METRO REGIONAL ENVIRONMENTAL MANAGEMENT

WASTE CUTOFF STUDY
ST. JOHNS LANDFILL
PORTLAND, OREGON

JUNE 1999

Cornforth Consultants Inc.

TECHNICAL MEMORANDUM

Technical Memorandum to:

Metro
Regional Environmental Management
Engineering and Analysis Division
600 NE Grand Avenue
Portland, Oregon 97232-2736

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June 1999

By

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1. INTRODUCTION

1.1. General

In accordance with Metro's authorization, we have completed a preliminary evaluation of methods to construct a vertical waste containment barrier through a segment of the northern perimeter dike at the St. Johns Landfill, in Portland, Oregon. This technical memorandum presents conceptual barrier construction (or waste cutoff) techniques, conceptual cost estimates, and our comments regarding the suitability and constructibility for the waste cutoff options.

1.2. Scope of Work

The scope of work for this study included the following work tasks:

- Review Cornforth's files from previous site investigations.
- Evaluate three conceptual waste cutoff techniques, which would minimize the exchange of fluids between the refuse layer and the adjacent North Slough waterway.
- Provide conceptual-level cost estimates for each of the techniques.
- Prepare a report summarizing the conceptual cutoff techniques, analyses and conclusions.

1.3. Background/Previous Investigations

In 1990, our firm performed a leachate migration study of the perimeter dike (report to Metro dated October 1990). As part of the study, a total of 20 borings were performed through the perimeter dike road at varying intervals around the landfill. Two of the borings (J-12 and J-13) located along the North Slough encountered a layer of refuse below the road surface. The refuse layer measured up to 12 feet in thickness. Refuse was also encountered in Boring J-18, which was located along the Blind Slough segment of the dike in the southeast corner of the landfill. The refuse layer discovered in Boring J-18 was approximately 11 feet in thickness.

In 1995, Metro constructed a compacted clay trench barrier through the Blind Slough dike segment to reduce seepage in that area. It is our understanding from conversations with Metro personnel that the clay trench has worked reasonably well in reducing the occurrence of leachate seeps.

Based on the discovery of refuse in Borings J-12 and J-13, Metro asked our firm in November 1997 to perform a test pit investigation to further explore the extent of the refuse along the North Slough. Two test pits (CC-1 and CC-2) were excavated through the road surface at equal spacing intervals between Borings J-12 and J-13. The refuse layer was observed in both test pits, and was measured between 7½ and 9 feet in thickness. The results of the test pit investigation were summarized in a report submitted to Metro titled "North Levee Test Pit Investigation, St. Johns Landfill," dated December 4, 1997.

In March 1998, Metro requested that our firm further investigate the extent of the refuse layer within the north dike by performing another series of borings. A total of nine borings were performed (Q-1 through Q-9) to determine the lateral extent and depth of the refuse layer beneath the dike alignment. In these Q-series borings, the refuse layer was found to range between 0 and 18 feet in thickness. The results of this investigation were submitted to Metro in a report titled "Phase II Investigation of North Levee, St. Johns Landfill," dated April 3, 1998.

The locations of the borings and test pits from the previous field investigations discussed above are shown on the Site Plan, Figure 1.

1.4. Subsurface Conditions – North Perimeter Dike

General. Within the area of concern along the north dike, the subsurface conditions generally consist of a thin layer of road surfacing aggregate, underlain by a layer of medium stiff, mottled brown and gray, sandy, clayey silt fill material. The silt fill varies in thickness from about 1½ to 6 feet. The road aggregate/silt fill layers are underlain by a layer of refuse, which generally consists of wood, plastic, glass, paper, and occasional pieces of construction debris such as concrete and asphalt. The refuse layer is typically 5 to 10 feet in thickness, but ranges between ½ foot and 18 feet. The refuse layer, in turn, is underlain by native, gray, alluvial soils consisting of soft to medium stiff, slightly clayey silt, to loose, silty fine sand with trace clay. A cross-section through the dike alignment is shown on Figure 2 and Figure 3.

Limits of Refuse/Cutoff Length. The information from the borings and test pits indicates that the refuse layer lies within the area bounded by Borings J-11 and Q-9 (see Fig. 1). In Boring J-11 the road aggregate/silt fill layers are directly underlain by soft, native silt (alluvium). In Boring Q-9, the aggregate is underlain by stiff, relatively well-compacted dike fill to the maximum depth explored (14 feet). The stiff fill observed in Boring Q-9 appears to be part of the engineered levee that was constructed in the early 1980s to facilitate the landfill expansion. All of the other borings and test pits between J-11 and Q-9 revealed some refuse.

In Boring Q-1 there was only trace refuse observed at a depth of about 5 feet. In Boring Q-2 there was a thin layer of refuse observed at a depth of 6 to 6½ feet. Considering that there was no refuse in J-11, and only trace refuse in Q-1, we estimate that the cutoff barrier would need to extend about 25 feet west of Q-1. Similarly, on the east end of the alignment, the refuse layer appears to taper out between Borings Q-8 and Q-9. Therefore, we estimate that the cutoff barrier would need to extend about 15 feet east of Q-8 (Boring Q-9 is located about 15 feet east of Q-8). The total distance between these two ends of the barrier is approximately 1,025 feet.

Groundwater/Leachate Levels. During the Q-series borings, groundwater/leachate levels were checked in open auger holes in Borings Q-5 and Q-8. In Boring Q-5 the fluid level was observed at a depth of 12.1 feet below the ground surface, which was just below the base of the refuse layer. In Boring Q-8 the fluid level was observed at a depth of 19.6 feet below the ground surface, which was about 5½ feet above the base of the refuse.

Previous construction work at the landfill has shown that the leachate levels can be variable. During the final cover construction of Subareas 1, 2 and 3 (in 1992 through 1994), a continuous trench was excavated into refuse around the perimeter of the landfill for the installation of a gas collection system. In isolated areas, leachate was observed flowing into the trench through localized zones of refuse which were apparently more conductive. This condition was also observed in Test Pits CC-1 and CC-2. The pits were relatively close together (only 133 feet apart), with similar ground surface elevations and similar refuse base elevations. Despite these similarities, the leachate conditions were quite different. No leachate was observed in CC-1, whereas leachate flowed into CC-2 at a rate of 1 to 2 gallons per minute.

Based on the above measurements and observations of leachate levels, it appears likely that leachate would be encountered during the waste cutoff construction. Therefore, for any cutoff method that involves excavation through the refuse, it would be necessary to deal with some groundwater/leachate inflow.

2. WASTE CUTOFF OPTIONS

2.1. General

Based on the results of the field investigations, our knowledge of subsurface conditions at St. Johns Landfill, and our experience with seepage barriers, we recommend the following waste cutoff options: (i) compacted clay trench; (ii) a compacted clay trench with a liner material; (iii) soil bentonite or cement bentonite slurry wall; and (iv) grouted sheet pile wall. Our comments regarding the technical approach, conceptual costs, and advantages and disadvantages for each of these alternatives are presented below.

The conceptual costs presented below include the contractor's mobilization, profit and overhead. They do not include design or administrative costs. Values shown are in 1999 dollars. All of the cost estimates assume that any leachate or temporary trench slurry fluids collected from the waste cutoff construction would be disposed of on-site.

2.2. Option 1 – Compacted Clay Trench

A cross-section of the conceptual trench barrier option with compacted clay (low permeable soil) is shown on Figure 4.

<u>Technical Approach</u>

- Excavate a trench through the refuse and 3 feet into the underlying alluvium. The typical trench depth would be approximately 15 feet; however, near Boring Q-8 the required depth would be approximately 28 feet. Specialty trenching equipment is available that can excavate to these depths.
- Place 1-foot lifts of imported low permeable soil (clayey silt/silty clay) into the trench, and compact with a sheepsfoot roller attachment connected to a trackhoe.
- Pump groundwater/leachate from low points in the excavation as necessary to compact the low permeable soil in dry conditions.
- Perform the trench excavation and backfill work in short segments (30 feet or less) to minimize sloughing of the trench sidewalls and the temporary destabilizing effect on the dike.

Estimated Hydraulic Conductivity of Barrier

- On the order of 1×10^{-4} cm/sec. to 1×10^{-5} cm/sec.

Advantages

- Least cost option.
- Simplicity of construction; no specialty contractors required.
- Method used previously at the Blind Slough with reasonable level of success.

Disadvantages

- Higher hydraulic conductivity than other cutoff methods.
- The alluvium and refuse layers are relatively soft and flexible; therefore, it would be difficult to compact the soil backfill.
- Construction Quality Assurance (CQA) difficulties: considering the trench depth and proximity to refuse and leachate, it would be difficult for personnel to enter the trench and verify that the soil has been properly compacted.
- Method is sensitive to weather. The low permeable soil could not be placed during wet weather.

Conceptual-Level Cost Estimate

- $200,000 to $250,000.

2.3. Option 2 – Compacted Clay Trench with Liner

A cross-section of the clay trench with a liner option is shown on Figure 4.

Technical Approach

- Perform the trench excavation to the required depths and in short segments as discussed above for Option 1.
- Prior to backfilling the trench, place either: (i) a geomembrane; (ii) a bentonite mat; or (iii) a geomembrane with bentonite backing along the face of the trench as shown on Figure 4.

- Backfill the trench with compacted low permeable soil as discussed above for Option 1.

Estimated Hydraulic Conductivity of Barrier

- Compacted soil/geomembrane liner: 1×10^{-4} cm/sec. to 1×10^{-9} cm/sec.
- Compacted soil/bentonite mat liner: 1×10^{-4} cm/sec. to 1×10^{-7} cm/sec.
- Compacted soil/geomembrane with bentonite backing: 1×10^{-4} cm/sec. to 1×10^{-9} cm/sec.

The upper range of 1×10^{-4} cm/sec. is due to potential damage to the liner, and is discussed further at the end of this section under "Comments".

Advantages

- Liner materials could significantly lower the overall hydraulic conductivity of the compacted soil trench barrier (as low as 1×10^{-9} cm/sec.).
- Assuming the liner materials could be installed without significant damage, fine sand could be substituted in the trench backfill (instead of the clayey silt/silty clay) without raising the overall hydraulic conductivity of the barrier. Sand backfill work could be performed during wet weather conditions.
- Relative low cost.

Disadvantages

- The information available on similar applications is very limited. (The geomembrane with bentonite mat backing has not been used in a vertical waste containment barrier in the United States.)
- Liner installation would require a specialty contractor.
- Difficult installation of the liner due to space limitations on top of the dike, and sloughing of the trench sidewalls.
- A geomembrane with bentonite mat backing would be particularly difficult to install due to its heavy weight.
- CQA difficulties: Soil compaction and proper liner installation would be difficult to verify.

Conceptual-Level Cost Estimate

- Compacted soil/geomembrane: $225,000 to $275,000.
- Compacted soil/bentonite mat: $225,000 to $275,000.
- Compacted soil/geomembrane with bentonite backing: $250,000 to $350,000.

Comments on Hydraulic Conductivity. The lower range of hydraulic conductivity values shown above assume that the liner materials would be installed without damage or problems along the seams. Due to the limited history of use of liner materials in vertical waste containment barriers, it is not presently possible to forecast the impact of installation defects or damage. However, considering the potential construction difficulties and close proximity to refuse with potentially sharp objects, we anticipate that some damage could occur to the liners during installation. It is likely that the geomembrane with bentonite backing could withstand damage better than the other liner options, because it would be thicker, and the bentonite could seal perforations in the geomembrane. The upper range of hydraulic conductivity values (1×10^{-4} cm/sec.) shown above assume that the liners have been heavily damaged during installation, and that the low permeable soil provides the barrier to fluid flow.

2.4. Option 3A – Soil Bentonite Slurry Wall

A cross-section of the conceptual slurry wall options (both soil bentonite and cement bentonite) is shown on Figure 5.

Technical Approach

- Sample the groundwater/leachate in advance to check the compatibility with the soil bentonite mixture.
- Using standard trenching equipment, excavate a continuous trench through the refuse and 3 feet into the underlying alluvium.
- Infill the trench temporarily with a bentonite-water slurry to maintain stability of sidewalls.
- Import a silty or clayey soil and mix with bentonite slurry (outside of the trench) to create a low permeable backfill.
- Starting at one end, dump the soil bentonite mixture into the trench and collect any displaced liquid slurry. Continue the process until the wall is complete.

Expected Hydraulic Conductivity of Barrier

- On the order of 1×10^{-7} cm/sec.

Advantages

- Low hydraulic conductivity.
- High resistance to chemical aggression.
- The soil bentonite backfill can be tested after mixing to check that its hydraulic conductivity is appropriate.
- The bentonite-water slurry would minimize the inflow of water into the trench.
- Method has a long history of success at other landfill sites.

Disadvantages

- Requires a specialty contractor.
- The bentonite-water slurry could escape through more conductive zones in the refuse, which would present a risk of it entering the North Slough.
- There is a risk that lateral pressure on the trench walls from the bentonite-water slurry could cause a failure through the dike face.
- The soil bentonite backfill is not compacted; therefore, it would leave a weak zone within the dike. As a result, the long-term stability of the perimeter dike would be lower than the other methods.
- Settlement problems may occur in the perimeter road surface due to consolidation of the soil bentonite backfill.
- The top surface of the dike rises in elevation from the west to the east ends of the alignment; therefore, it may be necessary to temporarily regrade the surface to keep the bentonite-water slurry from overflowing the trench.
- The collected bentonite-water slurry would have to be treated as leachate.

Conceptual-Level Cost Estimate

- \$260,000 to \$330,000.

2.5. Option 3B – Cement Bentonite Slurry Wall

A cross-section of the conceptual option is shown on Figure 5.

Technical Approach

- Sample the groundwater/leachate in advance to check the compatibility with the cement bentonite mixture.
- Excavate a trench that extends through the refuse and 3 feet into the underlying alluvium.
- Backfill the trench by pumping in a cement-bentonite-water mixture.
- Perform the excavation and backfill work in 30-foot segments to minimize the amount of sidewall sloughing. Continue the work in 30-foot segments until the wall is completed.

Expected Hydraulic Conductivity of Barrier

- On the order of 1×10^{-6} cm/sec.

Advantages

- Reasonably low hydraulic conductivity.
- The trenching and backfill work is performed in short segments; therefore, temporary bentonite-water slurry is not typically required to keep the trench open.
- Cement bentonite mixture sets in a relatively short period of time to a consistency of medium stiff to stiff clay (15 to 20 psi); therefore, there is less risk of failures through the dike face due to fluid pressure.
- The added shear strength of the cement bentonite would prevent it from negatively impacting the long-term stability of the dike.
- The cement bentonite can be tested in advance to check its properties.
- No need to import soils.
- Fly ash can be added to the mixture to make it less permeable and more resistant to chemical attack.
- Method has been used with success recently on other landfills.

Disadvantages

- Requires a specialty contractor.
- Higher cost than the compacted clay trench and soil bentonite slurry wall options.
- Possibly shorter lifespan than soil bentonite slurry wall.

Conceptual-Level Cost Estimate

- $310,000 to $380,000.

2.6. Option 4 – Sheet Pile Wall

A cross-section of the conceptual option is shown on Figure 6.

Technical Approach

- Sample the groundwater/leachate to check the corrosion potential of the steel.
- Drive steel sheet piles through the dike alignment, and extend the sheets at least 3 feet into the underlying alluvium.
- Grout the interlocking connections between the sheet piles (Fig. 6).

Expected Hydraulic Conductivity of Barrier

- 1×10^{-7} cm/sec or lower.

Advantages

- Very low hydraulic conductivity (if installed without damage).
- No refuse and leachate disposal required.

Disadvantages

- Higher cost.
- May encounter difficult driving through the refuse in local areas due to the presence of construction debris (blocks of concrete, asphalt, wood, etc.).

- Installation would require a specialty contractor.
- Damage from difficult driving could result in separation of the sheets at the interlocks, which would lead to leakage problems.
- Possible corrosion problems.
- Method not commonly used on landfill facilities.

Conceptual Cost Estimate

- $360,000 to $450,000.

2.7. Longevity of Cutoff Options

There is little information available on the long-term durability of vertical barrier walls around landfills. Therefore, the longevity of the cutoff options discussed above cannot be accurately forecasted. In general, the longevity of a hydraulic barrier is related to the chemistry of the leachate and the resistance of the barrier materials to chemical aggression. It is our understanding that the leachate samples which Metro has tested in the past have been relatively neutral (i.e. high salt, pH level near 7, high conductivity). Therefore, this leachate probably would not produce rapid degradation of the barrier materials.

Soil- and Cement-Based Cutoff Walls. Long-term observations of soils and cement-treated soils in other applications (such as landfill covers, treatment ponds or reservoirs, etc.) provide some confidence that the materials can maintain their barrier function for long time periods. Clays are very stable materials, and their properties are not significantly affected by dilute solutions of organic contaminants (Filz and Mitchell, 1995). Bentonite mats and HDPE geomembranes are also highly resistant to chemical attack. Therefore, either a clay trench, a clay trench with a liner, or a soil bentonite slurry wall should be very durable.

Cement bentonite is expected to be somewhat less durable than soil bentonite because cement is more susceptible to chemical attack. However, studies in the United Kingdom (where cement bentonite walls have been used since the early 1970s) indicate that long-term changes in hydraulic conductivity due to contaminant interaction is probably limited to a 10- to 50-fold increase (Jefferis, 1995).

Slurry wall contractors in the western United States generally count on lifespans of 20 to 40 years for soil bentonite walls, and about 20 years for cement bentonite walls in highly contaminated sites. Given the neutral nature of the leachate at St. Johns Landfill, we anticipate that either type of slurry wall could last considerably longer at this site.

Sheet Pile Walls. There is no hard data on the longevity of sheet pile walls at landfill facilities. On typical waterfront projects, the U. S. Corps of Engineers count on sheet pile corrosion rates of 0.004 to 0.005 inch per year. At this corrosion rate, a standard sheet pile measuring 3/8-inch in thickness could last up to 70 years. However, the chemical environment around a landfill could alter the corrosion rate, and could shorten the design life substantially. There are coating materials available that could help reduce the rate of corrosion; however, the coatings are difficult to protect during installation. In order to further evaluate the longevity of a sheet pile barrier, it would be necessary to sample the leachate from St. Johns Landfill and perform laboratory corrosion tests.

2.8. Disposal of Excavated Materials

For the compacted clay trench and slurry wall cutoff options, it would be necessary to excavate a trench through the refuse and into the underlying alluvium. Assuming that the trench would be 1,025 feet long, 3 feet wide, and would extend 3 feet into the alluvium, we estimate that the trench volume would be approximately 1,800 cubic yards. Due to sloughing of the trench sidewalls excavated through refuse, it is expected that the trench volume would increase by a factor of 30 to 70 percent. Therefore, the volume of material removed could be on the order of 3,100 cubic yards.

From conversations with Metro personnel, it is our understanding that the material excavated from the trench would likely be kept on-site and used to infill localized sags in the existing landfill cover. After placing the excavated materials into the sags, a new cover layer would be constructed over the materials. The design issues related to the infill of sag areas are beyond the scope of this study; therefore, the cost estimates discussed above do not include the costs for hauling and placing the excavated materials into the sags. However, the estimates do include the costs for loading excavated materials into haul trucks.

2.9. Dike Stability Concerns

In recent years, slope instability problems have occurred along several segments of the perimeter dike. Concurrent to this waste cutoff study, Metro authorized our firm to perform a separate study to evaluate methods for stabilizing the perimeter dike. The results of the separate study are summarized in a report titled "Preliminary Dike Stabilization Study, St. Johns Landfill," dated June 1999. With regards to the stability of the perimeter dike, one of the primary areas of concern is the segment along the North Slough where the waste cutoff is required. The shoreline slope is relatively steep through this area, and the toe of the slope has been undermined by erosion.

As part of the present study, we performed a slope stability analysis on the dike in its existing condition. The stability analysis determined that the excavation for a waste cutoff trench would temporarily destabilize the slope until it was backfilled. The added weight and vibrations from sheet pile driving equipment could also cause the slope to fail. Therefore, we recommend that the stability of the slope be improved prior to the construction of the waste cutoff barrier. Our conceptual methods and costs for stabilizing the slope are addressed in the dike stabilization study discussed above.

2.10. Summary of Cutoff Options

For comparative purposes, we present below an overall summary of the waste cutoff options. The table includes: (i) the approximate hydraulic conductivity of the cutoff barrier; (ii) the degree of construction difficulty (low, moderate, or high)); (iii) conceptual cost; and (iv) longevity.

Summary of Waste Cutoff Options

Cutoff Option	Hydraulic Conductivity (cm/second)	Construction Difficulty	Approximate Cost*	Approximate Lifespan
Compacted Clay Trench	$1 \times 10^{-4} - 1 \times 10^{-5}$	Low	$200,000 – $250,000	30+ years
Compacted Clay Trench w/Liner	$1 \times 10^{-4} - 1 \times 10^{-9}$	Moderate	$225,000 – $350,000	30+ years
Soil Bentonite Slurry Wall	1×10^{-7}	Moderate	$260,000 – $330,000	30+ years
Cement Bentonite Slurry Wall	1×10^{-6}	Moderate	$310,000 – $380,000	30+ years
Sheet Pile Wall	1×10^{-7}	High	$360,000 – $450,000	Up to 70 years

*1999 dollars; see other cost qualifiers in Section 2.1.

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REGISTERED PROFESSIONAL ENGINEER 8513 OREGON AUG. 22, 1975 ERMEL QUEVEDO

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3. REFERENCES

Daniel, D.E. and Koerner, R.M., 1995, Waste Containment Facilities, pp. 279-297.

Filz, G.M., and Mitchell, J.K., 1995, Design, Construction, and Performance of Soil- and Cement-Based Vertical Barriers. Prepared as part of the Assessment of Barrier Containment Technologies, International Containment Technology Workshop, Baltimore, Maryland, August 29-31, 1995.

Jefferis, S.A., 1995, UK Practice: Materials and Their Properties. International Containment Technology Workshop, Baltimore, Maryland, August 29-31, 1995.

Ryan, C.R., 1987, Vertical Barriers in Soil for Pollution Containment. Article from Geotechnical Practice for Waste Disposal '87'.

Tachavises, C. and Benson, C.H., 1997, Hydraulic Importance of Defects in Vertical Groundwater Cut-Off Walls. Proceedings from the In Situ Remediation of the Geoenvironmental Conference, Minneapolis, Minnesota, October 5-8, 1997. A.S.C.E. Geotechnical Special Publication No. 71.

Limitations in the Use and Interpretation of This Geotechnical Report

Our professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject facility and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive boring and test pit logs, cross-sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory borings, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observed in the exploratory borings and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse.

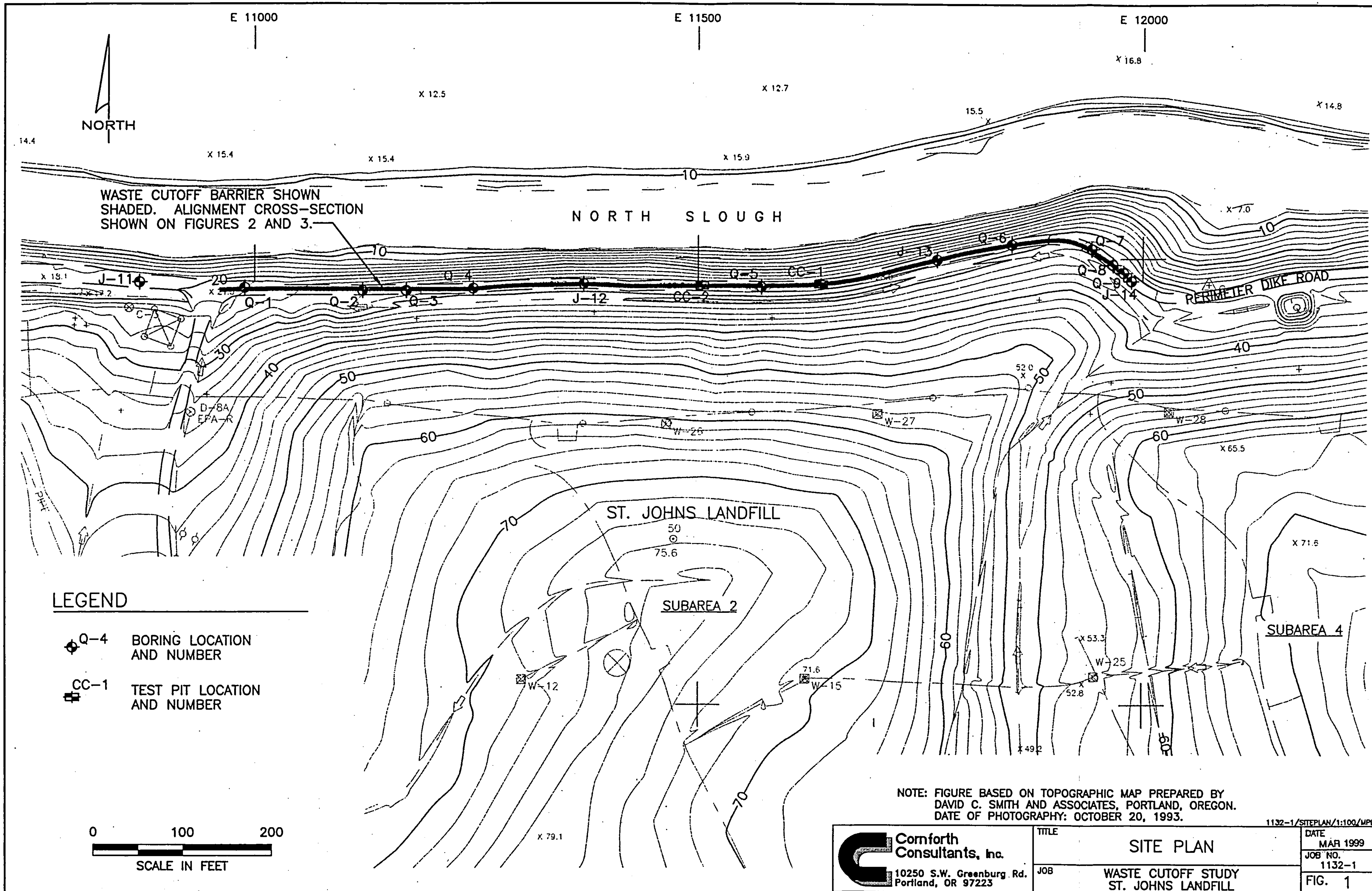
The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The boring logs and related information depict subsurface conditions only at these specific locations and at the particular time designated on the logs. Soil conditions at other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the soil conditions at these boring locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, borings or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report; nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.



0 100 200

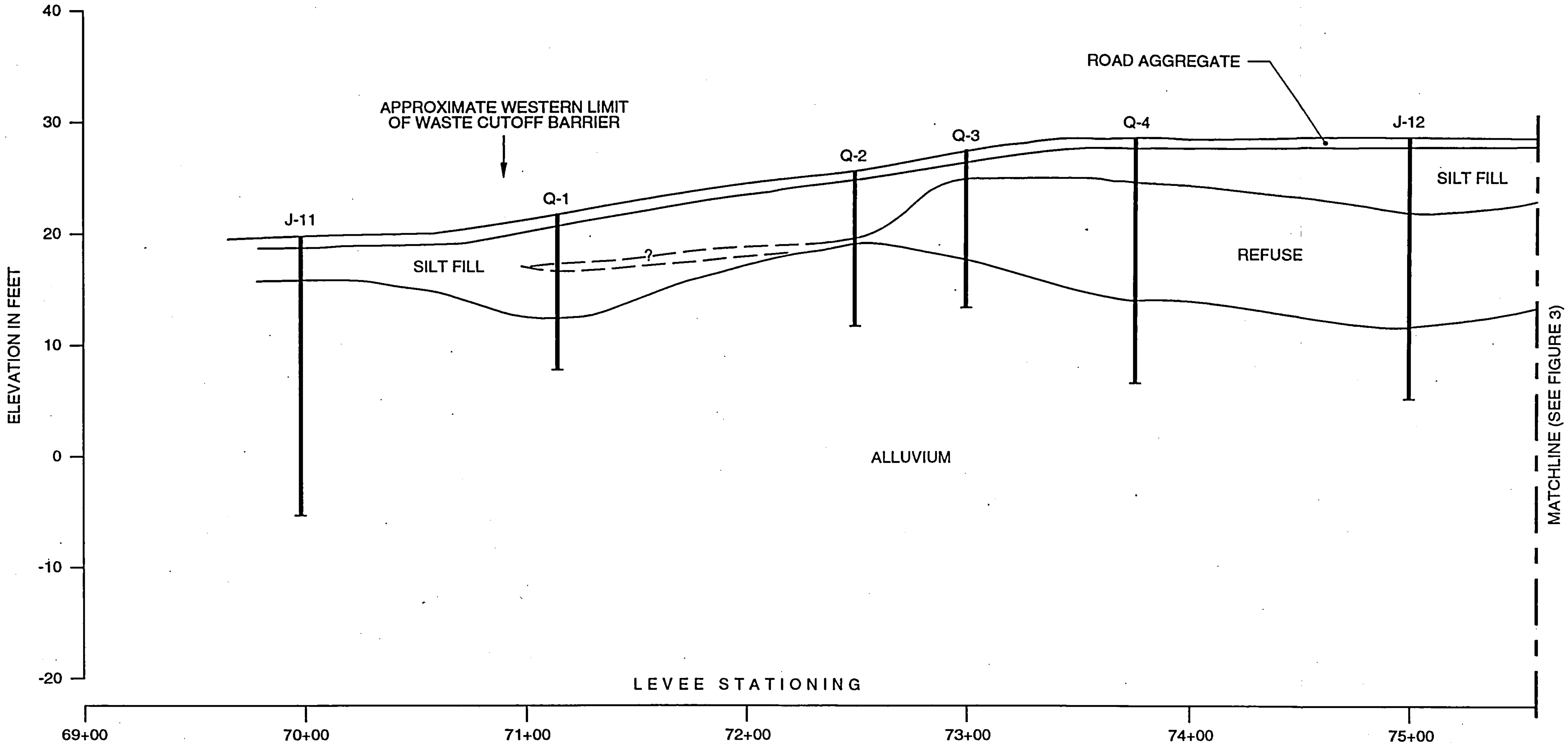
SCALE IN FEET

NOTE: FIGURE BASED ON TOPOGRAPHIC MAP PREPARED BY DAVID C. SMITH AND ASSOCIATES, PORTLAND, OREGON. DATE OF PHOTOGRAPHY: OCTOBER 20, 1993.

1132-1/SITEPLAN/1:100/MPL

Cornforth Consultants, Inc.
10250 S.W. Greenburg Rd.
Portland, OR 97223

TITLE	SITE PLAN
JOB	WASTE CUTOFF STUDY ST. JOHNS LANDFILL
DATE	MAR 1999
JOB NO.	1132-1
FIG.	1

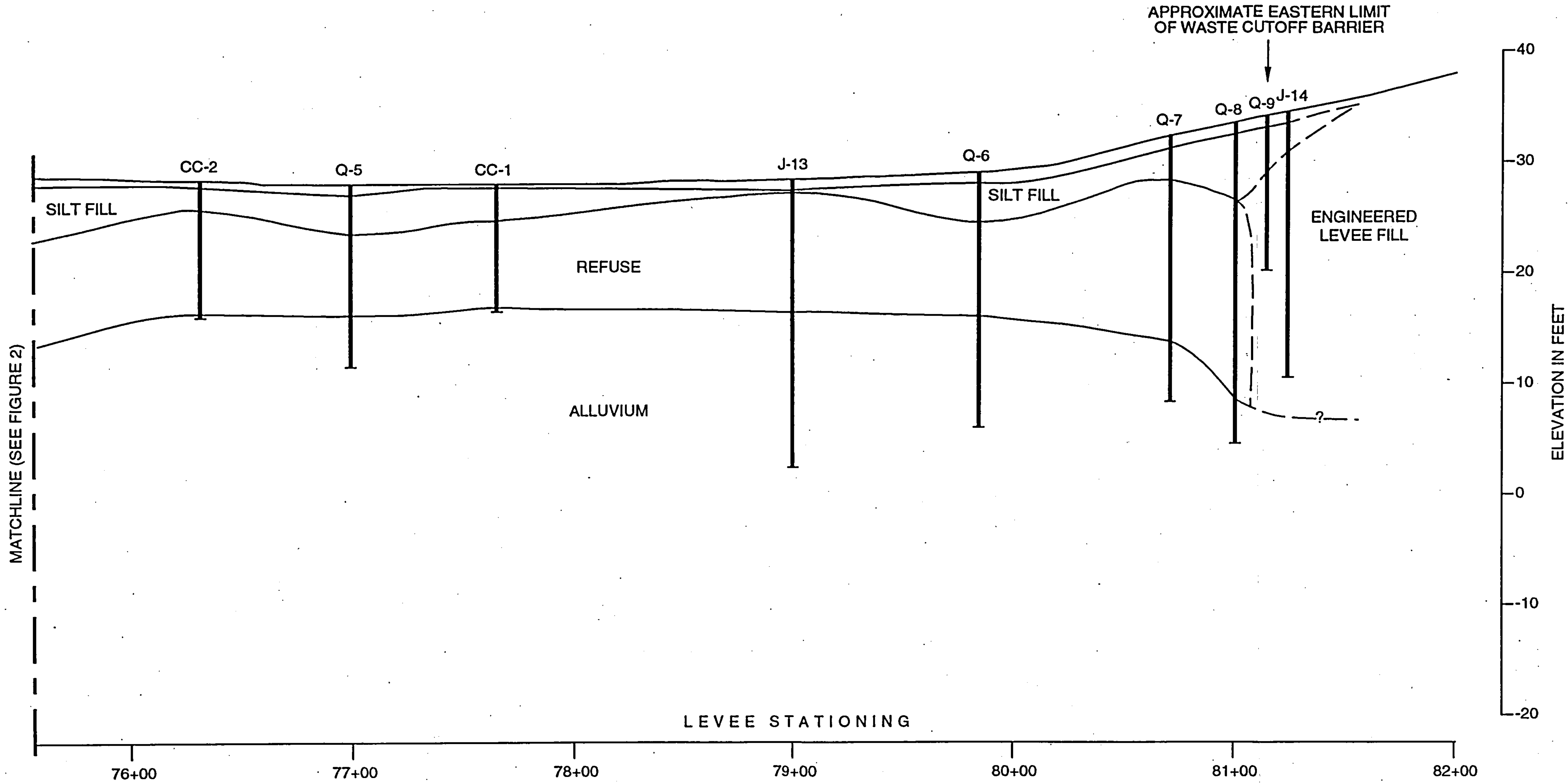


SCALE: HORIZONTAL 1 INCH = 50 FEET
VERTICAL 1 INCH = 10 FEET

NOTE:
1. ELEVATIONS SHOWN BASED ON OCTOBER 1993 TOPOGRAPHIC MAP, SEE FIGURE 1
2. STATIONING BASED ON CORNFORTH CONSULTANTS 1990 LEACHATE MIGRATION STUDY

M11132-1\FIGURE02 LJW

Cornforth Consultants, Inc. 10250 S.W. Greenburg Rd. Portland, OR 97222	TITLE CROSS SECTION THROUGH DIKE ALIGNMENT	DATE MAR 1999
		JOB NO. 1132-1
	JOB WASTE CUTOFF STUDY ST. JOHNS LANDFILL	FIG. 2



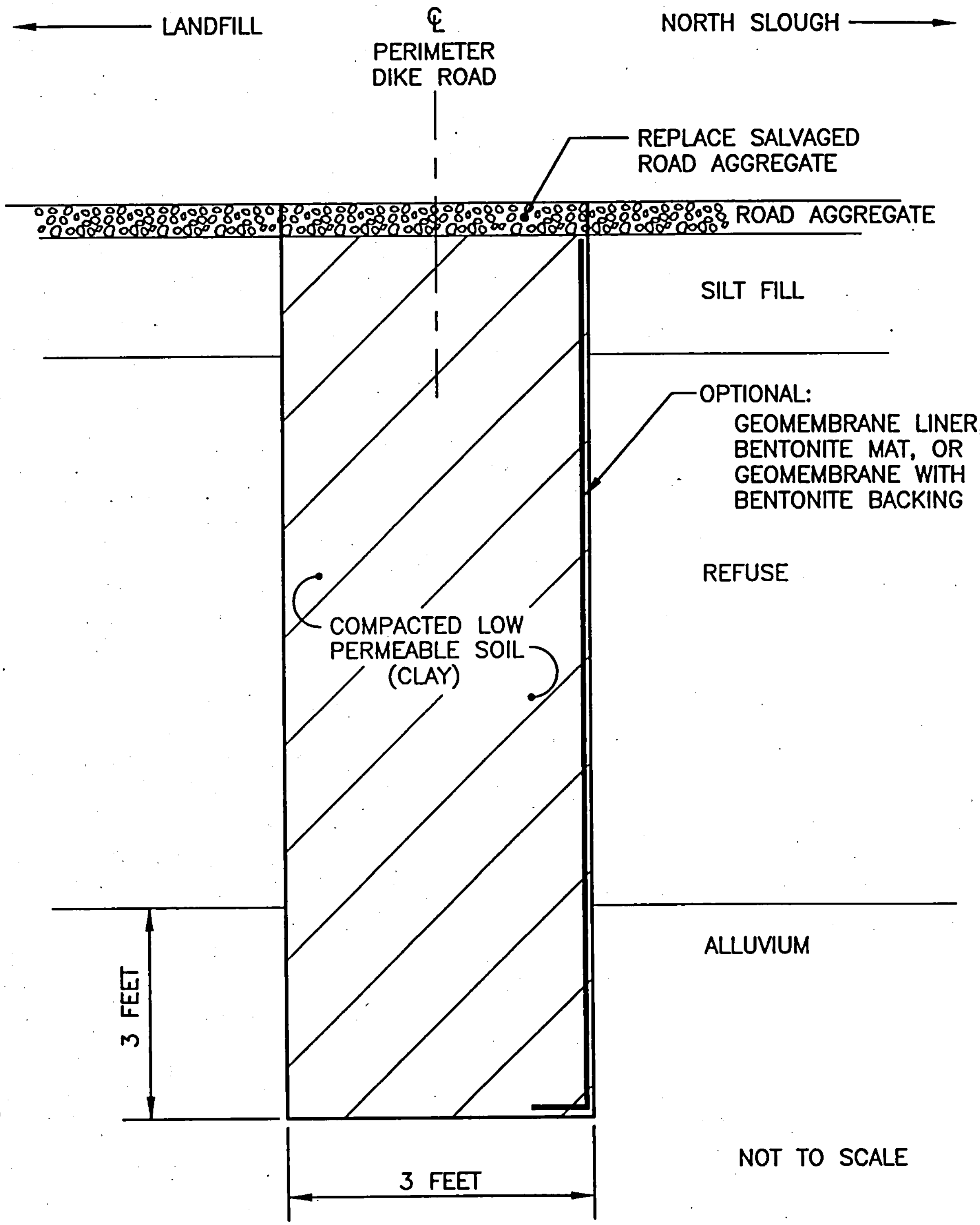
SCALE: HORIZONTAL 1 INCH = 50 FEET
VERTICAL 1 INCH = 10 FEET

NOTE: 1. ELEVATIONS SHOWN BASED ON OCTOBER 1993 TOPOGRAPHIC MAP, SEE FIGURE 1

2. STATIONING BASED ON CORNFORTH CONSULTANTS 1990 LEACHATE MIGRATION STUDY

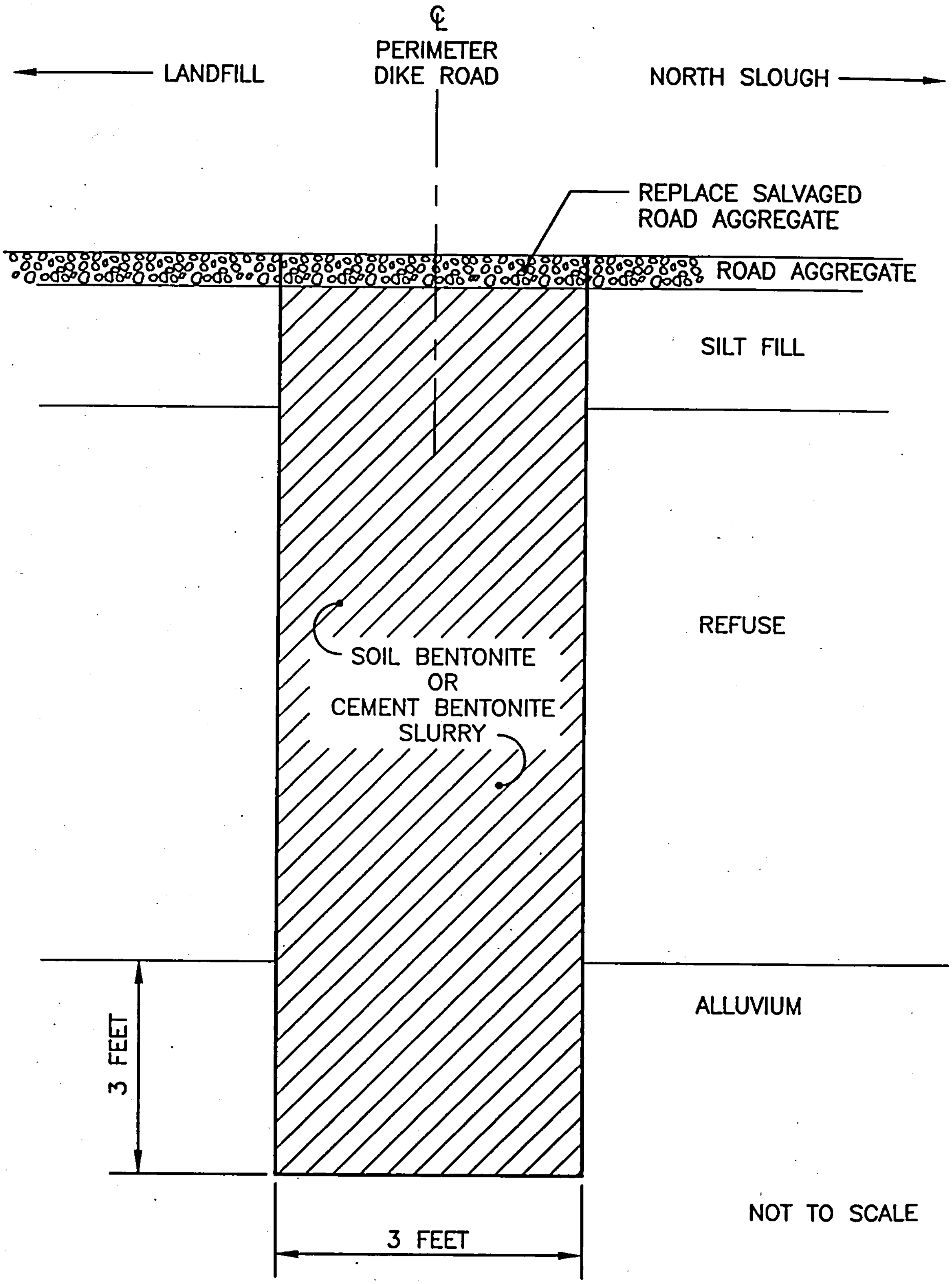
M1132-1\FIGURE03 LJW

Cornforth Consultants, Inc. 10250 S.W. Greenburg Rd. Portland, OR 97222	TITLE CROSS SECTION THROUGH DIKE ALIGNMENT	DATE MAR 1999 JOB NO. 1132-1
	JOB WASTE CUTOFF STUDY ST. JOHNS LANDFILL	FIG. 3



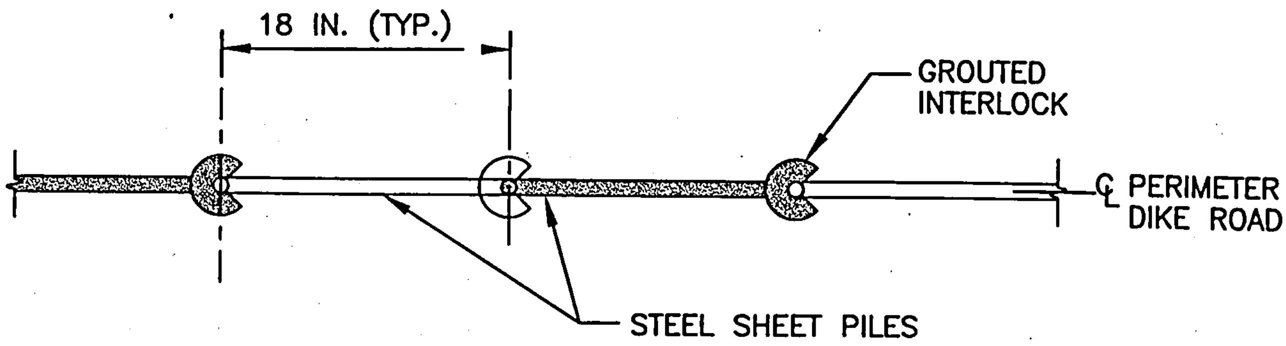
1132-1/FIG03/1:1/MPL

Cornforth Consultants, Inc.	TITLE COMPACTED CLAY TRENCH OPTION	DATE MAR 1999 JOB NO. 1132-1
10250 S.W. Greenburg Rd. Portland, OR 97223	JOB WASTE CUTOFF STUDY ST. JOHNS LANDFILL	FIG. 4



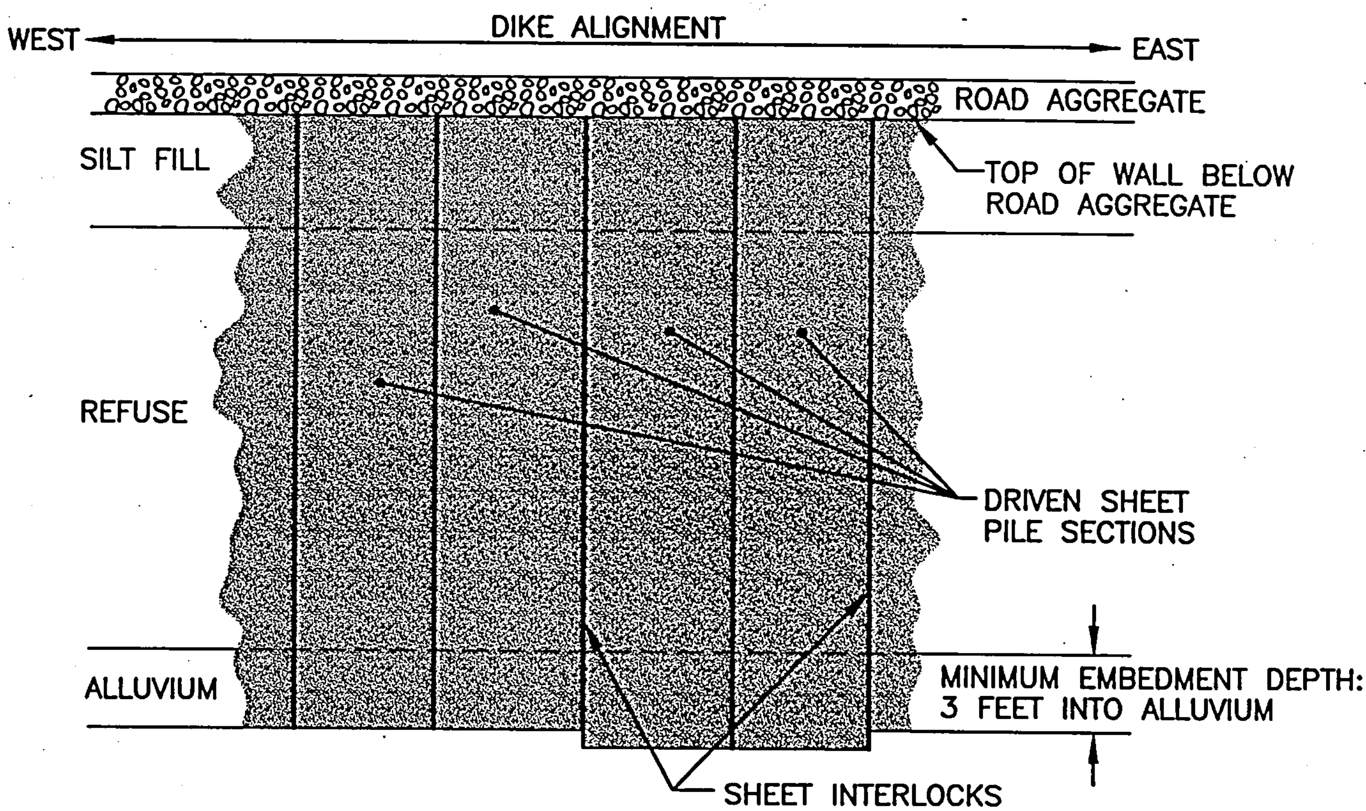
1132-1/FIG04/1:1/MPL

Cornforth Consultants, Inc. 10250 S.W. Greenburg Rd. Portland, OR 97223	TITLE SLURRY WALL OPTION	DATE MAR 1999
		JOB NO. 1132-1
	JOB WASTE CUTOFF STUDY ST. JOHNS LANDFILL	FIG. 5



OVERHEAD VIEW OF SHEET PILES

NOT TO SCALE



SIDE VIEW OF DRIVEN SHEET PILE WALL

NOT TO SCALE

1132-1/FIG05/1:1/MPL

Cornforth Consultants, Inc. 10250 S.W. Greenburg Rd. Portland, OR 97223	TITLE DRIVEN SHEET PILE OPTION	DATE MAR 1999 JOB NO. 1132-1
	JOB WASTE CUTOFF STUDY ST. JOHNS LANDFILL	FIG. 6