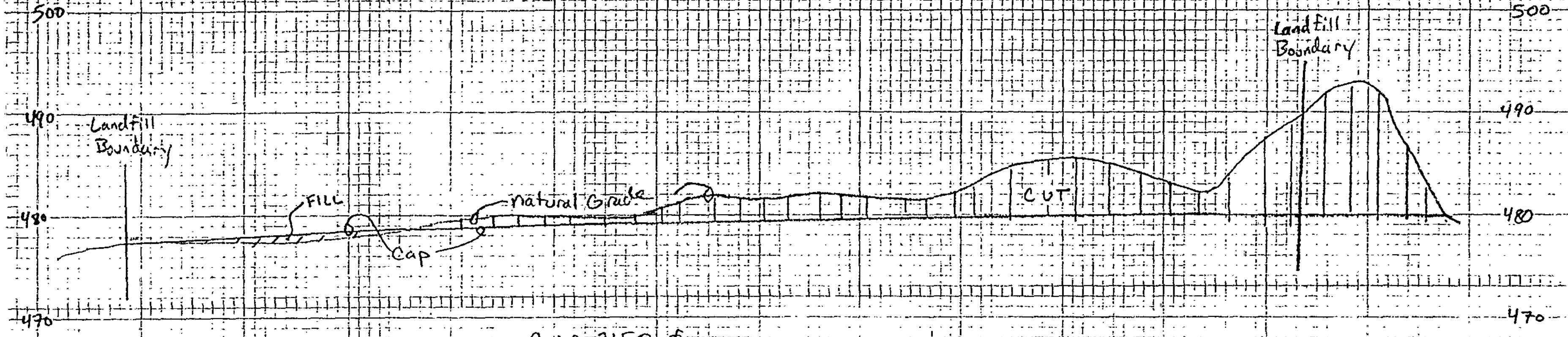


Cut: 1200 sf
Fill: 700 sf

Section #11
Horizontal scale 1" = 50'
Vertical scale 1" = 10'

1/28/88

HELEVA LANDFILL SUPERFUND SITE



Cut: 2150 sf.
Fill: 200 s.f.

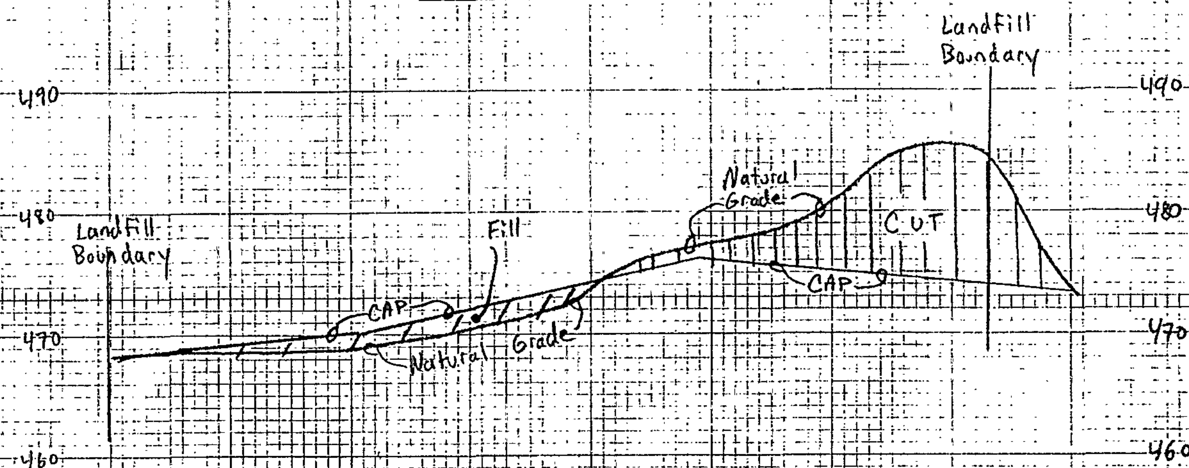
Section #12

Horizontal Scale 1" = 50'
Vertical Scale 1" = 10'

1/28/88

AR301531

HELEVA LANDFILL SUPERFUND SITE



Cut: 1100 s.f.
Fill: 300 s.f.

Section #13
Horizontal Scale 1"=50'
Vertical Scale 1"=10'

1/28/88

AR301532

DRAINAGE CALCULATIONS

SIRRINE ENVIRONMENTAL CONSULTANTS

CALCULATION SHEET

CLIENT Helen Landfill Superfund LOCATION Lehigh County Pa JOB NO. F-1536

SUBJECT Ditch #1 Sizing

BY Jon Caime DATE 12/7/87 CHECKED BY E. Harris DATE 3/1/88

From ~~Design~~ p. 18-01 fig C.:

Rainfall expected once in 50 years: 2.90 inches

Height of most remote point above outlet: 48 ft.

Maximum Length of travel: 560 ft.

From figure 1 attached: $T_c = 2.6$ min.

So use as minimum: 10 min

From Airfield Drainage figure attached: $i = 6.85$

From Design p. 18-02 Table B:

Earth surface - loam - light vegetation $c = 0.10 - 0.45$

use $c = 0.35$

$Q = Aci$

$A = 11.0$ Ac

$c = 0.35$

$i = 6.85$

$Q = (11.0)(0.35)(6.85) = 26.4$ cfs

SIRRINE ENVIRONMENTAL CONSULTANTS

CALCULATION SHEET

CLIENT [illegible] LOCATION lehigh County, Pa JOB NO. F-1536

SUBJECT Ditch Sizing

BY JC DATE 12/8/87 CHECKED BY E. Harris DATE 3/1/88

With a computer program developed by SEC that utilizes Manning's equation:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

the above value for Q (flow), n (0.035 for Rip Rap), S (Slope of varying degrees as shown below) A (Area - by using various sizings below), R (hydraulic radius determined by using the various sizings below) were analyzed to determine the optimum ditch characteristics.

VARIABLES

Side slope in all trials: 3:1

Number of iterations of each trial: 20

	trial #1	trial #2	trial #3
Bottom width:	5 ft	5 ft	5 ft
Bottom slope:	8%	5%	4%

AR301535

Results:

velocity:	6.96 ft/sec	6 ft/sec	5.5 ft/sec
depth of flow:	0.64 ft	0.6 ft	0.7 ft

AR301535

SIRRINE ENVIRONMENTAL CONSULTANTS

CALCULATION SHEET

CLIENT Hilon LOCATION JOB NO. 1536

SUBJECT Ditch sizing

BY JC DATE 12/8/87 CHECKED BY [illegible] DATE 3/1/88

Trial #:	4	5	6	7
Bottom width:	3 ft.	3 ft	3 ft	4 ft
Bottom slope:	5%	4%	3%	3%
Results				
Velocity:	6.2 ft/sec	5.7 f/s	5.2 f/s	5.1 f/s
depth of flow:	0.8 ft	0.83 ft	0.9 ft	0.8 ft

Trial #7 was selected for large ditch.

This ditch will have a 4 ft wide bottom and the bottom slope will vary due to design constraints.

SIRRINE ENVIRONMENTAL CONSULTANTS

CALCULATION SHEET

CLIENT Heleva Landfill Superfund Site LOCATION Lehigh Co Pa. JOB NO. F-1576

SUBJECT Ditch # 2 sizing

BY J. Caime DATE 12/7/87 CHECKED BY E. Harris DATE 3/1/88

From Design p. 18-01 fig. C.:

Rainfall expected once in 50 years: 2.90 inches

Height of most remote point above outlet: 26 ft.

Maximum length of travel: 360 ft

From fig. 1 attached: $T_c = 2.0$ min

so use as minimum: 10 min

From Airfield Drainage figure attached: $i = 6.85$

From Design p. 1802 Table B:

Earth surface – loam – light vegetation $c = 0.10 - 0.45$
use $c = 0.35$

$Q = cAi$
$A = 2.11$ Ac
$c = 0.35$
$i = 6.85$

$Q = (2.11)(0.35)(6.85) = 5.1$ c.f.s.

SIRRINE ENVIRONMENTAL CONSULTANTS

CALCULATION SHEET

CLIENT Ho'ola LOCATION JOB NO. 1536

SUBJECT Liner Sizing

BY JC DATE 12/8/87 CHECKED BY E. Harris DATE 3/1/88

Again by using the computer program developed by SEC that utilizes mannings equation:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

with Q = 5.1 cfs
n = 0.035 for RipRap
A = Area by trial sizing
R = hydraulic radius by trial sizing
S = slope by trial sizing

we determined the optimum ditch characteristics.

Trial # 1

1) V-bottom ditch with sides sloped at 3:1
2) 20 iterations
3) bottom slope of 4%

Results:
velocity: 3.9 ft/sec
depth of flow: 0.66 ft

Trial # 1 is sufficiently adequate.

DRAINAGE — RUNOFF — I

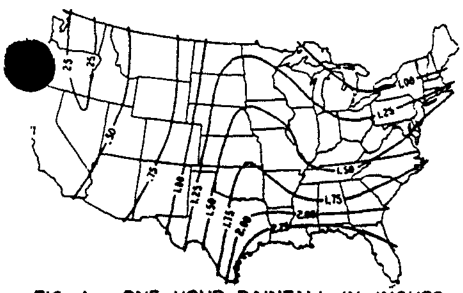


FIG. A. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 2 YEARS.

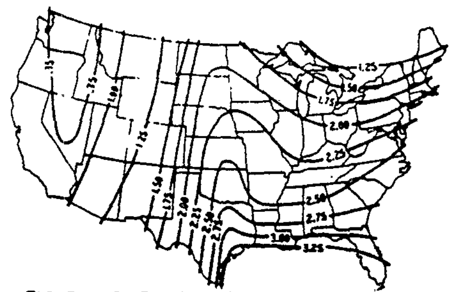


FIG. B. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 10 YEARS.

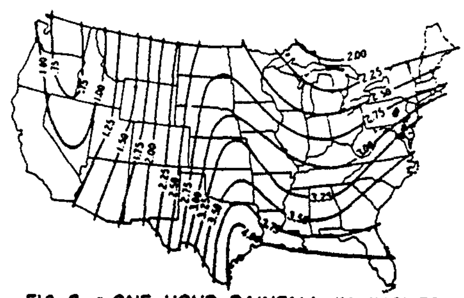


FIG. C. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 50 YEARS.

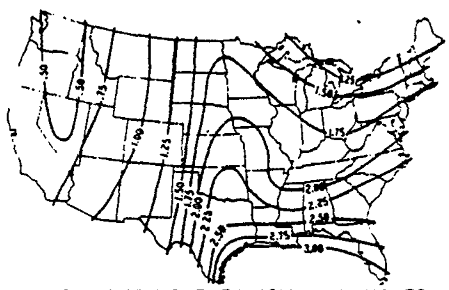


FIG. D. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 5 YEARS.

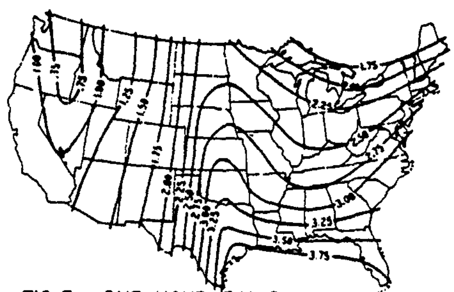


FIG. E. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 25 YEARS.

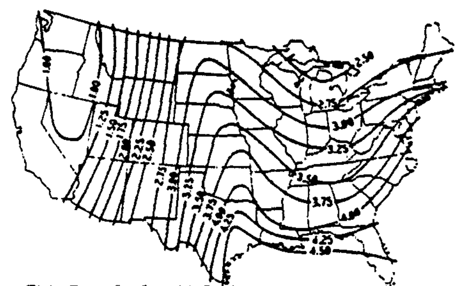


FIG. F. - ONE-HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 100 YEARS.

COMPUTATION OF i IN RATIONAL FORMULA.

EXAMPLE: Assume expectancy period = 5 years, see Fig. D, assume locality, find 1 hour intensity = 1.75 in. per hour.

FIG. G - INTENSITY EXPECTATION FOR ONE-HOUR RAINFALL.*

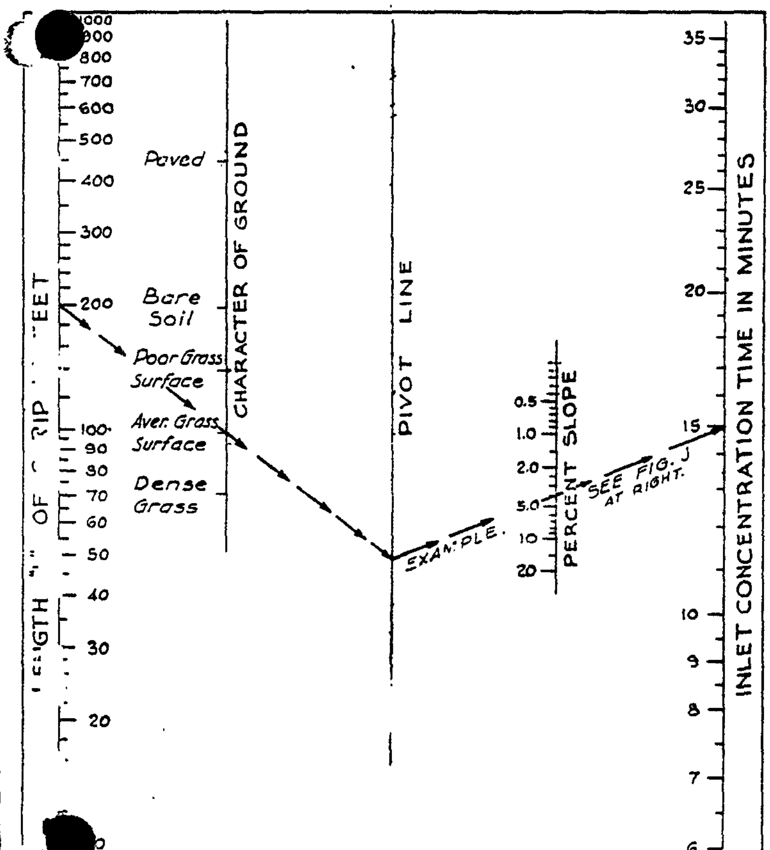


FIG. H - OVERLAND FLOW TIME.

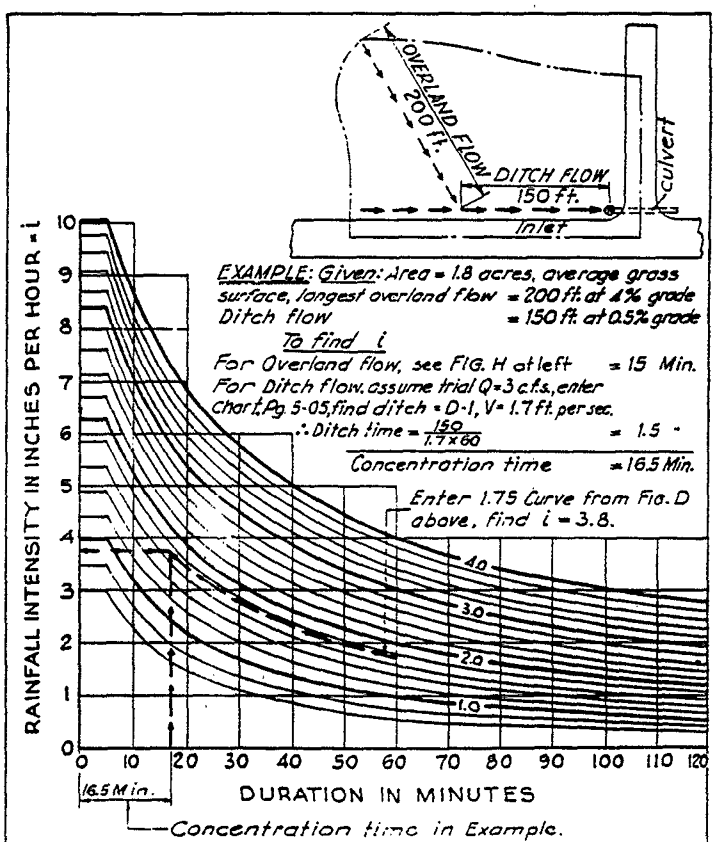


FIG. J - VALUES OF i RAINFALL INTENSITY-DURATION.+

* Reproduced from Miscellaneous Publication No. 204, U.S. Dept. of Agriculture, by David L. Yarnell.
\+ Adapted from Engineering Manual of the War Department, Part XIII, Chap. 1, Dec. 45.

Q=Aci RATIONAL FORMULA (Logical approach).

Q = RUNOFF = Peak discharge of watershed in cubic feet per second (c.f.s.) due to maximum storm assumed. See Figs. A to F, Pg. 18-01 (Usually 10 – 25 years).

A = Area of watershed in acres.

C = Coefficient of runoff, Table B below (Measure of losses due to infiltration, etc.).

i = Intensity of rainfall in inches per hour based on concentration time. See Pg. 18-01

Concentration time = time required for rain falling at most remote point to reach discharge point. Concentration time may include Overland flow time, Fig. H, Pg. 18-01, and Channel flow time, Pg. 18-05, 18-06, 18-69 and 18-71.

TABLE A-COMPUTATION FORM FOR RATIONAL FORMULA.

LOCATION			A			TIME OF FLOW - MIN.					DESIGN						PROFILE				
STREET	FROM	TO	INCREMENT	TOTAL	C	TO INLET	IN CHANNEL	TIME OF CONC	i *	Q c.f.s.	CHANNEL OR PIPE SIZE	SLOPE ft. per ft.	n	CAPACITY FULL c.f.s.	V ft. per Sec.	LENGTH ft.	FALL ft.	OTHER LOSSES ft. †	INV. ELEV. UPPER END	INV. ELEV LOWER END
FIRST ST.	A	B	1.8	1.8	.44	16.5	0.3	16.5	3.8	3.0	15"	.008	.015	4.6	3.9	60	0.48	0	82.00	81.52
MAIN RD.	B	C	1.9	3.7	.50		2.5	16.8	3.7	6.8	D-2	.011	.030	12.0	2.8	420	4.62	0	81.52	76.90
" "	C	D	2.0	5.7	.50		1.8	19.3	3.5	10.0	21"	.007	.015	11.1	4.5	480	3.36	2.20	74.70	70.34

*Note that the sequence of design as in example, Fig. J, Pg. 18-01 involves trial assumptions in determining i.

† Fall in manhole.

TABLE B – VALUES OF $C = \frac{RUNOFF}{RAINFALL}$

SURFACES			VALUE PROPOSED MIN.	VALUE PROPOSED MAX.	VALUE BY OTHER AUTHORITY MIN.	VALUE BY OTHER AUTHORITY M[illegible]
ROOFS, slag to metal.			0.90	1.00	0.70	0.9[illegible]
PAVEMENTS	Concrete or Asphalt.		0.90	1.00	0.95	1.00
	Bituminous Macadam, open and closed type.		0.70	0.90	0.70	0.90
	Gravel, from clean and loose to clayey and compact.		0.25	0.70	0.15	0.30
R.R. YARDS			0.10	0.30	0.10	0.30
EARTH SURFACES	SAND, from uniform grain size, no fines, to well graded, some clay or silt.	Bare	0.15	0.50	0.01	0.55
		Light Vegetation	0.10	0.40	0.01	0.55
		Dense Vegetation	0.05	0.30	0.01	0.55
	LOAM, from sandy or gravelly to clayey.	Bare	0.20	0.60		
		Light Vegetation	0.10	0.45		
		Dense Vegetation	0.05	0.35		
	GRAVEL, from clean gravel and gravel sand mixtures, no silt or clay to high clay or silt content.	Bare	0.25	0.65		
		Light Vegetation	0.15	0.50		
		Dense Vegetation	0.10	0.40		
	CLAY, from coarse sandy or silty to pure colloidal clays.	Bare	0.30	0.75	0.10	0.70
		Light Vegetation	0.20	0.60	0.10	0.70
		Dense Vegetation	0.15	0.50	0.10	0.70
COMPOSITE AREAS	City, business areas.		0.60	0.75	0.60	0.95
	City, dense residential areas, vary as to soil and vegetation.		0.50	0.65	0.30	0.60
	Suburban residential areas. " " "		0.35	0.55	0.25	0.40
	Rural Districts, " " "		0.10	0.25	0.10	0.25
	Parks, Golf Courses, etc., " " "		0.10	0.35	0.05	0.25

NOTE: Values of "C" for earth surfaces are further varied by degree of saturation, compaction, surface irregularity and slope, by character of subsoil, and by presence of frost or glazed snow or ice.

① Bryant & Kuichling, Report, Back Bay Sewerage District, Boston, 1909.
② Metcalf and Eddy, American Sewerage Practice, 1928. McGraw-Hill.
③ Used by City of Boston, reported by Metcalf & Eddy.
④ Used by City of Detroit, reported by Metcalf & Eddy.
⑤ L.C. Urquhart, Civil Engineering Handbook, 1940. McGraw-Hill.

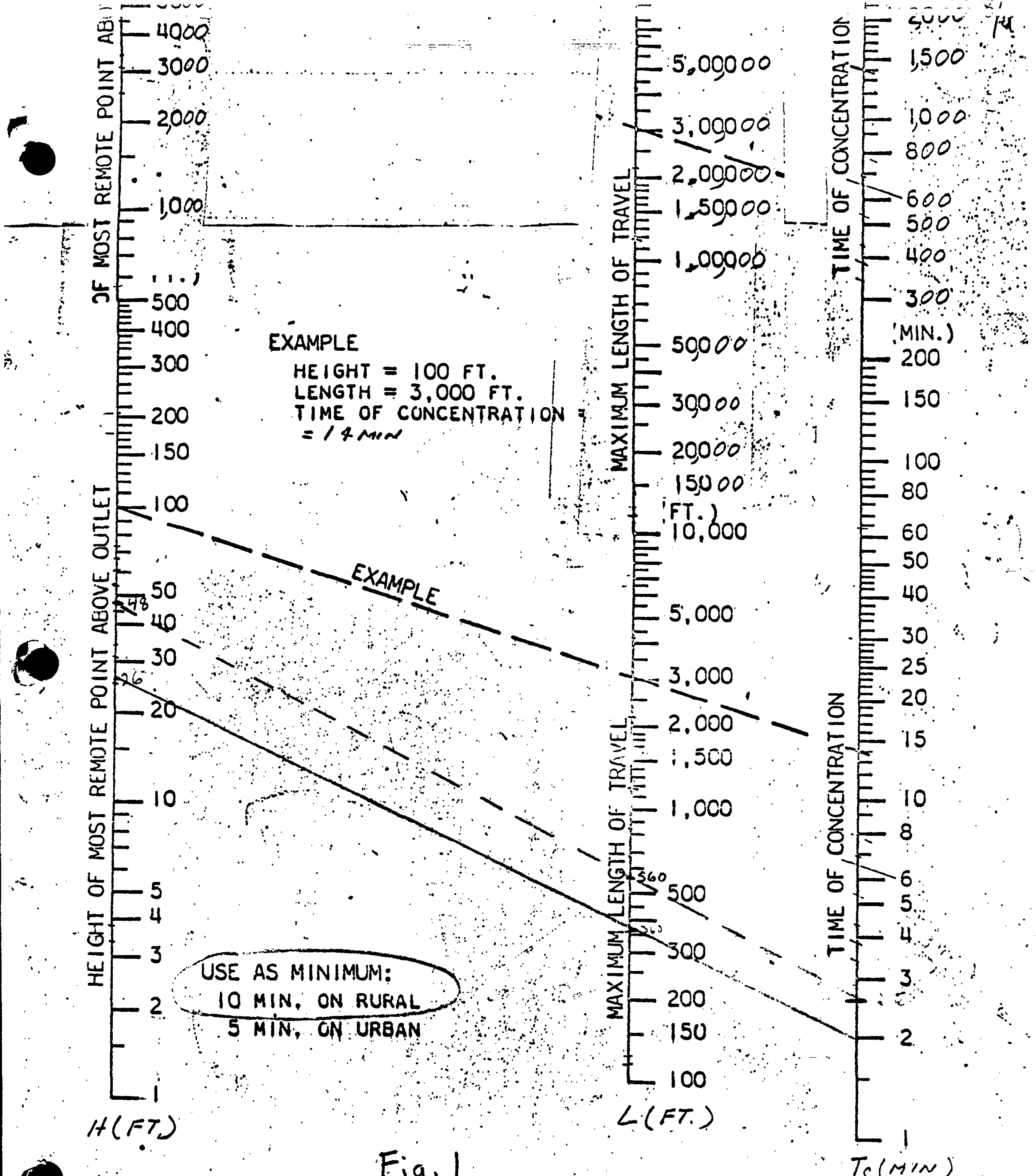
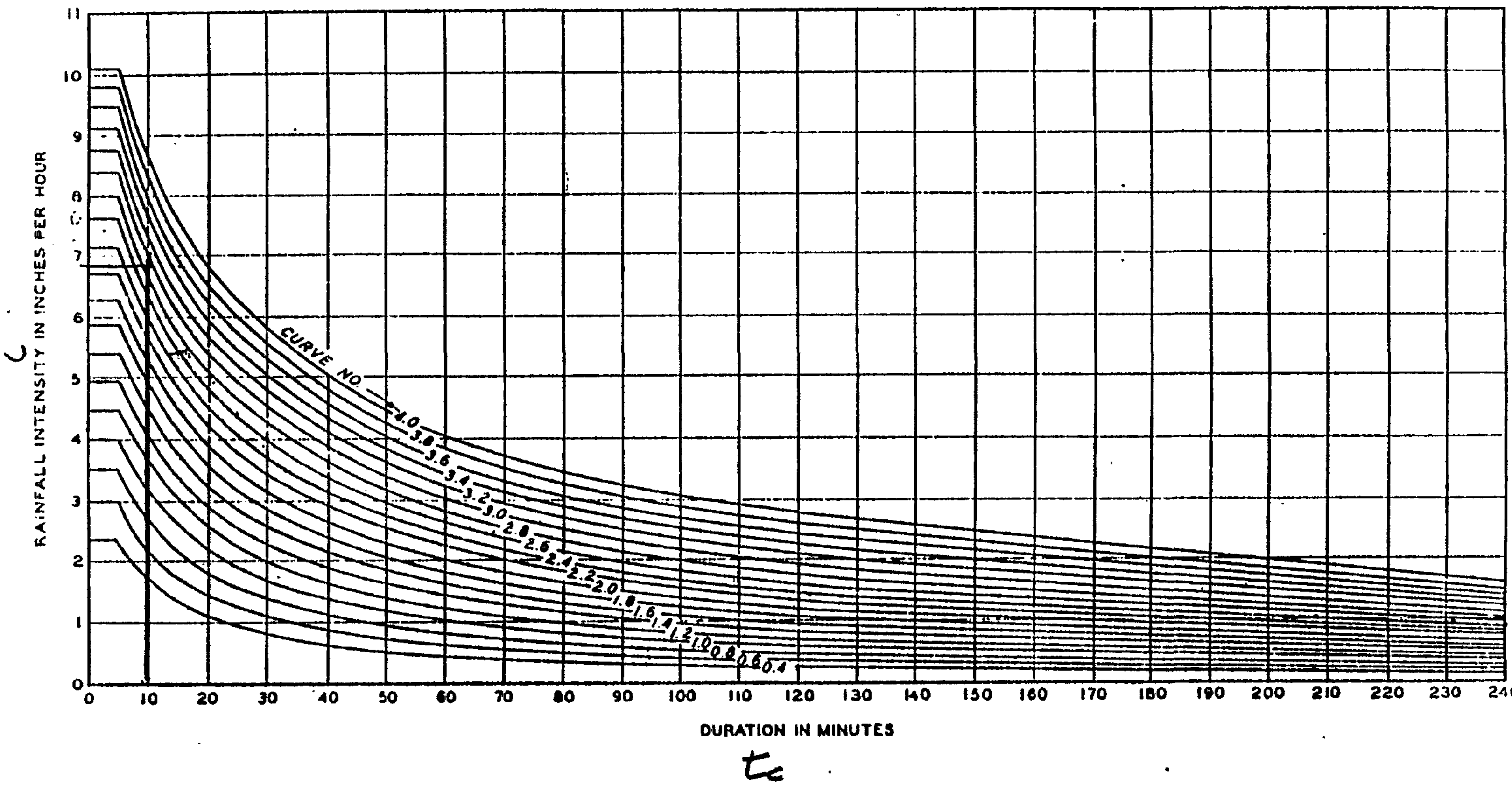


Fig. 1

TIME OF CONCENTRATION

OF SMALL DRAINAGE BASINS

AR301541



NOTES

CURVE NUMBERS CORRESPOND TO ONE-HOUR VALUES OF RAINFALL OR SUPPLY INDICATED BY RESPECTIVE CURVES

ALL POINTS ON THE SAME CURVE ARE ASSUMED TO HAVE THE SAME AVERAGE FREQUENCY OF OCCURRENCE

AIRFIELD DRAINAGE

STANDARD RAINFALL INTENSITY-DURATION CURVES OR STANDARD SUPPLY CURVES

4/9

APPENDIX A

PERMITTING BACKUP

North Whitehall Township
Zoning Office
R.R. #1, Coplay, PA 18037

January 25, 1988

RECEIVED
JAN 29 1988
SIRRINE ENVIRONMENTAL CONSULTANTS

William Cannon
Sirrine Environmental Consultants
P.O. Box 5229
Greenville, S.C. 29606

Dear Mr. Cannon:

In response to your telephone inquiry regarding the proposed construction at the Heleva Landfill, please be advised of the following:

1. Permit is required.
2. The permit fee will be 50 cents per thousand, or part thereof, cost of construction.
3. The permit will be valid for one year.
4. Application should be made at least two weeks prior to the construction starting date.

Enclosed you will find an application for the permit; please note that Sections E & F do not need to be filled out.

Should you have any questions feel free to call at 799-3411.

Sincerely,

Marie Dean

Marie Dean
Zoning Officer

MD:jw

Enclosure

Date Received:

North Whitehall Township
Lehigh County, Pennsylvania

Permit No. ______________

Date Granted ______________

APPLICATION FOR A ZONING AND BUILDING OR ALTERATION PERMIT

Note: If no setbacks are affected answer only questions in Red.

Application is hereby made for a permit for construction as indicated below and which shall be located as shown on the three (3) copies of the plot plan submitted herewith and/or to use the premises for the purpose herein described. Applicant agrees that such work will comply with all provisions of the Zoning Ordinance, with all deed restrictions and with all other applicable ordinances of North Whitehall Township.

A. This Application is for:
- ☐ New Building
- ☐ Exterior Alteration
- ☐ Interior Alteration
- ☐ Home Occupation
- ☐ Razing
- ☐ Addition to Building
- ☐ Accessory Building
- ☐ Temporary Building
- ☐ Change of Use

B. Proposed Use
- ☐ One Family Dwelling
- ☐ Two Family Dwelling
- ☐ Multi Family Dwelling
- ☐ Industrial Building
- ☐ Private Garage
- ☐ Professional Building
- ☐ Shopping Center
- ☐ Commercial Building
- ☐ Accessory Use

C. Exact Location of Property
- House Number ______________
- Street Name ______________
- Subdivision Name ______________
- Deed Reference: Vol. ______ Page ______
- Subdivision Improvements Agreement Yes ☐ No ☐

D. Type of Lot
- ☐ Interior
- ☐ Corner

Proposed Use of Building and/or Land (Additional Details) ______________

E. Lot and Building Dimensions and Areas

Lot Width ______ ft. Lot Depth ______ ft. Lot Area ______ sq. ft.
Building Width ______ ft. Building Depth ______ ft. Area of Main Building ______ sq. ft.
Right Side Yard ______ ft. Front Yard ______ ft. Area of Accessory Bldg. ______ sq. ft.
Left Side Yard ______ ft. Rear Yard ______ ft. Total Lot Coverage ______ %

F. Character of Building will be as follows:

Type of Construction ______________ (Brick, Frame, etc.) Basement Yes ☐ No ☐
Number of Stories ______ Height ______ ft. Number of Rooms ______ Number of Baths ______
Sq. ft. of Interior Floor Space ______ Type of Garage (i.e. Attached, Detached, etc.) ______
Number of Existing Buildings (if any) ______ Constructed in What Year ______
Garage Set Backs (If Detached) Front ______ Rear ______ Right Side ______ Left Side ______

Cost of Construction ______ Starting Date ______ Completion Date ______
Type of Water Supply ______ Type of Sewage Disposal ______

G Owner ______ Address ______ Phone ______
Applicant ______ Address ______ Phone ______
Contractor ______ Address ______ Phone ______
Is this application being made by owner of property ______ If not, by what Authority ______
Date ______ Signature of Applicant ______
Building Permit Issued by ______ Title ______

CERTIFICATE OF OCCUPANCY

When Construction is Complete Notify Zoning Officer and Request Certificate of Occupancy

This is to certify that the building or structure has been inspected and found to be in compliance with "The North Whitehall Zoning Ordinance of 1969" as amended and the above stated occupancy is hereby authorized.

Approved as to Building Code ______________ Building Inspector ______
Approved as to Zoning Ordinance and issued by ______________ Zoning Officer ______

FOR OFFICE USE ONLY

District ______ Zoning Fee ______ Date ______ Building Fee ______ Date ______ Appeal Fee ______ Date ______
Does Lot Frontage Conform ______ Does Lot Area Conform ______ Does Use Conform ______
Do All Setbacks Conform ______ Front ______ Rear ______ Right Side ______ Left Side ______
Does Building Area Conform ______ Does Height Conform ______ Block Number ______
Tax Map ______ Lot Number ______

FOR USE OF THE ZONING HEARING BOARD

Hearing Date ______ Type of Hearing: Regular ______ Public ______
☐ Approved ☐ Disapproved Conditions ☐ Yes ☐ No

Chairman ______________
Secretary ______________
Member ______________

AR301545

SIRRINE
ENVIRONMENTAL
CONSULTANTS

---------------------COMMUNICATION REPORT---------------------

Name Ms. Marie Dean

Company North White Hall Township

Address

Telephone No. 215-799-3411

Recorded By Bill Cannon

Project No. F-1536

Date 1/19/88 Time

[X] Telephone Conversation

[ ] Office Conversation

Re: Heleva Landfill
Permits

Ms. Dean, Zoning Officer, stated that North White Hall Township requires only a zoning permit. Processing time is two days. If a government agency is requesting the permit, the fee is waived.

Ms. Dean will send us a letter confirming this information.

SIRRINE ENVIRONMENTAL CONSULTANTS

Bill Cannon
Bill Cannon

bf

cc: Mr. Bill Hauser
Mr. Gordon Peterson
Project File

SIRRINE ENVIRONMENTAL CONSULTANTS

COMMUNICATION REPORT

Name Doug Lesher

Company Pennsylvania - Dept of Air Quality

Address

Telephone No. 717-787-9702

Recorded By Bill Cannon

Project No. F-1536

Date 2/2/88 Time

☒ Telephone Conversation

☐ Office Conversation

Re: Helova Landfill Permits

Data:

Mr. Lesher is sending a form which will allow the Department of Air Quality to determine whether a permit is needed. If a permit is required, 90 days should be allowed for processing. There is no fee at this time for air permits.

cc: Bill Hauser
Gordon Peterson
Jeff Impens
File

AR301547

FEB 4 1988

SIRRINE ENVIRONMENTAL CONSULTANTS

AIR QUALITY PERMIT APPLICATIONS SHOULD BE SUBMITTED DIRECTLY TO THE APPROPRIATE REGIONAL OR LOCAL AGENCY OFFICE AS INDICATED BELOW:

REGION I

Mr. Thomas McGinley
Engineering Services Chief
1875 New Hope Street
Norristown, PA 19401
Telephone: (215) 270-1920
Counties: Berks, Bucks, Chester, Delaware, Lehigh, Montgomery, Northampton

REGION II

Mr. Babu Patel
Engineering Services Chief
90 East Union Street
Wilkes-Barre, PA 18703
Telephone: (717) 826-2531
Counties: Carbon, Lackawanna, Luzerne, Monroe, Pike, Schuylkill, Susquehanna, Wayne, Wyoming

REGION III

Mr. Hartwin Weiss
Engineering Services Chief
3555 N. Progress Ave. (1 Ararat Blvd.)
Harrisburg, PA 17110
Telephone: (717) 657-4587
Counties: Adams, Bedford, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lancaster,

REGION IV

Mr. Richard Maxwell
Engineering Services Chief
200 Pine Street
Williamsport, PA 17701
Telephone (717) 327-3637
Counties: Bradford, Cameron, Centre, Clearfield, Clinton, Columbia, Lycoming, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga, Union

REGION V

Mr. Charles McCann
Engineering Services Chief
121 S. Highland Avenue
Pittsburgh, PA 15206
Telephone: (412) 645-7100
Counties: Armstrong, Beaver, Cambria, Fayette, Greene, Indiana, Somerset, Washington, Westmoreland

REGION VI

Mr. William Charlton
Engineering Services Chief
1012 Water Street
Meadville, PA 16335
Telephone: (814) 724-8530
Counties: Butler, Clarion, Crawford, Elk, Erie, Forest, Jefferson, Lawrence, McKean, Mercer, Venango, Warren

ALLEGHENY COUNTY

(Obtain local agency's forms)
Mr. J. D. Graham, Engineer
Plan Review Section
Allegheny County Health Department
Bureau of Air Pollution Control
301 39th Street
Pittsburgh, PA 15201
Telephone: (412) 681-6900

PHILADELPHIA COUNTY

(Obtain local agency's forms)
Mr. Thomas Elliot
Department of Public Health
Air Management Services
500 S. Broad Street
Philadelphia, Pa 19146
Telephone: (215) 875-5624

FOR GENERAL PERMIT INFORMATION

Mr. Douglas L. Lesher
Chief, Engineering Services Section
Bureau of Air Quality Control
P.O. Box 2063
Harrisburg, PA 17120
Telephone: (717) 787-4324

FOR INFORMATION ON AIR QUALITY MODELS

Mr. Robert Simonson
Chief Meteorologist
Bureau of Air Quality Control
P.O. Box 2063
Harrisburg, PA 17120
Telephone: (717) 787-4310

FOR INFORMATION ON AMBIENT MONITORING

Mr. Frederick P. Osman
Chief, Air Quality Section
Bureau of Air Quality Control
P.O. Box 2063
Harrisburg, Pa 17120
Telephone: (717) 787-6548

R–AQ–17 Rev. 9/85

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF AIR QUALITY CONTROL

Request for Determination of Requirement for Plan Approval/Operating Permit Application (Submit In Triplicate)

ype of Source: ______________________ Date of Installation: ______________________

)wner of Source: ______________________ Employer I.D. No.: ______________________

Mailing Address: ____

:ontact Person: ______________________ Telephone: ______________________

'.ocation of Source(s):

Street Address: ______________________ Municipality: ______________________

:stimated Emissions: County: ______________________

Pollutant				
Quantity lbs/hr				
Quantity lbs/yr				

____
Signature

____
Title

____
Date

OFFICIAL USE ONLY

)ate Received: ______________________ Reviewed By: ______________________

'ursuant to the authority contained in 25 PA Code §127.14(8) the source(s) is exempted from the plan approval and permitting requirements. This determination does not exempt the source(s) from ompliance with all other applicable air quality regulations.

____
Signature

____
Title

____
Date

The source(s) does not qualify for exemption from plan approval/permitting requirements under PA Code §127.14(8) and plan approval application(s) must be submitted. The Department is prohibited from acting on an application until 30 days after the municipality and county have received notification by the company. Pertinent forms are attached.

____
Signature

____
Title

____
Date

AR301549

(Over)

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
Post Office Box 2357
Harrisburg, Pennsylvania 17120
(717) 787-5828

Bureau of Topographic and Geologic Survey

January 21, 1988

Mr. William Cannon
Sirrine Environmental Consultants
P.O. Box 5229
Greenville, SC 29606

Dear Mr. Cannon:

This letter is in response to your request for written verification on water well drilling and well permitting under the Pennsylvania Water Well Drillers Licensing Act 610 of 1956.

Under Act 610 a water well is defined as "any excavation that is drilled, bored, cored, washed, driven, dug, jetted or otherwise constructed, when the intended use of such excavation is for the location, diversion or acquisition of groundwater..." "...No person shall drill a water well within the Commonwealth unless he has first secured from the department a license..." There are no well permitting or abandonment requirements under this Act. Public supply water wells are permitted and regulated under the Safe Drinking Water Act under the jurisdiction of the Bureau of Community Environmental Control of this Department. Monitoring wells constructed under superfund or RCRA would come under standards set by those programs.

I hope this letter has answered your questions concerning water well drilling, construction, well permitting, and abandonment in Pennsylvania.

If you have any questions, please do not hesitate to contact me.

Sincerely,

Donna M. Snyder
Program Coordinator
Water Well Drillers Licensing Program

DMS:lr

RECEIVED

JAN 25 1988

SIRRINE ENVIRONMENTAL CONSULTANTS

SIRRINE ENVIRONMENTAL CONSULTANTS

COMMUNICATION REPORT

Name Ms. Donna Snyder

Project No. F-1536

Company Pennsylvania Dept. of

Date 1/19/88 Time

Address Environmental Resources

[X] Telephone Conversation

[ ] Office Conversation

Telephone No. 717-787-2169

Re: Heleva Landfill Permits

Recorded By Bill Cannon

Ms. Donna Snyder, Coordinator, Water Well Drillers Licensing, stated that there are no permits, regulations, or procedures required for abandoning a water well in the State of Pennsylvania, that are issued by her department. Since this is a superfund site, RCRA and other regulations will apply.

Ms. Snyder will send us a letter confirming this information.

SIRRINE ENVIRONMENTAL CONSULTANTS

Bill Cannon

Bill Cannon

bf

cc: Mr. Bill Hauser
Mr. Gordon Peterson
Project File

SIRRINE
ENVIRONMENTAL
CONSULTANTS

COMMUNICATION REPORT

Name: Mike Sherman
Project No.: F-1536
Company: Bureau of Soil & Water Conservation
Date: 1/25/88
Time:
Address: Harrisburg, PA
☑ Telephone Conversation
☐ Office Conversation
Telephone No.: 717-783-7578
Re: Heleva landfill Permits
Recorded By: Bill Cannon

Data:

Earth disturbance permits are applied for, and forms received through the County Conservation District. The procedure calls for a letter to be sent to both the Township Supervisor, and the County Commissioners, stating "... in accordance with Act 14, we are making an application to the Department of Environmental Resources for an earth disturbance permit." The letter is also supposed to describe the project. This letter is to be sent by certified mail.

The package submitted to the County Conservation District is to include three notarized application forms; three copies of the erosion plan; proof that copies of letters to the Township Supervisor and County Commissioners were sent and received; a check for $200.00; and a location (topographical) map showing boundaries of the site.

The package is then turned over to a regional reviewing engineer, who is responsible for notifying other bureaus, such as Bureau of Waste Management, Bureau of Water Quality Management, Bureau of f Dams and Waterways Management, and possibly others. These bureaus will send their comments back to reviewing engineer, who will en inform the party making the application of the modifications required. This process normally takes 60-90 days.

In Lehigh County, the reviewing engineer is Mr. Joe Blyer. He will be the contact person once the application has been sent, and is located in Potsville, telephone 717-621-3118.

Permit application forms can be obtained from

Lehigh County Conservation District
5100 Tilghman St.
Commerce Plaza, Rm 10
Allentown, PA 18104

AR301552

SIRRINE ENVIRONMENTAL CONSULTANTS

F-1536
HELLEVA
1/25/88
CANNON

Sherman also suggested I contact the Bureau of Waste Management, to see if they have special requirements or permits for a landfill closure. Time could be saved by addressing those requirements now, rather than after the permit application has been made.

If the earth-moving activity disturbs less than 25 acres, a permit is not required.

cc: Bill Hauser
Gordon Peterson
Project File

AR301553

POLICIES AND PROCEDURES

November 13, 1984

Earth disturbance permits are required under the authority of the Erosion Control Regulations, 25 Pa. Code Chapter 102 of the Department of Environmental Resources' Administrative Code. These permits are required for all earth-moving activities within the boundaries of Pennsylvania where over 25 acres of land are disturbed in a contiguous project. Agricultural activities for plowing and tilling and projects requiring certain other DER permits are exempt.

The following steps are to be taken to process an Earth Disturbance Permit.

1. The Bureau of Soil and Water Conservation (BSWC), DER prepares and provides approved permit application forms (ERSWC-20). Conservation districts are expected to maintain a supply of forms for applicants. Conservation districts will provide four (4) copies of the application forms to each applicant, who is required to secure an Earth Disturbance Permit.

2. The applicant secures four (4) copies of the forms ER-SWC-20 and prepares an application consisting of three (3) copies of the application form, all properly notarized, and three (3) copies of an erosion and sedimentation control plan consisting of a map, a narrative and a check for two hundred dollars ($200).

3. The applicant must notify the municipality wherein the proposed permitted project is located. Such notification may be by return receipt (certified mail) as proof of notice. The Earth Disturbance Permit may not be issued without the 30-day notice to the municipality. (According to Legislative Act 14 of 1984). Applicant must provide BSWC a copy of receipt of notification.

4. The application is then submitted to the conservation district.

5. The conservation district checks the application for completeness... (three forms, three plans, and one $200 check).

6. The conservation district assigns a number to the application. The first two digits are the county number, the next two are the current year, the next is "8" identifying an Earth Disturbance Permit, and the last two are the number of applications for the current year (example: 01-83-8-01). The district then notifies the applicant that his application has been received and is complete. The use of Form ER-SWC-22 revised 2/85 is recommended.

7. When the application is accepted as complete, the conservation district completes one tracking form no. DER-SWC-990, with appropriate actions to date, and forwards one copy of the tracking form, and one notarized application, and the $200 check for the application fee to the State Office of the Bureau of Soil and Water Conservation within five (5) days of receipt.

8. The conservation district retains one tracking form to be kept on file and up-to-date, one notarized application and pertinent information from the check (copy of the check, if possible).

9. Within the five (5) acceptance review days, the conservation district sends one up-to-date copy of the tracking form, one notarized application, and one erosion and sedimentation control plan (one map and one narrative) to the regional soils engineer of BSWC. also Act 14 notification + proof of notification (certified mail receipt)

10. The conservation district submits one erosion and sedimentation control plan to its technical staff or the Soil Conservation Service for review and comment. The conservation district notifies the Pennsylvania Fish Commission that an application has been received and solicits their review and comments. This

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11. The Bureau of Soil and Water Conservation's State Office forwards the $200 check to the Comptroller's Office within one business day.

12. The Bureau of Soil and Water Conservation's State Office supplies the application information to the Pennsylvania Bulletin within one business day.

13. The Bureau of Soil and Water Conservation's State Office prepares and forwards the "Form No. 1" notices to the regional DER office and the Bureau of Dams and Waterways Management.

14. The conservation district comments on the adequacy of the plan and forwards their comments, and the two plans which they reviewed, to the Bureau of Soil and Water Conservation regional soils engineer within 35 days.

15. The BSWC regional soils engineer evalutes the erosion and sedimentation control plan, considers the conservation districts' and other recommendations and determines the adequacy of the plan. If the plan is inadequate, the soils engineer prepares and sends a correction letter to the applicant with a copy to the district. The applicant is given 10 days to respond to the letter and/or 30 days to provide a corrected plan.

16. The BSWC regional soils engineer forwards his final recommendation on permit issuance along with ~~two~~ 3 plans (maps and narratives) stamped with his approval and a copy of the tracking form which he has updated to the BSWC State Office within 10 days of receiving the conservation district comments. Time used by the applicant to correct the plan is not included in the process time and should be shown on the tracking form. Use an X in Column 20 for applicants time with dates in the "START", "END" and "DUE" Columns.

17. The conservation districts forward their district board recommendations and a copy of the updated tracking form to the BSWC State Office within 35 days of accepting a complete application.

18. The BSWC State Office compares the soils engineer's recommendation with the conservation district comments.

19. The BSWC State Office checks with the status of "Form 1" replies to learn if permits are in process for the project and if the Permit is to be coordinated by the appropriate DER regional office.

20. If another permit for the project is in process, the BSWC State Office prepares the Permit and forwards it to the DER regional office for coordination. If no other Permit for the project is in process or if it has been cleared, the BSWC State Office issues the Permit directly to the applicant. When the DER regional office coordinates the permit process and all permits are cleared, it will send the Earth Disturbance Permit directly to the applicant and notify the State Office of the BSWC.

21. When the Earth Disturbance Permit is issued, a notice is forwarded to the Pennsylvania Bulletin by the BSWC State Office.

22. The original Earth Disturbance Permit is sent to the applicant, a copy to the BSWC field representative, the BSWC soils engineer, the local municipality wherein the project is located, the appropriate DER regional office, and the conservation district. One copy of the approved erosion and sedimentation control

ENVIRONMENTAL CONSULTANTS

COMMUNICATION REPORT

Name Dinesh Rajkotia
Company Bureau of Solid Waste Management
Address Norristown, PA

Telephone No. 215-270-1900
Recorded By Bill Gunon

Project No. F-1536
Date 1/26/88 Time
☑ Telephone Conversation
☐ Office Conversation
Re:

Data:

For landfill closures which are less than 25 acres, the Bureau of Solid Waste Management requires a letter of approval to be issued. This can be obtained by sending a proposal to

Lawrence H. Lunsk
1875 New Hope St.
Norristown, PA 19401

The proposal should include drawings, procedures for closing, materials specifications, calculations, and schedules. Chapter 75 of the Pennsylvania Solid Waste Regulations contain the applicable regulations. These regulations are in the process of being revised, with the new issue being in March 1988.

If the land disturbance is greater than 25 acres, the Soil and Water Conservation is the issuing authority; less than 25 acres, the Solid Waste Management is the issuing authority. The area under a cap does not count as a disturbed area!

Mr. Rajkotia would not send a letter confirming this information.

cc Bill Hauser
Gordon Peterson
Project File

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